Willow March 2021

Poplar March 2021

Investigating silage quality and feed value of chopped willow and poplar material in the Waikato in autumn 2021

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In cooperation with DairyNZ and NIWA. As per contract **2020-1745:** Productive Riparian Buffers phase 3[1]

Summary

A previous study for the Productive Riparian Buffer project[2] found that there were large differences between pre and post ensiling willow material. The objective of this project was to test feed value and silage quality pre and post ensiling using multiple replicates of representative chopped willow and poplar material to evaluate best practice of sampling and the feed quality and silage quality of these materials. It can be concluded that:

- Using the quartering method and multiple samples (4 for pre and 8 for post ensiling) allowed a good evaluation of feed value and silage quality
- Silage quality of willow and poplar material harvested in this trial was good
- Feed value of all materials were low due to very high fibre levels

Background

Willow and poplar branches are harvested in NZ as potential feed for ruminants. Silage quality and feed value of willow branches have been evaluated in a previous study for the Productive Riparian Buffer project[2]. It was found that there were large differences between pre-ensiling willow material (8.6-9.9 MJ ME/kgDM ; 25-35 NDF %DM) and willow silage (5.1-6.95 MJ ME/kgDM; 57-64 NDF %DM). Also duplicate drums used for ensiling willow material differed widely in feed value. It was discussed "...that the difficulty of producing a representative and uniform sample from the rather heterogeneous mixture of willow leaf and woody willow material in the experimental drums has contributed to data variability". The following research has been suggested to gain additional information which will aid in more robust recommendations on feed value and silage quality of willow and poplar material:
1. Improving representative sampling of heterogenous material (branch & leaves) for analysis and
2. Providing representative samples for laboratory analysis of silage quality.

1. Representative sampling of heterogenous material is not easy and procedures have been developed to establish guidelines. The code of practice for maize trading[3] shows that 12 samples are required using the hand scoop method for truck sampling or 2-3 core samples from stacks to achieve an accuracy of 2% in Laboratory DM% testing. Similarly, the code of practice for the trading of pasture and whole crop forages recommends a minimum of 8 pit core samples for pasture silage or 4 samples for whole crop silage. This ensures that samples reflect what is in the lot or in the stack. Methods are described to reduce the amount of sample material taken representatively from a 'lot' (e.g. being a field or a stack). These are either the Riffle Box which is costly and typical for routine procedures or the "quartering-method" (see Fig 1)[4].

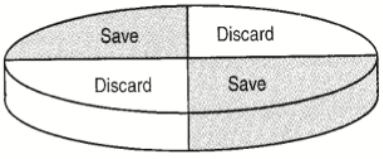

Fig.1. Quartering method

Quartering is used to reduce a sample to a smaller, more manageable size in an unbiased manner. Prior to quartering, forage samples collected by hand must be cut into 2-3" pieces with shears or scissors and thoroughly mixed. Care must be taken to prevent leaf loss. Cored samples can be mixed as is. Pour the entire sample evenly into a pile on a clean surface, preferably paper, plastic, etc. Level the pile and divide into equal quarters (see diagram). Select and save two opposite quarters including the fines. If the sample is still too large, repeat the entire quartering procedure until the proper sample size is obtained. Always use the quartering method when reducing sample size to obtain a representative sample for analysis

[1] https://www.dairynz.co.nz/environment/waterways/productive-riparian-buffers/
[2] NIWA Client Report No: 2020150NH for MPI SFF40560. Willow biomass ensiling trials
[3] https://www.far.org.nz/assets/files/uploads/FTDG+Code+of+Practice.pdf
[4] http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-2553/PSS-2589web2013.pdf

2. Providing representative samples for laboratory analysis of silage quality. Glass jars have been used traditionally as laboratory scale silos to investigate silage fermentation under defined conditions with replicate measurements. Recently they are replaced by vacuum packages which are easier to handle and produce similar repeatable results (Hoedtke & Zeyner 2011)[5].

