J. Dairy Sci. 101:4020–4033
https://doi.org/10.3168/jds.2017-13909

Silage review: Interpretation of chemical, microbial, and organoleptic components of silages[1]

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ABSTRACT

The goal of making silage is to produce a stable feed with a high recovery of dry matter, energy, and highly digestible nutrients compared with the fresh crop. Microbial fermentation in the silo produces an array of end products and can change many nutritive aspects of a forage. High-quality silage should be void of undesirable compounds that could negatively affect animal performance, the environment, or net farm income. This review discusses the interpretation of the common fermentation end products, microbial populations, organoleptic properties, and changes in nutritive aspects of silages during storage of silages with emphasis on a North American perspective.
Key words: silage, fermentation

INTRODUCTION

In the absence of air, the fermentation of soluble carbohydrates in forages results in a variety of end products, ultimately resulting in the preservation of a forage crop as silage. Measuring the pH and quantifying the production of organic acids and alcohols are the main basis of evaluating silage fermentations. When deemed necessary, other components that are commonly quantified in silages include mycotoxins and a variety of nitrogenous compounds. Organoleptic characteristics can be used to assess silage quality because the volatile nature of many fermentation end products produces a variety of distinct odors. Cherney and Cherney (2003) provide a detailed summary of laboratory methods used to assess silage quality.

Although the chemical processes occurring in a silo have generally been thought to quickly reach a steady state after a few weeks of fermentation, it is clear that small but significant changes in some components continue to take place for months, and such processes can affect silage quality. In general, data from silage fermentation analyses can be used to determine whether an excellent, average, or poor fermentation has occurred. Based on these analyses, educated assumptions can be made that can be used to explain various outcomes. For example, the fermentation that a crop undergoes often can be explained by factors including moisture content, buffering capacity, sugar content, and types of organisms that dominated the process. Management factors such as the speed of packing, pack density, type of additive used, chop length, covering management, and silo management during feed-out can also affect silage fermentation and its subsequent quality. In some cases, fermentation analyses can qualitatively explain poor nutritive value or low intakes. The best way to evaluate the quality of silage is by sampling it appropriately and requesting both fermentative and nutritive analyses from an endorsed analytical laboratory. Cherney and Cherney (2003) provide recommendations for sample collection and shipment of forage samples to analytical laboratories. Our objective was to review the common chemical, microbial, and organoleptic properties of silages and the factors affecting them as they relate to the efficiency of silage fermentation, aerobic stability, nutritive value, animal performance, and potential effects on the environment, with emphasis primarily on a North American perspective.

INTERPRETATION OF DATA FROM CHEMICAL AND MICROBIAL ANALYSES OF SILAGES

The most common measurements used for evaluating silage fermentation include pH; the concentrations of organic acids, alcohols, and NH_3-N; and the size of various microbial populations. In an ideal fermentation, homolactic acid bacteria use water-soluble carbohydrates (e.g., glucose) for growth and produce only lactic acid, resulting in a relatively high recovery of DM and energy (Pahlow et al., 2003). However, the fermenta-

Received September 27, 2017.
Accepted January 8, 2018.
[1]This article is part of a special issue on silage management.
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Table 1. Typical suggested concentrations of common fermentation end products in various silages

Item	Legume silage <30–35% DM	Legume silage 45–55% DM	Grass silage 25–35% DM	Corn silage 30–40% DM	High-moisture corn 70–75% DM
pH	4.3–4.5	4.7–5.0	4.3–4.7	3.7–4.0	4.0–4.5
Lactic acid, %	6–8	2–4	6–10	3–6	0.5–2.0
Acetic acid, %	2–3	0.5–2.0	1–3	1–3	<0.5
Propionic acid, %	<0.5	<0.1	<0.1	<0.1	<0.1
Butyric acid, %	<0.5	0	<0.5–1.0	0	0
Ethanol, %	0.5–1.0	0.5	0.5–1.0	1–3	0.2–2.0
NH_3-N, % of total N	10–15	<12	8–12	5–7	<10

