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Corn grains drying using direct-fired furnace with wood chips: Performance, quality and polycyclic aromatic hydrocarbons

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Abstract

The objective of this work was to evaluate the drying performance, the quality of the corn grain and the contamination by polycyclic aromatic hydrocarbons (PAHs) using a direct-fired furnace fed automatically by wood chips. Samples were collected at five-minute intervals, 12 samples before drying and 12 samples after drying. The following experimental evaluations were carried out: dryer – performance and fuel consumption; grains – moisture content, germination, electrical conductivity, apparent specific mass, mass of a thousand grains, color and PAHs. The dryer showed an average efficiency of 83.61%. The average consumption of wood chips was 0.3932 kg of chips per kilogram of evaporated water. Differences were observed in the grains after drying for the characteristics of mass of a thousand grains, apparent specific mass, germination and electrical conductivity. The average concentrations of PAHs in corn grains were higher than the maximum values allowed by the European Union legislation.

Keywords: food security; PAHs; renewable energy; *Zea mays* L.

Practical Application: New solutions to reduce grain contamination by carcinogenic agents.

1 Introduction

Drying aconts for a costly fraction in the indursty in terms of energy consumption, and it which may vary from 27 to 70% depending on the type of the product processed, making the efficient use of the fuel used essential (Kudra, 2004). This high energy demand is associated with the heat required for water removal, the inefficiency of the heat transfer process between the drying air and the product, as well as the losses related to most industrial dryers (Brito et al., 2019).

The use of biomass for energy generation is considered carbon neutral, as it is obtained in a sustainable fashion (Acda & Devera, 2014). In Brazil, wood is the main source of fuel in direct fired furnaces for drying grains (Weber, 2005). With the processing of wood in smaller sizes, the chip is obtained, which offers the possibility of automating the furnace supply, increasing combustion due to a larger contact area, reducing ash formation, more precise control and regularity in the drying air temperature, a reduction in labor and accident risks, as well as a reduction in costs.

During the biomass combustion process, significant amounts of ash, carbon monoxide (CO) and other compounds are generated (Girón et al., 2013). When biomass burning is incomplete, it can cause the formation of chemical compounds, denominated polycyclic aromatic hydrocarbons (PAHs); some of which are considered carcinogenic and genotoxic (World Health Organization, 2005). The PAHs may contaminate grains during the drying process, as they use the heated air from the direct fired system furnace, using the burning of biomass and high combustion temperatures (Silva et al., 2018).

Human contamination with PAHs is associated with 2–12% by inhalation and the diet contributes with 88–98% (Alomirah et al., 2011). Although more than 30 PAHs have been isolated and studied, 13 stand out in foods for being the most toxic: benzo(a)anthracene (B(a)A), chrysene (ChR), benzo(b) fluoranthene (B(b)F), benzo(j)fluoranthene (B(j)F), benzo(k) fluoranthene (B(k)F), benzo(a)pyrene (B(a)P), dibenzo(a, h) anthracene (DhA), dibenzo(a, e) pyrene (DeP), dibenzo(a, h) pyrene (DhP), dibenzo(a, i)pyrene (DiP); dibenzo(a, l)pyrene (DalP); indene(1,2,3-c, d)pyrene (IcP) and 5-methylcrysene (5MC) (Food and Agriculture Organization, 2008).

Consequently, researchers and companies seek to improve combustion processes and to develop more efficient equipment, as well as energy alternatives to replace fossil fuels. In this sense, the objective of this study was to evaluate the drying performance, the quality of the corn grain as well as the contamination by PAHs using a direct fired furnace fed automatically by wood chips.

2 Materials and methods

2.1 Corn grain samples

The corn grains (second harvest 2019) were mechanically harvested and then transported by trucks to a storage unit in the

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municipality of Montividiu, State of Góias, for drying in a dryer coupled to an automatic furnace powered by chips of eucalyptus firewood. Twelve samples were collected at 5-minute intervals before drying (wet grains), which were taken from the duct that feeds the dryer bucket elevator and after drying (dry grains), 12 more samples were taken from the dryer discharge conveyor, (redler), totaling 24 samples around 1.0 kg each. The total drying time was 210 minutes. After collecting the samples, they were sent to the Post-harvest and Plant Products Laboratory of the Instituto Federal Goiano - Rio Verde campus, for evaluations.