Objective

Test feed value pre-ensiling using multiple replicates of representative chopped willow and poplar material at typical harvest maturity and silage quality in multiple vacuum packages to evaluate best practice of sampling.

Trial design

Freshly harvested willow and poplar material was sourced at harvest on 15th March 2021 on the Bruce Fawcett Ltd family dairy farm near Waharoa, Waikato. About 15kg of typical material was spread equally across the surface of a trailer. Material was separated into 12 sections. Randomly 4 parts were selected and bagged completely for analysis of feed value and dry matter analysis (pre-ensiling material). The remaining 8 parts were individually ensiled in vacuum packs. Vacuum packs were stored for 8 weeks and then analysed for feed value and fermentation quality.

Fig. 2. Willow material before sampling

Fig. 3. Poplar material before sampling

Fig.4. Vacuum packs

[5] https://onlinelibrary.wiley.com/doi/abs/10.1002/jsfa.4255

Table 1. Analysis of willow and poplar material

Material	Replicates	Analysis
Pre-ensiling Willow Poplar	 4 4	Dry Matter (DM), Ash, Crude Fat, Soluble sugar, Starch, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Lignin, Crude Protein (CP), Organic Matter (OM), Digestibility of Organic Matter in Dry Matter (DOMD), Non Structural Carbohydrates (NSC), Metabolisable Energy (ME).
Silage Willow Poplar	 8 8	Dry Matter (DM), Ash, Crude Fat, Soluble sugar, Starch, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Lignin, Crude Protein (CP), Organic Matter (OM), Digestibility of Organic Matter in Dry Matter (DOMD), Non Structural Carbohydrates (NSC), Metabolisable Energy (ME), pH, Ammonium-N/Total-N ratio, Lactic acid, Acetic acid, Propionic acid, Butyric acid, Formic acid

Results and discussion

Comparing willow pre-ensiling with silage feed value (Table 2.)

Willow silage DM% was slightly lower in silage which is typical because in the ensiling process some DM% is fermented, and water is released. All fibre fractions (ADF, NDF and Lignin) were on average very high and quite similar between pre and post ensiling considering the magnitude of the Standard Deviation, which is a result of sampling. Soluble sugar, starch and NSC are lower in silage (1.8, 2.3 and 4.4 % resp.) which can be explained by the ensiling process which ferments water soluble carbohydrates to fermentation acids. CP is low and was 2.2% higher in silage. Ash is 1.8% higher in silage, hence Organic Matter 1.8% lower. ME and DOMD in silage are higher with a relatively high Standard Deviation. There is no good explanation for improved feed value in silage except variation through sampling. Overall, pre-ensiling and silage analysis show a similar profile of feed value with high fibre and low CP and ME values. It is therefore recommended to take multiple samples using proven sampling techniques when evaluating willow material. The Standard Deviation of silage results although 8 samples were taken was not smaller than in pre-ensiling material. This could mean that 4 samples are sufficient.

Table 2. Willow feed value and silage quality results

	Pre-ensiling n=4		Silage n=8	
Willow	Mean	STD	Mean	STD
DM%	46.6	0.4	45.3	0.7
CP %DM	5.3	0.8	7.5	1.2
ADF %DM	41.8	5.7	42.1	5.8
NDF %DM	65.1	3.0	64.9	3.8
Lignin %DM	16.2	0.3	17.6	0.8
Sol. Sugar %DM	6.1	0.4	4.3	0.8
Starch %DM	5.8	0.5	3.6	0.7
Crude Fat %DM	2.6	0.5	3.1	0.4
Ash %DM	4.0	0.3	5.8	1.2
OM %DM	96.0	0.3	94.2	1.2
NSC %DM	23.1	1.7	18.7	1.4
DOMD %	36.1	0.9	39.0	3.2
ME MJ/kgDM	5.8	0.1	6.2	0.5
pH			4.2	0.0
NH_4N/total N%			1.4	0.2
Lactic acid %DM			1.9	0.2
Acetic acid %DM			0.7	0.4
Propionic acid %DM			<0.2	
Butyric acid %DM			<0.2	
Formic acid %DM			<0.2	

Comparing poplar pre-ensiling with silage feed value (Table 3.)

