AS VARIAÇÕES NAS CONDIÇÕES DE GRÃOS E LOGÍSTICA DURANTE O TRANSPORTE DE SOJA DA FAZENDA PARA O ARMAZENAMENTO EM SINOP, MT

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RESUMO: Tempo chuvoso durante a colheita e deficiência na infra-estrutura de armazenamento de grãos representam grandes desafios na colheita da soja e transporte no estado de Mato Grosso. No período de colheita da safra 2013/2014, a região de Sinop recebeu 993 mm de chuva com concentração no pico da colheita. Já em 2014/2015, a região recebeu 917 mm, com concentração no final da colheita. Nos dois anos, foram monitoradas cargas de soja medindo-se os seguintes parâmetros: teor de umidade (*MC*); temperatura (*T*), umidade relativa (*UR*), dióxido de carbono acumulado ($\Sigma CO_2 \cdot t_D$) durante a viagem; distância de viagem (*D*); e duração (t_D). Foram avaliadas 61 viagens feitas por 36 caminhões de 11 fazendas para 17 unidades armazenadoras. Os resultados incluem os seguintes valores: *MC*, 10,8–25,7%; *T*, 23,7–44,2 °C; *UR*, 31,7–87,9%; $\Sigma CO_2 \cdot t_D$, 0,0–4,4 x 10^3 ppm-h; *D*, 2,9–158,4 km; e t_D, 0,4–47,9 h. Em geral, a temperatura e a umidade relativa do ar no interior das cargas apresentaram-se relativamente uniformes na carga e não variaram durante o transporte. O CO_2 acumulados nas cargas aumentou com teor de umidade, temperatura e duração da viagem e poderia ser usado para estimar as taxas de respiração e perdas de matéria seca dos grãos.
PALAVRAS–CHAVE: respiração de grão, perda de pós-colheita, perdas de matéria seca.

VARIATIONS IN SOYBEAN HARVEST CONDITIONS AND LOGISTICS DURING TRUCK TRANSPORT FROM FARM TO STORAGE IN SINOP, MT

ABSTRACT: Rainy weather during harvest and deficits in grain storage infrastructure pose great challenges in soybean harvest and transportation in Mato Grosso. During the 2013/2014 harvest, the area surrounding Sinop received 993 mm of rain, mostly during the peak of harvest. During the 2014/2015 harvest, the region received 917 mm, mostly at the end of harvest. During these two harvest seasons, measurements of the following parameters were obtained to better understand grain transport conditions and their effects on postharvest loss: moisture content (*MC*); temperature (*T*), relative humidity (*RH*), and accumulated carbon dioxide ($\Sigma CO_2 \cdot t_D$) from grain respiration inside the trailer during the trip; trip distance (*D*); and trip duration (t_D). This study analyzes conditions during 61 trips made by 36 trucks from 11 farms to 17 storage facilities. Results included the following transport conditions: *MC*, 10.8–25.7% (w.b.); *T*, 23.7–44.2°C; *RH*, 31.7–87.9%; $\Sigma CO_2 \cdot t_D$, 0.0–4.4 x 10^3 ppm-h; *D*, 2.9–158.4 km; and t_D, 0.4–47.9 h. In general, temperature and relative humidity inside the trailers were uniform and relatively constant during transport. Accumulated CO_2 levels inside the trailer increased with moisture content, temperature, and trip duration and could be used to estimate respiration rates and dry matter losses.
KEYWORDS: grain respiration, postharvest loss, dry matter loss.

INTRODUCTION: Mato Grosso is the most important soybean producing state in Brazil, contributing 29.3% of 95.07 million tonnes of soybeans produced in 2014/2015 (CONAB, 2015) despite the challenges posed by rainy weather during harvest and deficits in grain storage infrastructure in the region. During a typical year, farmers plant soybeans in September through October, with the first three weeks of October generally considered to be the ideal planting window. Farmers spread their risks by planting soybeans of different maturities. Early maturing beans are ready for harvest in January and other varieties mature through March. Substantial differences in weather during the last two soybean cropping seasons presented an opportunity to investigate the effects of weather on soybean transportation conditions.