2.2 Drier and furnace

Grain drying was carried out in a mixed flow dryer (Kepler Weber, ADS) with a nominal capacity of 75 tons per hour for corn grains. The temperature and relative humidity of the ambient and exhaust air inside the dryer were monitored using a data logger. The drying air temperature was measured using a thermocouple sensor and the air temperature inside the furnace was recorded using an infrared thermometer.

2.3 Evaluation of the dryier

System performance evaluation was based on the methodology proposed by Bakker-Arkema et al. (1978), where the energy specific consumption (ESC) was determinded using Equation 1:

$$ESC = \frac{(FCt \times CV_1) + EC}{Lw} \quad (1)$$

Where, ESC – energy specific consumption, kJ/kg; FCt – total fuel consumption, kg; CV_1 - Lower calorific value of fuel, kJ/kg; EC – electric power consumpton, kJ and Lw – Water loss, kg.

Eficiency of the dryier was obtained by means of the temperatures of the drying air, exhaustion air and room temperature, according to Equation 2:

$$\eta = \frac{Tda - Tea}{Tda - Tra} \times 100 \quad (2)$$

Where, η - drying efficiency, (%); Tda – drying air temperature (ºC); Tea – exhaustion air temperature (ºC) and Tra – room air temperature (ºC).

The calorific value of the fuel (kJ/kg) was determined directly in a calorimetric pump.

Fuel consumption (kg of chip/kg of evaporated water) was determined by the amount of eucalyptus chips used in drying measured by weighing on a mechanical scale, in relation to the total amount of the dry product.

2.4 Corn grain evaluations

Moisture content (%, wet basis) – moisture content was determined before and after drying, using the forced air circulation oven method at a temperature of 103 ± 1 ºC, for 72 h, in three repetitions, according to ASAE recommendations (American Society of Agricultural Engineers, 2000), method S352.2.

Germination (%) – Germination was determined according to the Rules for Seed Analysis (Brasil, 2009), using four replicates of 50 grains, in duplicate. After assembling the paper rolls, they were placed in a B.O.D. chamber at 25 ± 1 ºC. The evaluations took place on the 7th day after the test was assembled and the 1 mm root protrusion was considered.

Apparent specific mass (kg/m^3) - a container of known volume filled with grains at a fixed drop height was used. After filling and weighing, the apparent specific mass was determined through the ratio between the mass (g) and volume (m^3) in a hectoliter weight scale, in three repetitions.

One-thousand grain mass (g) – it was measured from a grain sampling from each treatment. The value was obtained by determining the mass of 100 grains, in eight replicates, and, later, estimated for 1,000 grains (Brasil, 2009).

Electrical conductivity (µS/cm/g) - the methodology described by Krzyzanowski et al. (2020) was adopted. It was used four 50-grain subsamples of each treatment weighed on a scale with a resolution of 0.001 g.

Color – Color was determined on a spectrophotometer (Color Flex EZ, Canada), in duplicate. The results were expressed in L^*, a^* and b^*, where the values of L* (luminosity or brightness) can vary from black (0) to white (100); those from chroma a^* vary from green (-60) to red (+60) and from blue (-60) to yellow (+60) in chroma b^*, as reported by Paucar-Menacho et al. (2008).

Polycyclic Aromatic Hydrocarbons (µg/kg) - the samples were analyzed at the Food Technology Institute - ITAL, and the levels of 13 PAHs were determined: benzo(a)anthracene (BaA); benzo(b)fluoranthene (BbF); benzo(j)fluoranthene (BjF); benzo(k)fluoranthene (BkF); benzo(a)pyrene (BaP); chrysene (Chr); dibenzo(ah)anthracene (DahA); dibenzo(ae)pyrene (DaeP); dibenzo(ah)pyrene (DahP); dibenzo(ai)pyrene (DaiP); dibenzo(al)pyrene (DalP); indene (1,2,3-cd) pyrene (IcdP) and 5-methylcrysene (5MChr).

