NUTRIENT AND FERMENTATION CHARACTERISTICS OF CAROLINA WILLOW (*Salix caroliniana*) SILAGE

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Abstract

The objective of this study was to evaluate the nutrient and fermentation characteristics of Carolina willow (*Salix caroliniana*) silage. Twelve laboratory scale silos (10.2 cm diameter x 45.7 cm long) were packed by hand with chopped willow (1.41 kg as-is, range 1.28 – 1.65 ± 0.18 SD) and opened on 0, 21, 42, and 84-d post-ensiling (three replicates per period). Silage dry matter weight and DM concentration did not differ at 0, 21, 42, and 84 d-post ensiling. Silage pH decreased 21 % ($P < 0.05$) from d 0 to 84. During the 84-d ensiling period, silage lactic acid concentration tended ($P < 0.10$) to increase 66%, acetic acid content increased ($P < 0.05$) 600%, and total organic acids increased ($P < 0.05$) over 100%. During the 84-d ensiling process, willow silage had increased ($P < 0.05$) neutral detergent fiber (14%), acid detergent fiber (17%), and lignin (22%) content. The fiber bound protein tended ($P < 0.10$) to increase in the silage. Total sugars decreased ($P < 0.05$) 78% and starch decreased ($P < 0.05$) 30% in the willow silage during the 84-d period. Vitamin E content of the silage decreased 52%. Mineral concentration of the willow silage did not change during the ensiling process. Although pH decreased during the ensiling process, mold was observed on the top of 89% of the silos. For proper fermentation, it is important to start with material that has an appropriate initial DM content and pack the silos tightly to reduce the extent of initial aerobic fermentation.

Introduction

For many zoos, providing an adequate supply of browse during the winter is difficult. Tree browse has been dried, frozen, and ensiled to preserve it for winter use. Ensiling tree browse has been evaluated as a domestic livestock feed,[1,12] used with wildlife, [6,7] and zoo herbivores.[8,9] Baertsche et al (1986) described the pH, nutrients, fiber fractions, and organic acid content of multiple hardwood silages after a 24-d ensiling period, but did not characterize the changes during the fermentation process. The objective of this study was to evaluate the fermentation characteristics and nutrient changes of Carolina willow (*Salix caroliniana*) ensiled for 84 d.

Materials and Methods

Carolina willow harvested within the previous 24 h was delivered at 0730 the morning prior to silage preparation. Six bundles (wet weight ~ 11.7 kg each) of willow were put through a brush chipper (Model BC625A, Manufacturing Co., Pella, IA 50219) to chop the willow for ensiling. The first willow bundle was used to clean out the chipper and discarded. The remaining bundles were collected on a tarp. Additionally, all branches greater than ~2.5 cm were removed and used to clean out the chipper. The chipped willow was ensiled in laboratory silos (10.2 cm diameter x 45.7 cm long) constructed of polyvinylchloride pipe and fitted with rubber caps (4" Qwik-Cap, Fernco, Inc., Davison, MI 48423) and tightened with hose clamps.[2] A one-way check valve (Fisher Scientific, Pittsburgh, PA 15275) was inserted into the cap to allow gas release during ensiling. Twelve silos were packed by hand with chopped willow and weighed (1.41 kg as-is, range 1.28 – 1.65 ± 0.18 SD). Empty silo weight was determined prior to packing. The silos were randolmly assigned to be opened on 0, 21, 42, and 84-d post-ensiling (three replicates per period).

On the assigned day, silos were weighed, emptied, and mixed by hand to collect a homogeneous sample. Aqueous extracts of the ensiled willow were prepared by combining 50 g of silage with 450 ml of distilled-deionized water, mixed in a Waring blender (Model 38BL61, Waring Commercial, Torrington CT 06790) for two minutes, and strained through two layers of cheese cloth. The pH of the aqueous solution was determined within 5 min using a combination glass electrode (Corning, Corning Inc., Corning, NY) attached to a digital pH meter (530; Corning Inc., Corning, NY). Remaining aqueous solution was frozen (-4 °C) for organic acid analysis (DairyOne, Ithaca, NY 14850).

Additional subsamples were collected and dried in a 55°C oven (50 g), or freeze dried for 72 h (150 g; model 77530; Labconco Corp., Kansas City, MO). Oven dried samples from d 0 and 84-post-ensiling were analyzed for crude protein, fiber fractions, fiber-bound protein (ADICP), sugars, starch, and minerals (Ca, P, Mg, K, Na, Fe, n, Cu, Mn, Mo) (DairyOne, Ithaca, NY 14850). Freeze-dried samples from 0 and 84-d post-ensiling were analyzed for vitamin E (Nutritional and Environmental Analytical Services, Ithaca, NY 14850). Any remaining silage was mixed to expose the silage to air and placed in a styrofoam container to evaluate aerobic stability. Cooking thermometers were placed into each Styrofoam container and a beaker of water to measure daily temperature changes for eight days. Samples were analyzed with the GLM procedure of SAS (SAS Inst. Inc., Cary, NC 27513 USA). Means were separated using Tukey's T-test.