Poplar silage DM% is slightly lower which again is typical because in the ensiling process some DM is fermented, and water is released. All fibre fractions (ADF, NDF and Lignin) were on average very high and quite similar except ADF was 2.9% higher in silage. Soluble sugar and starch are lower in silage (3.2 and 2.3 % resp.) which can be explained by the ensiling process which ferments water soluble carbohydrates to fermentation acids. CP is low and was 2.0% higher in silage. Ash is 2.1% higher in silage, hence OM is 2.1% lower. ME and DOMD in silage are higher. Again there is no good explanation except variation through sampling. Overall pre-ensiling and silage analysis of poplar material show a similar profile of feed value with high fibre and low CP and ME values. It is recommended to take multiple samples using proven sampling techniques when evaluating poplar material. As mentioned before, probably 4 silage samples are sufficient.

Table 3. Poplar feed value and silage quality results

	Pre-ensiling n=4		Silage n=8	
Poplar	Mean	STD	Mean	STD
DM%	47.3	1.1	45.3	1.5
CP %DM	5.8	0.2	7.8	0.8
ADF %DM	38.3	1.5	41.2	3.4
NDF %DM	61.1	3.0	61.1	3.2
Lignin %DM	17.0	0.4	17.8	0.3
Sol. Sugar %DM	9.0	0.6	5.8	1.7
Starch %DM	4.7	0.5	2.3	0.5
Crude Fat %DM	2.5	0.2	2.6	0.1
Ash %DM	5.1	0.7	7.2	1.4
OM %DM	94.9	0.7	92.8	1.4
NSC %DM	25.6	2.7	21.3	1.2
DOMD %	35.4	2.2	37.5	1.9
ME MJ/kgDM	5.7	0.4	6.0	0.3
pH			4.6	0.2
NH_4N/total N%			0.9	0.2
Lactic acid %DM			1.7	0.5
Acetic acid %DM			0.5	0.2
Propionic acid %DM			<0.2	
Butyric acid %DM			<0.2	
Formic acid %DM			<0.2	

Evaluating silage quality of willow and poplar

Willow and poplar material ensiled well. Willow and poplar silage pH values were lower (4.2 and 4.6) than typical pH of higher Dry Matter legume silages (Table 4). The fermentation acid profile showed a slightly lower lactic acid than the typical values of drier legume silage but also the acetic acid level was low. Both willow and poplar silage showed a ratio of around 3/1 lactic to acetic acid typical for reasonably well fermented silage. The absence of propionic, butyric and formic acid indicates that predominantly a lactic fermentation took place rather than a fermentation influenced by other less efficient microorganisms e.g. Clostridia. A further indication for an efficient lactic acid fermentation is the very low Ammonium-N/ % of total N (NH4N/total N%) level, much lower than the recommendation of less than 10% which indicates that very little feed protein was degraded to ammonia.

Levels of soluble sugar in the pre-ensiling material were more than adequate (6.1 and 9%DM) which is important to allow a lactic acid fermentation. Based on the results which are a repeat of last year's results it is assumed that the buffering capacity although not measured here was low which allowed a good fermentation to take place.