PAH standards were acquired from the brands Supelco (B(a)A, D(ah)P, D(ah)A, D(al)P, D(ae)P, B(j)F) (Bellefonte, PA, USA) and Sigma-Aldrich (D(ai)P, B(k)F, Chr, B(b)F, B(a)P, I(cd)P (Saint Louis MO, USA) and IRMM BCR-08IR (5-MChr) (Geel, Belgium). The HPLC grade solvents and reagents used were: hexane, N-dimethylformamide (Scharlab S.L., Sentmenat, Spain), methanol, acetonitrile (JT Baker, Mexico City, Mexico), anhydrous sodium sulfate (Synth, Labsynth, Diadema, SP, Brazil) and silica gel (70–230 mesh, ASTM, Merck, Darmstadt, Germany). Filters of 0.45 µm (HV PVDF 0.45 µm, Millipore, Cork, Ireland) were also used to filter the extracts before injection into the chromatograph. The water used was obtained by means of a Milli-Q purification system (Millipore, Bedford, MA, USA).

The methodology used in this study was based on Speer et al. (1990), in which 5 g of sample were weighed, 50 mL of hexane were added, and the mixture was placed in an ultrasound bath (Unique Ultracleaner 1400, Indaiatuba, SP. Brazil) for 15 minutes and transferred to a separation funnel. Extraction was done with 3 portions of dimethylformamide-water (9:1, v/v) (50, 25 and 25 mL) and then 100 mL of 1% sodium sulfate were added to the aqueous phase, followed by another extraction with

3 portions of hexane (50, 35 and 35 mL). The organic phase was then washed with water (40 and 40 mL), dried with anhydrous sodium sulfate and evaporated in a rotary evaporator at 45 ºC (IKA, HB10 RV 10, Guangzhou, China). For cleaning the extract, a glass column packed with silica gel (deactivated with 15% water) was used. The extract was eluted with hexane, collected in a round-bottomed flask, concentrated in a rotary evaporator and suspended in 2 mL of acetonitrile for later injection into the chromatograph.

The technique used was high-performance liquid chromatography with fluorescence detection (HPLC-FLD), using a Shimadzu chromatographic system (Kyoto, Japan) composed of an LC-20AT quaternary pump, DGU-20A5 online degasser system, SIL-20A automatic injector (30 µL injection volume), CTO-20A column oven and RF-10AXL fluorescence detector. The compounds were separated using a C18 column (Vydac 201 TP54, 25 cm x 4.6 mm i.d., 5 µm, stabilized at 30 ºC, Vydac, Hesperia, CA, USA) and a mobile phase gradient composed of acetonitrile (A) and water (B) at a flow rate of 1 mL/min, as follows: 0-20 min - 70 to 75% of A, 20-35 min - 75 to 100% of A, 35-55 min - 100% of A, 55-60 min - 75 to 70% of A, 60-75 min - 70% of A. PAHs were detected using the following excitation and emission wavelengths (nm): BaA, Chr and 5MChr (274/414), BjF (3 12/507), BbF, BkF, BaP, DalP and DahA (290/430), IcdP (300/500), DaeP (397/403) and DaiP and DahP (304/457).

The compounds were quantified using the external standardization method. The analytical curves were constructed from the injection of standard solutions, containing the 13 PAHs, in seven levels of concentration in acetonitrile (0.30 to 20 µg/L).

2.5 Statistical analysis

The experiment was carried out in a completely randomized design (CRD), where the samples were collected before and after drying. The results were subjected to analysis of variance (ANOVA) by the F test with the means compared by the t test at the 0.05 probability level, using the Sisvar software. Descriptive statistics were used to evaluate the dryer.