Results and Discussion

Silage dry matter weight and DM concentrations did not differ at 0, 21, 42, and 84-d post ensiling (data not shown). Silage pH decreased 21% ($P < 0.05$) from d 0 to 84 (Figure 1). During the 84-d ensiling period, silage lactic acid concentration tended ($P < 0.10$) to increase 66%, and acetic acid content increased ($P < 0.05$) 600% (Table 1). Isobutyric acid content of the silage was not present on d 0, but was determined on d 84. Silage butyric acid concentration decreased ($P < 0.05$) 78%. Total acids increased ($P < 0.05$) more than 100%.

Ideally, pH drops below 4.5 for well preserved grass and legume silages,[12] but the pH for ensiled hardwoods ranged from 4.66 to 6.45.[1] In Baertsche et al. (1986) study, the willow silage pH was 6.40 after a 24 d of ensiling with mold growth observed. The poor willow silage observed by Baertsche et al. (1986) was attributed to an initial DM greater than 40%. Hardwood silages that fermented appropriately had DM concentrations from 31.22 – 36.84%,[1] but DM below 30% would be undesirable and promote butyric acid production and foul spelling silage.[12] In the current study, after 84 d, the silage pH reached 4.8. Although the pH dropped during the ensiling process, mold was present on the top of eight of the nine silos (89%) opened after d 0.

Lactic acid concentration was below concentrations detected for hardwood silages (2.32 – 4.83 % of DM)[1] and expected concentrations for legume and grass silages[2] (Table 2). Acetic acid is produced during the initial aerobic phase of the ensiling process, but excessive amounts could be an indication of a prolonged aerobic fermentation at the beginning of the ensiling process. Acetic acid concentration in the current study was also below those determined in hardwood silage (1.46 – 3.24% of DM)[1] and expected values for legume and grass silages.[2] Increased aerobic fermentation maybe due to the silos not being packed tight enough to eliminate air pockets and available oxygen. The silos in the current study averaged 0.15 g DM/cc. The goal for alfalfa silage is above 0.20 g DM/cc[4], suggesting the laboratory silos needed to packed tighter. Proprionic and butryric acid concentrations were within expected concentrations for legume and grass silages.[2] Total organic acids determined in the current study were lower than detected in hardwood, legume, and grass silages,[1,2] but lactic acid represented 72% of all organic acid which is above the 60% suggested for well-made silages[12] and the lactic:acetic acid ratio (5.76) was above the expected ratio of 2-3.[2]

Ensiling willow for 84 d increased ($P < 0.05$) neutral detergent fiber (14%), acid detergent fiber (17%), and lignin (22%) content. The fiber bound protein (ADICP) tended ($P < 0.10$) to increase. The increase in fiber fractions was in part due to the decrease in sugars and starch that were fermented to organic acids during the ensiling process. Total sugars decreased 78% and starch decreased 30% during the 84-d ensiling period. Vitamin E content of the silage decreased 52%. Mineral concentration of the willow silage did not change during the ensiling process (averaging 1.00% Ca, 0.11% P, 0.10% Mg, 0.80% K, 0.12% Na, 57 ppm Fe, 58 ppm Zn, 8.2 ppm Cu, 8.8 ppm Mn, 0.63 ppm Mo).

There were very few changes in the nutrient content of ensiled willow which is in agreement with Baertsche et al. (1986). One of the concerns with ensiling grasses and legumes is adequate carbohydrates (sugar and starch) for the ensiling process. The recommendations for hexose sugars ranged from 6 to 7% of DM[12] to 15% of DM[10] If the initial chopped willow contained 19.6% nonstructural carbohydrates (sugar and starch), then there should have been sufficient carbohydrates for the fermentation process.

During the aerobic stability trial, silage temperature reached a maximum of 4-5 °C above ambient temperature after five days of aerobic exposure. This is considerably less than the 8 - 25°C increases observed with ensiled high-moisture corn[2,14] and would suggest that the browse silage was stable for at least four days when exposed to air.

Ensiling willow browse would be beneficial to provide browse for winter use. Most nutrient concentrations are maintained during the ensiling process except vitamin E. To improve the fermentation process and prevent mold growth, silos may need to contain additional moisture and be packed sufficiently to reduce initial aerobic fermentation. Additionally, acceptance and intake by exotic animals needs to be determined.

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Table 1. Influence of an 84-day ensiling period on Carolina willow (*Salix caroliniana*) browse silage organic acid and nutrient content.