During the 2013/2014 season, soybean planting in Mato Grosso began during the first week of October and was completed six weeks later (IMEA, 2015). The concentrated planting season meant that harvest season would be short. Harvest was delayed during February but was completed by the end of March. In contrast, during the 2014/2015 season, soybeans were planted as early as mid-September because the region experienced above normal rainfall. However, because of hot and dry conditions for most of October, planting was delayed and more than 80% of the crop was sown outside the ideal planting window (IMEA, 2015). Because of planting delay and wet weather in February, the ensuing harvest was slower compared to the last two harvest seasons. Harvest was completed in April.

In this study, we describe the variations in harvest moisture content, logistics, and overall grain conditions during handling and transportation of soybeans from farm to storage and how these conditions might contribute to postharvest loss.

MATERIALS AND METHODS: Grain monitoring probes described by OLSEN et al. (2013) were used to monitor *T*, *RH*, and CO_2 concentration from grain respiration inside the trailer, as well as recording global positioning system (GPS) coordinates and time stamps, during 61 trips made by 36 trucks during soybean transport from 11 farms to 17 storage facilities within 150 km of Sinop, MT. Each probe contained four chambers (C1 to C4, bottom to top), each equipped with a Model K33-BLG sensor (CO2Meter, Inc., Ormond Beach, Florida, USA), and could be fitted with a fifth chamber (C5) for measuring conditions atop the grain pile and under the tarp cover. Data were collected every 3 or 6 min during a trip and were stored on an on-board SD card. Two probes were installed in each trailer prior to grain loading. After loading, three vertical soybean profile samples (approx. 250 g each) were collected using a grain sampler along the length of the truck. The truck was followed as it traveled to a storage facility where samples were collected using a hydraulic grain sampler and analyzed for moisture content.

Soybean samples collected at the farm and the probes were brought back to the lab for further processing. Harvest moisture content was determined by drying beans at 103°C for 72 h in a convection oven (ASABE, 2012). *T*, *RH* and CO_2 measurements were adjusted for calibration and analyzed for their minimum, maximum, mean, and standard deviation values during a trip. Measurements recorded prior to loading represented ambient conditions in the empty trailer. The accumulated CO_2 from grain respiration inside the trailer during the trip ($\Sigma CO_2 \cdot t_D$) was estimated using a numerical integration technique. The GPS data were used to determine distance (*D*) and trip duration (t_D) between farm and storage, following procedures outlined by SNYDER (1987). All data processing and statistical analyses were conducted in a spreadsheet (MS Excel 2013, Microsoft Corp., Redmond, Washington, USA) and a graphing software (DPlot Version 2.3.3.8, Hyde Computing LLC, Vicksburg, Mississippi, USA).

Once soybeans were loaded into the trailer, an increase in *RH* occurred in at least one of the lower chambers (C1) of the probes and defined the start of the trip. Grain loading was marked as finished when all chambers registered increases in *RH*. From the GPS data, the trailer was considered in transit when its velocity was greater than 5 km/h and traveling away from the farm. Transit ended when the velocity fell below 5 km/h at the terminal/storage location. The start of grain discharge was noted as the time when at least one of the top chambers (C4) registered a decrease in *RH* or CO_2 measurements. Discharge was defined as complete when all chambers recorded *RH* and CO_2 measurements near ambient conditions and this time was also designated as the end of the trip. The difference between t_D and the sum of loading, transit and discharge periods was noted as idle time, and included the time when the truck was just waiting at the farm, in the middle of transit, or at the storage facility.