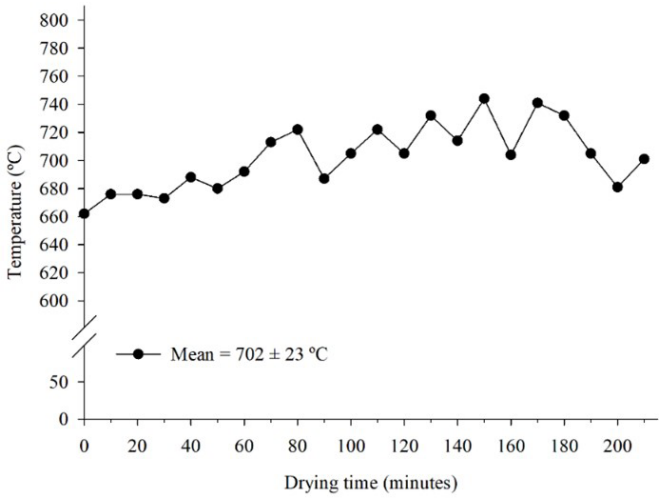

Figure 1. Temperature inside the furnace (average ± SD) over corn grain drying.

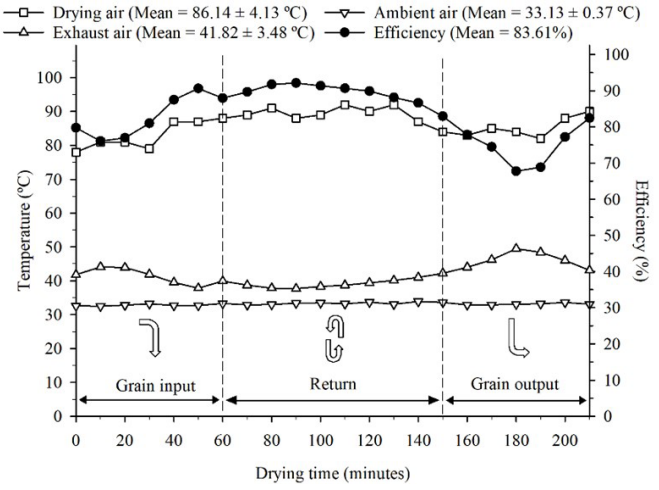

Figure 2. Efficiency and temperatures of the drying air, exhaustion air and room temperature during the corn grain drying period.

3 Results and discussion

3.1 Dryer and furnace

In the corn grain drying, variations in the internal temperature of the furnace were identified, which can be explained by the intermittency of the chip supply, which is controlled according to the temperature used for drying (Figure 1). Thus, these oscillations take place until reaching the desired temperature of the drying air, which depends on the initial conditions of the product as well as the dryer and the fuel used. The average temperature inside the furnace was 702 ± 23 ºC. Because of the high quantity of grains, a high volume of air is required during drying, making it necessary to use high temperatures in the furnace to increase the drying potential of the air.

The dryer had an average efficiency of 83.61%, which is considered satisfactory for the systems that use a direct-fired furnace (Kudra, 2012) (Figure 2). The efficiency value is influenced by the room air temperature, which is mixed in the cyclone with the hot combustion air from the furnace, and according to the distribution inside the dryer and the passage through the grains, it promotes the transfer of heat and mass, and consequently, the drying process. Thus, in terms of energy, the closer to the exhaust temperature at room temperature, the greater the drying efficiency. Quequeto et al. (2022) also obtained satisfactory results with 75.61% in the average performance of drying soybeans using direct-fire furnace.

Due to the high- moisture content and the physic-chemical characteristics of the corn grain, rotation was necessary, in which the grains pass through the drying chamber again, a moment when the energy efficiency reached the highest levels (92.12%). In addition, the higher drying air temperature (86.14 ºC) is required. Depending on the purpose of the product, care must be taken with the temperature of the drying air, with maximum values of corn grain from 100 to 110ºC being recommended

Table 1. Characteristics of the fuel and dryer during corn grain drying.

FCt	FC	LCP	EC	Lw	ESC
3,374.14	0.3932	18,542.13	834,057.00	8,579.62	7,389.35

Total fuel consumption (FCt, kg), Fuel consumption (FC, kg of wood chips/kg evaporated water), Lower Calorific Power (LCP, kJ/kg), Electric power consumption (EC, kJ), Water loss (Lw, kg) and Energy Specific Consumption (ESC, kJ/kg).

(Weber, 2005). Therefore, the temperature used to dry the corn grains in the present work was below this stipulated threshold.