	Days post ensiling		
Item	0	84	SEM
DM, %	39.4	38.4	0.58
Lactic acid, %[a]	0.73[k]	1.21[j]	0.137
Acetic acid, %[a]	0.03[y]	0.21[x]	7.52
Proprinic acid, %[a]	0.033	0.025	0.0039
Iso-butyric acid, %[a]	0[y]	0.23[x]	0.018
Butyric acid, %[a]	0.032[x]	0.007[y]	0.0050
Total acids, %	0.825[y]	1.682[x]	0.1273
CP, %[a]	6.3	6.5	0.44
ADICP, %[a]	1.23[k]	1.53[j]	0.088
NDF, %[a]	58.4[y]	66.6[x]	1.86
ADF, %[a]	45.5[y]	53.4[x]	1.46
Lignin, %[a]	13.1[y]	16.0[x]	0.30
NSC, %[a]	19.6[x]	6.6[y]	0.28
Starch, %[a]	4.7[x]	3.3[y]	0.27
Sugar, %[a]	14.9[x]	3.3[y]	0.11
Vitamin E, IU/kg[a]	18.5[x]	8.8[y]	2.35

[a]Dry matter basis.
[jk]Means with unlike superscripts differ ($P < 0.10$).
[xy]Means with unlike superscripts differ ($P < 0.05$).

Table 2. Representative organic acid concentrations and target levels of organic acids of legume and grass silages.

Item	Legume silage[a]	Legume Silage expected values[b]	Grass silage[a]	Grass silage expected values[b]
DM, %	36-40	-	36-40	-
pH	4.7	< 4	4.59	< 5
Lactic acid, %[c]	4.95	> 3	4.59	> 3
Acetic acid, %[c]	2.15	< 3	1.59	< 3
Proprionic acid, %[c]	0.09	< 1	0.14	< 1
Butryric acid, %[c]	0.20	< 0.10	0.16	< 0.10
Iso-butryric acid, %[c]	-	-	-	-
Lactic:acetic acid ratio	2.30	2 – 3	2.89	2 – 3
Total acids, %[c]	7.4	5 – 10	6.5	5 – 10
Lactic acid, % of total acids	67.0	-	71.6	-

[a]Ward, 2000.
[b]Dairy One Laboratories, Inc.
[c]Dry matter basis.

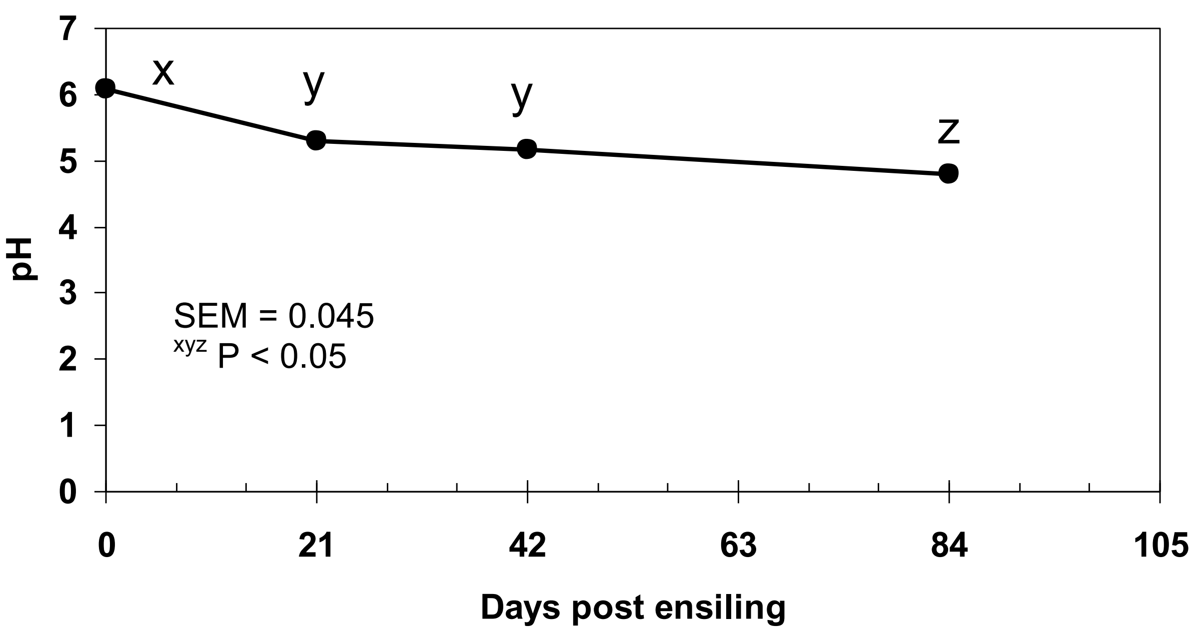

Figure 1. Influence of the number days post ensiling on Carolina willow (*Salix caroliniana*) browse silage pH.