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Response of storage molds to different initial moisture contents of maize (corn) stored at 25 °C, and effect on respiration rate and nutrient composition ☆

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Abstract

Maize was stored for 2 months in chambers maintained at 25 °C to simulate conditions observed in the central part of the "Corn Belt" of the United States when the grain warms because of high summertime temperatures after a period of winter storage. Maize was brought to three moisture contents (m.c.) within the range typically observed in farm and commercial storage, and was inoculated to simulate the amount of storage mold contamination typical of this situation. Certain of the experimental units were packed in insulation so that heat could accumulate within the grain masses to simulate hot spots. The wettest grain heated rapidly and became semi-anaerobic. The hot grain then dried rapidly, with the amount of moisture loss influenced by the ratio of water vapor pressures inside and outside the grain. The hot grain cooled and became more aerobic over time. New infections by storage molds, disappearance of viable field molds, development of kernel damage, and changes in atmospheric gases within the grain masses were correlated with the grain moisture or temperature and the rate at which the moisture and temperature changed. The rate of increase in new kernel damage was as high as 3.3% per week. Both the rate of respiration and the estimated ratio of starch to fat consumed were associated with the mean grain m.c. during the trial, and the estimated ratio of starch to fat consumed was in the range of 2.2/1–2.6/1 in the grain containing 16.6–18.2% m.c. That both fat and starch were consumed calls into question loss estimates based on starch metabolism alone. The fat content of the grain decreased more than 10% in some experimental units, but increased less than 5% in others. The protein content generally increased as other grain constituents were consumed.

Keywords: Maize storage; Deterioration; Molds; Respiration

1. Introduction

Approximately 175 million metric tons of maize is held in storage each winter (USDA, 2005) in the central part of the United States "Corn Belt", which includes the area approximately 40–44°N and 82–100°W. The grain is harvested at the start of the cold season, and some is stored through the following warm season. Storage molds constitute a major threat to the quality of this grain, especially during the warm months, when parts of the grain masses warm to above the mean ambient temperatures (20–25 °C).

The molds most often involved in deterioration of warm maize stored at the moisture content (m.c.) (14–18% w.b.) typical of farm and commercial storage in this geographical area are species of the genera *Eurotium* and *Aspergillus* (Qasem and Christensen, 1958; Christensen, 1971). In storage, these xerophilic "storage molds" often replace to a great extent the more hydrophilic "field molds" that infected many of the kernels before harvest (Christensen and Meronuck, 1986). Deterioration by storage molds often reduces the nutritional and commercial value of the maize. The commercial value is reduced when the

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appearance of kernels is altered in a manner recognized by the grain industry as kernel damage (Qasem and Christensen, 1958). The chemical composition may be altered due to enzymatic action that results in loss of energy and the production of free fatty acids and other undesirable by-products (Golubchuk et al., 1956; McGee and Christensen, 1970), but the changes typical of maize stored under the conditions noted previously have not been described.

A significant body of research has been published concerning the factors that influence the rate and extent of mold-induced deterioration during storage. Those factors were summarized by Bottomley et al. (1950), and include water activity (a function of the temperature, m.c., and substrate), previous storage history, amount of broken kernels and impurities, aeration (oxygen and carbon dioxide concentration in the grain mass), and duration of storage. Within the grain mass in a typical commercial or farm bin, these factors are likely to differ greatly from one part of the mass to another (Christensen and Meronuck, 1986). Small differences in the initial grain m.c., temperature, or previous storage time may result in large differences in the rate of seed infection and deterioration (McGee and Christensen, 1970; Christensen, 1971; Perez et al., 1982). If molds begin to grow in the warmer and/or wetter parts of the grain mass, heat of respiration causes these portions of the grain to become warmer, accelerating the rate of respiration and deterioration (Milner and Geddes, 1945). The presence of a temperature gradient in the grain mass causes air to move, which assists in the transfer of moisture to cooler grain (Milner and Geddes, 1945; Sinha and Wallace, 1965). The results of storage deterioration often include an increase in kernel damage, an increase in fat acidity, and a slight increase in protein content as non-protein constituents are consumed by mold respiration (Pomeranz, 1992).

Many articles have described studies of maize storage, but many of these used grain containing more than 18% m.c. In the geographical area of interest to this study, a m.c. greater than 18% is more typical of freshly harvested maize held for drying than of maize in farm or commercial storage. Of the few studies with maize stored with the m.c. commonly observed in farm and commercial storage bins in the Corn Belt of North America, the grain temperature was held constant throughout the trials in most cases (i.e., Bottomley et al., 1950; Qasem and Christensen, 1960; McGee and Christensen, 1970; Wicklow et al., 1998). Maintaining a constant grain temperature facilitates repeatability but does not simulate real-life conditions. Little information is available from studies in which the grain had a m.c., initial temperature, and mold infection profile typical of the US Corn Belt and in which the grain temperature was allowed to change normally during the trials.

The studies presented here were conducted to simulate storage of maize under conditions common in the major maize-production areas of the United States when the grain is held through the warm season. Often, some maize is stored at moderately high m.c. (16–18%) during the first several months of cold-weather storage. Grain managers attempt to market the higher-moisture grain before warm, springtime weather arrives, but many of the maize lots that are stored into the warm months contain layers of moist grain. These trials were intended to provide information on the environment within the grain masses and the consequences for grain quality under these conditions.

To investigate the effects of the initial m.c., we dried freshly harvested maize to three m.c. levels representing the range of moisture commonly observed in commercially-stored maize in the Corn Belt of the United States. By drying wet grain, we intended to avoid the artifacts produced when dry grain is wetted to increase its m.c. Those artifacts include respiration products not related to normal mold activity (Milner and Geddes, 1945) and an inter-seed equilibrium relative humidity (r.h.) higher than if the grain were dried to the same m.c. (Hubbard et al., 1957). To ensure that adequate storage mold inoculum was present in the experimental maize, the new grain was mixed with a small amount of old, moldy grain. To simulate summer storage, the experiments were conducted in a chamber held at 25 °C. To simulate grain masses in which heat of respiration accumulates, some of the experimental bins were embedded in insulation.

2. Materials and methods

2.1. Preparation of grain and experimental units

Maize containing 18.1% m.c. was procured directly from a field in NW Iowa (ca. 43 °N, 95 °W) in early November, transported to the laboratory during cold weather (<10 °C), and placed in storage at −28 °C within 24 h of its harvest. After one month in frozen storage, the grain was removed from the freezer. To prepare maize with the desired m.c. (18.0%, 16.5%, and 15.0%), to inoculate it to simulate the amount of storage mold inoculum likely to be present after 6–8 months of storage in typical bins, and to create the required number of experimental units, the following procedures were adopted:

To facilitate handling and mixing during mold inoculation, the maize was randomly divided into three portions of approximately equal weight. Each of the three portions was divided through a randomizing divider to produce 12 lots of approximately 21 kg each. Each lot was inoculated with 500 g of previously stored maize, and was thoroughly mixed in a mechanical mixer. The old maize was 62% infected with *Eurotium* spp., and contained an additional 6% of kernels infected with various species of *Aspergillus*. To promote uniformity in mold load and other characteristics among the experimental units, four inoculated lots were randomly selected and combined in an overhead bin. The grain from the combined lots was passed through a randomizing divider as it flowed out of the overhead bin, creating two lots of 42 kg each. This process was repeated until 18 new lots of ca. 42 kg had been created. Each lot of