RESULTS AND DISCUSSION: The following observations and comparisons were made between the two harvest seasons. In 2013/2014, soybean harvest *MC* from 38 trips studied ranged from 10.8–25.7% with mean (μ) and standard deviation (σ) of 17.0 ± 3.6%. In 2014/2015, *MC* from 23 trips studied ranged from 13.8 to 19.0% with μ ± σ = 16.6 ± 1.6% (Figure 1). These results show, on average, soybeans were harvested above the optimum 14.0% for safe storage during both seasons. In 2013/2014, *D* ranged from 5.4 to 132.4 km (μ ± σ = 35.4 ± 33.6 km) while t_D ranged from 0.5 to 24.4 h (μ ± σ = 6.7 ± 6.8 h). In 2014/2015, observed *D* was longer, ranging from 2.9 to 158.4 km (μ ± σ = 59.9 ± 59.3 km). t_D was also greater, ranging from 0.4 to 47.9 h (μ ± σ = 11.7 ± 14.7 h).

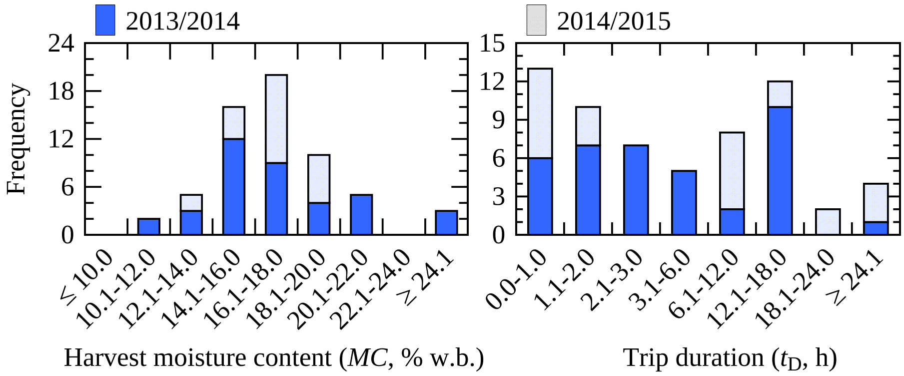

FIGURE1. Variations in harvest moisture content and trip duration.

Grain loading and discharge periods tended to be quick – generally, less than 2 h. Long loading periods occurred when rain events interrupted harvest. Transit periods ranged from 0.1 to 5.9 h with μ ± σ = 0.9 ± 1.1 h. Long transit periods occurred during transport along unpaved roads to get to BR-163, the highway on which most storage facilities are located.

All trucks in this study were filled in the afternoon. Temperatures inside the trailer ranged from 23.7 to 44.2°C but averaged from 33.4 to 35.2°C once the trailers were full and in transit. These temperatures were generally higher than maximum daily dry bulb temperatures. On average, grain temperatures across C1 to C4 for both probes during a trip were within 1.0°C of each other, indicating temperatures inside the trailers were uniform during a trip regardless of its duration. Average *RH* in trailers ranged from 56.9 to 74.3%. *RH* values could be as low as 31.7% (during filling) and as high as 87.9% (once the trailer was full with high moisture beans). On average, *RH* values across C1 to C4 for both probes inside a trailer were within 4.5% of each other during a trip.

CO_2 measurements were expected to vary with multiple parameters. As *MC* increases, respiration rate increases, so CO_2 also increases (RUKUNUDIN ET AL., 2004). Similar trends were expected with increased *T*. A tarp cover over a full trailer provided an adequate seal for CO_2 to accumulate inside the trailer. Hence, longer trips were associated with higher $\Sigma CO_2 \cdot t_D$. Most farms with on-site storage did not bother covering their trailers with a tarp during transport. Indeed, very low $\Sigma CO_2 \cdot t_D$ values were observed during these trips since CO_2 did not accumulate and t_D was under 2 h. Because CO_2 is more dense than air, CO_2 levels increased from C4 chamber to C1 chamber of the probe.