tion of forage crops is very complex and involves many types of microorganisms, resulting in variety of different end products. Table 1 shows typical recommended values for common fermentation end products from the primary types of silages in the United States (Kung and Shaver, 2001). Figures 1, 2, and 3 show trends in concentrations for these end products based on the DM of the crop for corn silage, legume silage, and high-moisture corn (**HMC**). The values in these figures must be viewed with caution because many silages sent in for analyses are "problem samples" and the potential exists for samples to be compromised during shipment to the laboratory, which may result in the analyses not truly reflecting the composition of the sample at the farm. For example, not all legume silages below 30% DM are clostridial, as shown in Figure 2; however, the probability of this happening certainly is greater when the moisture content is very high in these silages.

Silage pH and Lactic Acid

The pH of an ensiled sample is a measure of its acidity. Whole-plant corn and alfalfa (the primary forage crops for dairy cows in the United States) have pH levels that range from about 5.5 to 6 immediately after chopping. During ensiling, lactic acid (pK_a of 3.86), produced by lactic acid bacteria (**LAB**), is usually the acid found in the highest concentration in silages, and it contributes the most to the decline in pH during fermentation because it is about 10 to 12 times stronger than any of the other major acids [e.g., acetic acid (pK_a of 4.75) and propionic acid (pK_a of 4.87)] found in silages. Typical

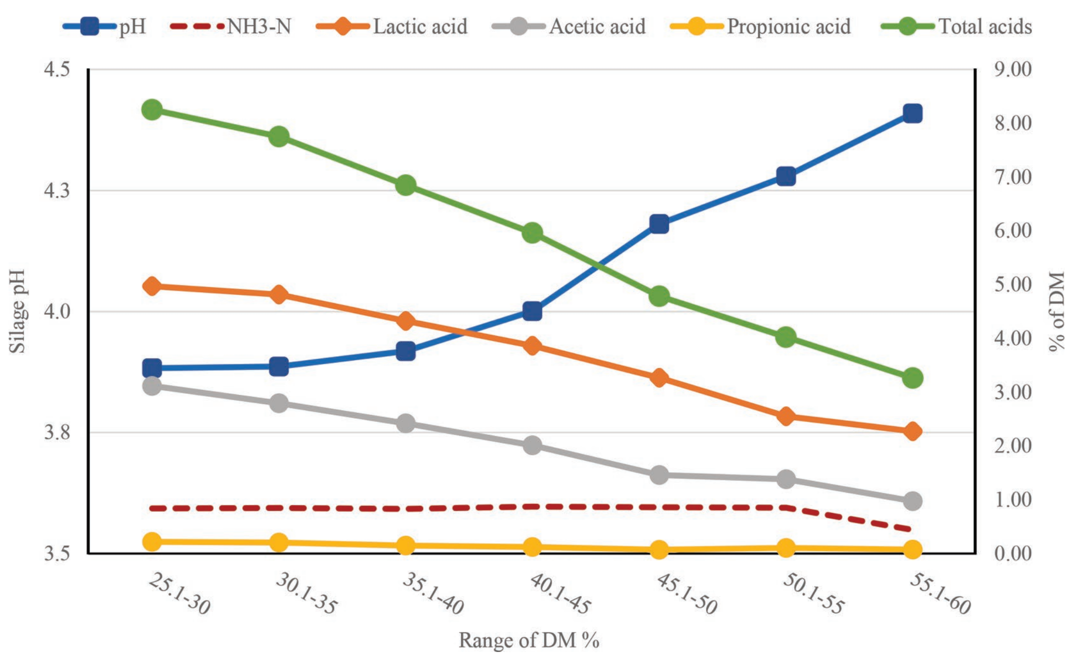

Figure 1. The pH and common fermentation end products of corn silage in the United States as affected by DM content. Ammonia-N is presented on a CP equivalent basis. Butyric acid was generally not found in corn silage samples, so values are not shown. Values are from samples analyzed by Cumberland Valley Analytical Services (Waynesboro, PA) between January 1, 2012, and August 31, 2017. Values are from wet chemical analyses. Color version available online.