According to Table 1, during the drying process to remove 1.0 kg of water, 7,389.35 kJ of specific energy was spent. The average consumption of wood chips was 0.3932 kg of chips/kg of evaporated water and the moisture content was 47.23% (wet basis). It is recommended that the biomass for power generation should have a moisture content equal to or less than 30% (wet basis) (Garstang et al., 2002) and the desired minimum lower calorific value is 7,949.60 kJ/kg (Brand et al., 2014). The wood chips used for drying had a greater moisture content than the recommended. As a disadvantage, part of the energy generated during combustion is used to evaporate the water contained in the fuel, which is denominated latent heat. However, the wood chips PCI showed satisfactory values for power generation.

The energy consumption per unit of evaporated water varies depending on several parameters, such as: the moisture content of the product over drying (drying rate), the room air conditions and the type of dryer used. The drying rate of the grains, in turn, is a function of the temperature and flow of the drying air, the initial moisture content and the hygroscopic balance of the product and their speed in the dryer.

3.2 Corn grain

Figure 3 shows the evaluations for characterizing the corn grains before and after drying. The weight of one-thousand grains showed a difference between the means for grains before and after drying (Figure 3A). The reduction in the mass of the grains is associated with the removal of water that occurs during drying, and through this evaluation, it is possible to determine and relate the average productivity of the area harvested in the field, adjusting the moisture content for a given value depending on the calculation of water removal.

The average moisture content of the grains (Figure 3B) after drying was 13.56 ± 0.71% (wet basis) with slight variations during the drying time, in which the control of the product water loss was satisfactory over the operation. This mean value is in line with the expectations, as recommended for the commercialization of grains, 14.00% (wet basis) (Brasil, 2011). Keeping the values of moisture content and temperature of the grains low during storage, the attack of microorganisms and respiration will have their effects minimized, therefore, drying becomes essential to maintain the quality of the grains.

The apparent specific mass showed difference for the grain averages before (wet) and after drying (dry) (Figure 3C). There was little variation for the grains during the drying time, corresponding in an even fashion to water loss. As the moisture content decreases and, consequently, the volume, the grains are more easily arranged inside the chamber, resulting in the increase in the values of the apparent specific mass. High values of specific mass guarantee a better quality of the agricultural product for trade purposes (Botelho et al., 2015). According to ASAE (American Society of Agricultural Engineers, 2008), the apparent specific mass for corn grains as standard is 721 kg/m^3, thus, the corn grains in this work have a good quality (758.50 kg/m^3).

The germination of corn grains showed a difference in the means before and after drying, considering only the root protrusion in the evaluation (Figure 3D). There was a marked reduction in germination from 92.06% before drying to 32.91% after drying, which was impaired by the high temperature of the drying air (average = 86.14 °C) which causes damage to the embryo and loss of quality. However, although the germination test is also used as a parameter of nutritional reserve, these grains will still be processed and traded for human and or animal consumption. Thus, this test does not directly indicate an impairment in the final quality of the product for consumption as food, however, it can impair the maintenance of the quality of the grains during storage.

The behavior of the electrical conductivity corresponded to that of germination, presenting high values after grain drying. Compared to the samples before drying, the means differed statistically, and the higher this value, the lower the integrity of the cell membrane of the grains (Figure 3E). Due to the high temperature of the drying air, the water contained inside the grains is removed quickly, with the occurrence of an internal pressure which generated cellular microcracks. In the electrical conductivity test, mechanical damage to the grains is evaluated, which is related to the physical integrity of cell membranes (Borém et al., 2014). Corroborating the results after drying (24.96 μS/cm/g), Silva et al. (2018) evaluated the quality of dried corn grains at 113 °C and obtained means values of electrical conductivity of 21.84 μS/cm/g.

The chroma and hue parameters, referring to the typical color of the grains, showed close values and no difference between the samples before and after drying (Figure 3F and G), demonstrating that there was no significant influence on this property. The drying process can cause color degradation due to changes in heat-sensitive compounds (Savlak et al., 2016), however, based on these criteria, it can be inferred that no injury was caused in these compounds, even with the high temperature of the drying air (86.14 °C).