Variation in $\Sigma CO_2 \cdot t_D$ across three levels of *MC* (i.e., 14.0% and below; between 14.1 and 20.0%; and 20.1% and above) and three levels of trip duration (i.e., 2.0 h and below; between 2.1 and 12.0 h; and 12.1 h and greater) are presented in Figure 2. Most trips with t_D less than 2.0 h occurred at farms with on-site storage and most of the grain was harvested at *MC*'s between 14.1 and 20.0%. Only two trips at farms with on-site storage had *MC*'s outside this range – one trip at *MC* = 14.0% with t_D = 0.7 h and the other at 20.6% at t_D = 0.7 h. $\Sigma CO_2 \cdot t_D$ per chamber at the end of these trips are presented in bar graphs in Figure 2. The remaining 59 trips were scattered across the *MC* x t_D matrix, with the number of trips (*n*), indicated. Figure 2 shows a significant increase in $\Sigma CO_2 \cdot t_D$ with both *MC* and t_D, and provides a picture of the magnitude of grain respiration, and thus dry matter loss (*DML*), that occurred during grain transport. *DML* is the loss of available carbohydrates via aerobic respiration. Numerically, the evolution of 14.7 g CO_2 per kg of dry matter is equivalent to a loss of 1.0% dry matter (BERN ET AL., 2002). Better control of *MC* and t_D would help mitigate *DML* that occurs during transport from farm to storage.

CONCLUSIONS: This study provides evidence from two consecutive harvest seasons of the wide variations encountered in soybean parameters including moisture content, temperature, relative humidity, and CO_2 concentration and exposure; distance from farm to storage; and trip duration during soybean harvest in response to weather conditions and storage deficits in Sinop, MT.

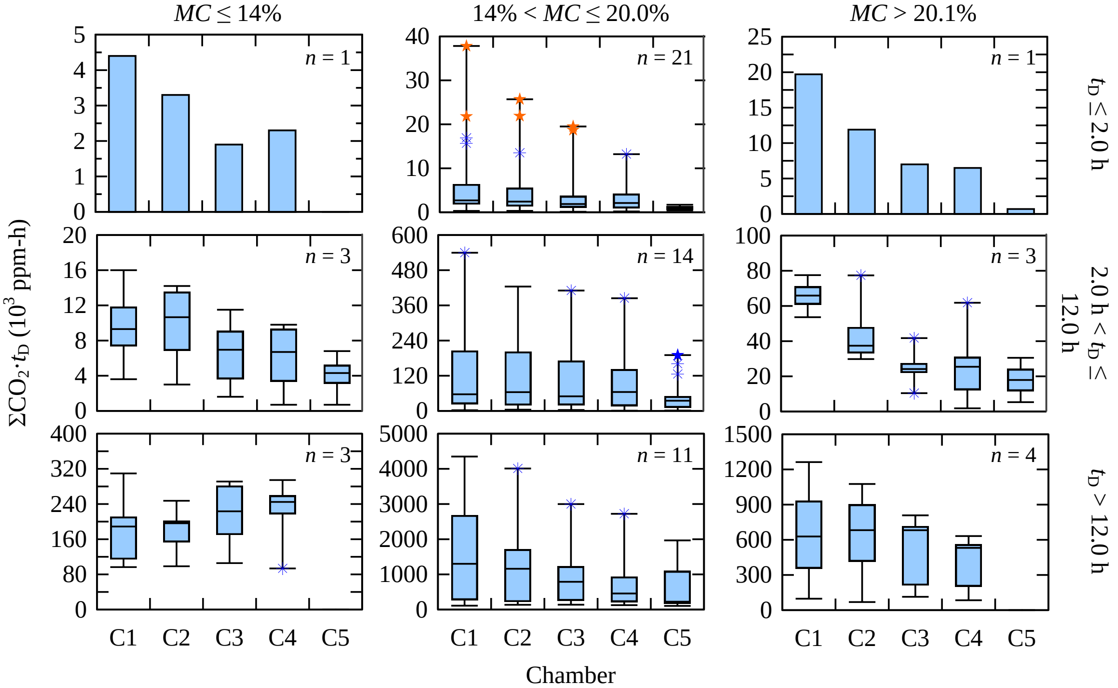

FIGURE 2. Variations in accumulated CO_2 due to grain respiration during the trip across the range of harvest moisture content and trip duration. The variable *n* represents the number of trips in each moisture-duration combination. Bar graphs show the accumulated CO_2 per chamber while median-based box plots show the minimum, maximum, interquartile range (IQR), outlier (✳, 1.5IQR) and extreme (★, 3IQR) values per chamber.

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