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Concentration of mycotoxins and chemical composition of corn silage: A farm survey using infrared thermography

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ABSTRACT

This work evaluated the chemical composition and mycotoxin incidence in corn silage from 5 Brazilian dairy-producing regions: Castro, in central-eastern Paraná State (n = 32); Toledo, in southwestern Paraná (n = 20); southeastern Goiás (n = 14); southern Minas Gerais (n = 23); and western Santa Catarina (n = 20). On each dairy farm, an infrared thermography camera was used to identify 3 sampling sites that exhibited the highest temperature, a moderate temperature, and the lowest temperature on the silo face, and 1 sample was collected from each site. The chemical composition and concentrations of mycotoxins were evaluated, including the levels of aflatoxins B_1, B_2, G_1, and G_2; zearalenone; ochratoxin A; deoxynivalenol; and fumonisins B_1 and B_2. The corn silage showed a highly variable chemical composition, containing, on average, 7.1 ± 1.1%, 52.5 ± 5.4%, and 65.2 ± 3.6% crude protein, neutral detergent fiber, and total digestible nutrients, respectively. Mycotoxins were found in more than 91% of the samples, with zearalenone being the most prevalent (72.8%). All samples from the Castro region contained zearalenone at a high average concentration (334 ± 374 μg/kg), even in well-preserved silage. The incidence of aflatoxin B_1 was low (0.92%). Silage temperature and the presence of mycotoxins were not correlated; similarly, differences were not observed in the concentration or incidence of mycotoxins across silage locations with different temperatures. Infrared thermography is an accurate tool for identifying heat sites, but temperature cannot be used to predict the chemical composition or the incidence of mycotoxins that have been analyzed, within the silage. The pre-harvest phase of the ensiling process is most likely the main source of mycotoxins in silage.

Key words: aflatoxin, dairy cow, epidemiology, maize, zearalenone

INTRODUCTION

Silage quality and concentration of mycotoxins can vary broadly and such variation can be due to many factors, including forage composition, losses during anaerobic storage, and aerobic deterioration after the silo is opened. The aerobic phase can alter the chemical composition and affect the safety of the silage. Under these conditions, yeast can oxidize lactic acid and increase silage pH, which then facilitates the growth of other microorganisms (McDonald et al., 1991). The elevated pH (>6.0) caused by the growth of spoilage-causing yeasts results in the active growth of toxigenic fungi during the feed-out phase, particularly in poorly managed silage (González-Pereyra et al., 2008).

Mycotoxins are secondary metabolites of certain fungal genera and cause several undesirable effects in humans and animals. Silage can be an important mycotoxin source, and little is known about the potential synergistic or antagonistic effects of mycotoxins that result in chronic health problems (Driehuis et al., 2008a). Mycotoxins can be derived from the field or introduced during ensilage; contamination during ensilage is directly related to air infiltration during storage and after the silo is opened, occurring mainly in high-porosity silos or in silos with a low rate of silage removal (González-Pereyra et al., 2008).

Brazilian dairy farmers frequently associate reproductive or metabolic disorders with the intake of fungi-spoiled silages. However, these feeds are not analyzed to determine the presence of mycotoxins because of high analytical costs and the lack of reference values for forages. Few data are available on the incidence of mycotoxin under controlled field conditions. Driehuis et al. (2008b) performed a survey in which 20 mycotoxins in corn (n = 140), grass (n = 120), and wheat (n = 30) silage samples were evaluated in the Netherlands. The incidence of *Fusarium*-related mycotoxins, such as deoxynivalenol (**DON**) and zearalenone (**ZEA**), was high in whole-crop corn silage (72 and 49%, respectively), and these mycotoxins co-occurred in 46% of the samples. Other toxins, such as fumonisins, aflatoxins, T2-toxin, and roquefortine C, were found at low inci-

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dences (below 2%) or were not detected. In Argentina, González-Pereyra et al. (2008) analyzed 60 corn silage samples from different sections of 2 silos. All samples contained fungal colonies, with ZEA, DON, and fumonisin being the primary toxins. These toxins co-occurred in 83.5% of the samples. The authors also analyzed the concentration of aflatoxin B_1 (**AFB_1**), which was found in all samples from the visible moldy upper section of the silos, but only in 6 samples from the middle section, at low concentration (<10 μg/kg).