Table 4. Typical concentrations of fermentation end products. Kung and Shaver (2001)[6]

	Legume silage (45-55%DM)	Grass silage (30-35%DM)
pH	4.7-5.0	4.3-4.7
NH_4N/total N%	<12	8-12
Lactic acid %DM	2-4	6-10
Acetic acid %DM	0.5-2	1-3
Propionic acid %DM	<0.1	<0.1
Butyric acid %DM	0	0.5-1

Evaluating feed value of willow and poplar material from this trial

Analysis of feed quality was done using NIR at Hill Laboratories because analysis cost for wet chemical analysis (the gold standard) is expensive and for this project many repeated measurements were necessary to investigate sampling error; however, there is a risk that unusual material like willow and poplar material can be outside the typical sample population for the used NIR calibration. Therefore a composite sample each from all willow (n=8) and poplar silage samples (n=8) was analysed for all fibre fractions using wet chemistry methods to compare to NIR measurements.
Table 5 shows that ADF was underestimated with NIR in both materials, NDF was in a similar range and lignin was overestimated assuming that wet chemistry analysis is the benchmark for nutrient analysis of feeds. ADF is typically used as a predictor for digestibility and therefore ME. NDF helps to predict intake and Lignin describes the undigestible part of fibre. Overall also wet chemistry analysis confirmed that these materials have very high fibre levels especially ADF which indicates low ME values. Although lignin was overestimated it is still very high and matches well with lab results for woody materials measured in the US at DairyOne lab (Table 6) in over 300 samples, which is not surprising given the high proportion of woody material.

Table 5. Wet chemistry fibre analysis of composite samples from willow and poplar silage material compared to mean of NIR analysis

	Willow			Poplar		
	NIR*	wet chem.#	Difference	NIR*	wet chem.#	Difference
ADF %DM	42.1	49.4	7.3	41.2	47.1	5.9
NDF %DM	64.9	63.5	-1.4	61.1	61.2	0.1
Lignin %DM	17.6	13.5	-4.1	17.8	14.9	-2.9

*Mean of 8 samples #composite sample of 8 dried ground samples

Kemp et al (2001)[7] reported feed quality of willow and poplar at 9.8 and 9.9 MJ ME/kgDM and CP of 14.2 and 14.9 %DM. That is comparable to summer pasture. However, the material referred to was 64% and 65% leaf plus stems 5 mm or less. Material from our trial included much thicker branches (see Fig 5 and 6) and therefore resulted in much lower feed value of around 6 MJ ME/kg DM, which is similar to straw.

Fig. 5. Poplar before chopping

Fig. 6. Willow silage

[6] http://fyi.uwex.edu/forage/files/2014/01/Fermentation.pdf
[7] Proceedings of the New Zealand Grassland Association https://www.nzgajournal.org.nz/index.php/ProNZGA/article/view/2444

Table 6. DairyOne laboratory results of woody plant material[8]

Main Library

FR WOODY PLANTS, Accumulated Crop Years: 5/1/2004 - 4/30/2020

Item	Samples	Average
% Dry Matter	325	42.583
% Crude Protein	586	7.448
Soluble Protein, % of CP	54	30.741
Degradable Protein, % of CP	0	0.000
% ADICP	24	1.503
% NDICP	18	1.650
% Lignin	304	15.493
% Acid Detergent Fiber	586	44.481
% Neutral Detergent Fiber	356	65.032
% Crude Fiber	2	46.272
% Crude Fiber (Ankom)	0	0.000
% WSC (Water Sol. Carbs.)	234	8.090
% ESC (Simple Sugars)	211	6.210
% Starch	214	1.639
Starch Digestibility	0	0.000
% Non Structural Carbo. (NSC)	1	8.473
% Non Fiber Carbo. (NFC)	348	17.116
% Crude Fat	255	2.837
% Ash	243	4.053

Conclusions

The objective of this study was to test feed value and silage quality pre and post ensiling using multiple replicates of representative chopped willow and poplar material at typical harvest maturity and silage in vacuum packages to evaluate best practice of sampling. It can be concluded that:

- Using the quartering method and multiple samples (4 for pre and 8 for post ensiling) allowed a good evaluation of feed value and silage quality
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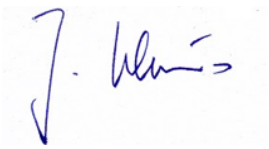

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[8] https://dairyone.com/services/forage-laboratory-services/feed-composition-library/interactive-feed-composition-libraries/