Among the 13 PAHs analyzed for the corn grain samples, seven compounds were detected before and six after the drying process (Table 2). The following PAHs were not detected: dibenzo(ah) anthracene (DahA); dibenzo(ah)pyrene (DahP); dibenzo(al) pyrene (DalP); dibenzo(ai)pyrene (DaiP); dibenzo(ae)pyrene (DaeP) and Indene (1,2,3-cd) pyrene.

Among the PAHs identified in the corn grains, only benzo(a) anthracene and chrysene showed a difference between the means before and after drying. Regarding the total concentration of PAHs, there was also a difference after grain drying, confirming that the combustion gases provide increased levels of contamination in the product. The formation of PAHs is favored by high temperatures

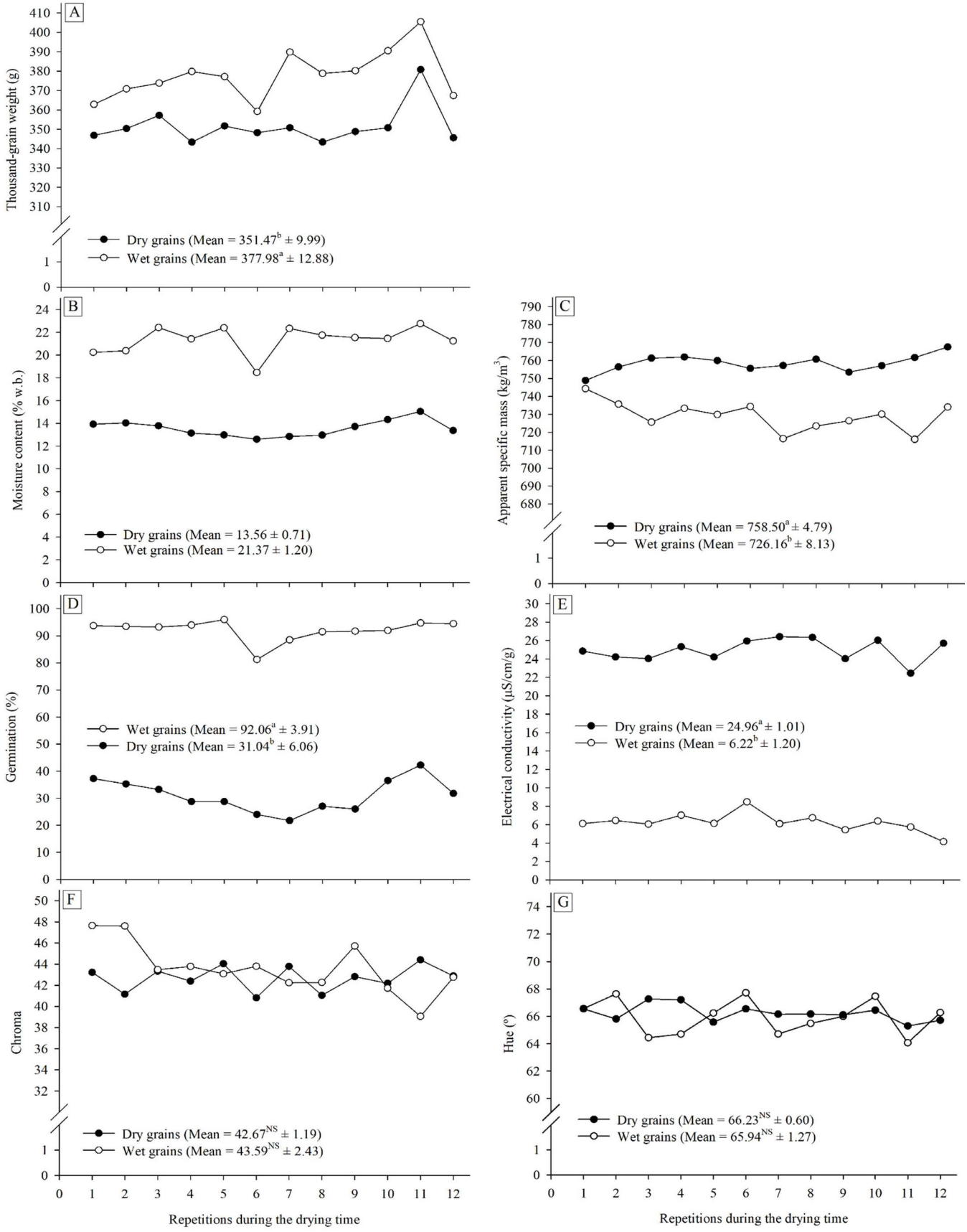

Figure 3. Characterization of the quality of corn grains before and after drying. (n = 3). (A) Mass of one-thousand grains; (B) Moisture content; (C) Apparent specific mass; (D) Germination; (E) Electrical conductivity; (F) Chroma; (G) Hue angle. Means followed by the same letters do not differ by the t-test at the 0.05 probability level. ^{NS} Not significant.

Table 2. Average PAH levels found in the corn grain samples before (wet) and after (dry) drying using wood chips fed furnace dryer.

PAHs	PAH Level (μg/kg)*		CV (%)**
	Wet	Dry	
Benzo(a)Anthracene	0.3825[b]	1.3548[a]	15.69
Chrysene	0.2422[b]	0.7206[a]	11.56
5-Methylchrysene	0.0994[a]	0.1536[a]	7.61
Benzo(j)Fluoranthene	0.0238	< LOD	-
Benzo(b)Fluoranthene	0.2799[a]	0.6928[a]	21.98
Benzo(k)Fluoranthene	0.2394[a]	0.1794[a]	9.90
Benzo(a)Pyrene	0.1140[a]	0.5801[a]	23.39
Total	1.3812[b]	3.6814[a]	31.40

Means followed by the same letter in the line are not different from each other by the t test at the 0.05 probability level; LOD = 0.04 μg/kg PAHs; LOD = 0.4 μg/kg Indeno and Benzo(j)Fluoranthene. *Original mean values (n = 12, with 3 determinations); **CV: Coefficient of variation, transformed data $(x+1)^{0.5}$.