Silage may contain a complex mixture of mycotoxins that originate from preharvest contamination, mainly with *Fusarium* spp., and postharvest contamination with toxins produced by fungal species such as *Aspergillus* and *Penicillium* (Cheli et al., 2013). The feed-out phase is a critical time during which mold and mycotoxin contamination of silage can occur. During this phase, differences in microaerophilic conditions, humidity, pH, and farm management practices produce differences in the silo environment. Thus, reports on mycotoxin occurrence and distribution in the literature are inconsistent.

The growth of spoilage microorganisms in silages produces heat, which is a typical indicator of aerobic degradation (Kung et al., 2000). However, the relationships among silo face temperature, silage quality, and concentration of mycotoxins remain poorly understood. Borreani and Tabacco (2010) evaluated the temperature at 11 locations on 54 silos and correlated the temperature with chemical composition and microbial count. Samples from peripheral areas showed greater temperatures, pH values, and yeast counts than samples from the central area. Those authors concluded that temperature is linked to microbial activity and can be an important indicator of the early stages of aerobic degradation. However, the concentration of mycotoxins was not assessed in that study.

Infrared thermography (**IRT**) is a useful tool for detecting variations in temperature over large areas, such as the working face of silos. However, our previous trials (unpublished data) have shown that IRT measurements are strongly influenced by the external environment and that the relevance of the values must be considered with caution.

In this study, a survey on whole-crop corn silage obtained from 109 dairy farms in 5 regions in Brazil was performed using IRT to discern 3 sites (the highest-temperature site, a moderate-temperature site, and the lowest-temperature site) of the silo face for sampling. The chemical composition and concentrations of mycotoxins in these 327 samples are presented. Correlations of these data with IRT, internal (100-mm depth) silage temperature, and ambient temperature were assessed.

MATERIALS AND METHODS

Sample Collection and Temperature Measurements

In total, 109 farms were visited between May and September 2010 by researchers from the Centro de Pesquisas em Forragicultura (CPFOR), Curitiba, Brazil. The farms were located in 5 dairy-producing regions: Castro, in central-eastern Paraná State (**CA**, n = 32); Toledo, in southwestern Paraná (**TL**, n = 20); southeastern Goiás (**GO**, n = 14); southern Minas Gerais (**MG**, n = 23); and western Santa Catarina (**SC**, n = 20). These 5 counties are located in the south (CA, TL, and SC), southeast (MG), and midwest (GO) regions of Brazil. All livestock were fed whole-crop corn silage that was ensiled in 2010. The farm size and technology varied according to the regional conditions; dairies ranged from 15 to 3,000 lactating cows. In each region, farms were selected from a list provided by the local cooperative of milk producers, which included ranked data on average daily milk production and herd size. Farms were classified into 3 groups according to these variables. To be representative of the region, 7 to 10% of the farms from the list were selected, including farms from the 3 groups. The staff of the cooperative contacted the farmers to schedule the visits.

At each farm, the ambient temperature (**AT**) in the shade was measured approximately 3 m in front of the silo face using a digital thermometer. An additional survey of 32 questions was administered at each farm. This survey included details on corn production, the ensiling process, and the management of feed-out.

Using an infrared thermography camera (Fluke Ti25; Fluke Corp., Lynnwood, WA), the working face of the silo was scanned to identify 3 different sites on the silo face: **H** = the highest temperature; **M** = moderate temperature; and **L** = the lowest temperature. These sites were automatically identified by the camera. Loose silage or visibly rotten sites were not considered when determining these sites. At each site, the external temperature (**ET**; superficial), as measured by IRT, and the internal temperature (**IT**), which was measured with a probe at a length of 100 mm, were taken using an infrared thermometer coupled with a probe (Fluke 66; Fluke Corp.).

At each site, after the temperatures were measured, samples (1,100 g) were collected from the surface layer (maximum depth = 150 mm) and immediately vacuum sealed (Orved & Brock EcoVacuum, Musile di Piave, Italy) at the farm. The samples were kept in a styrofoam box at room temperature. The maximum duration between sample collection and processing was 3 d (2.3 ± 0.5).

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