(400 to 800 °C) during the incomplete combustion of organic matter, and depending on this variation, different PAHs can be formed. Generally, low molecular mass (MM) PAHs (128 to 202 g/mol) are formed in the temperature range between 400 and 500 °C. Above this range, it is observed that the formation of high MM PAHs (228 to 278 g/mol) occurs (McGrath et al., 2003), corroborating with the results obtained in the present study, with the average temperature inside the furnace of 702 °C (Figure 1).

All PAHs detected in this work have four to six aromatic rings, with MM greater than 202 g/mol. These heavier compounds, in addition to being more stable, have a higher lipophilic character, a characteristic that facilitates their absorption by the material (Rey-Salgueiro et al., 2009), and are considered more dangerous in relation to the carcinogenic and mutagenic properties. Resende et al. (2022) also detected the presence of PAHs with high MM in corn grains after drying with direct-fire furnace.

Lima et al. (2017) evaluated the contamination by PAHs in corn grains submitted to drying at different temperatures using eucalyptus firewood, and detected seven compounds with high values, four (pyrene, phenanthrene, fluorene and anthracene) of low MM (<128 to 202) and three (fluoranthene, benzo(a) anthracene and chrysene) of high MM (between 228 and 278); these values were justified due to the long exposure time of the product, 780 and 450 min, in the use of the drying temperature, 60 and 80 °C, respectively. The lower values of PAHs found in the present study can be attributed to several factors, such as: lower moisture content of the grains, consequently shorter exposure time to the drying air (210 min); fuel used in drying, being chips of eucalyptus wood, which because of its smaller particle size has greater contact area during firing in the furnace; and the aid of insufflation of forced air under the grid by means of fans, which also contributes to better combustion of the chip and, consequently, less formation of gases, therefore, generating less contamination in the grains.

Despite the differences between the levels of PAHs in this study (total = 3.68 μg/kg) compared to the work by Lima et al. (2017) (total = 105.74 μg/kg), both show a direct relationship of the PAH contamination in corn grains through drying using a direct-fired furnace.

Although there is no consensus on the mechanism of PAH formation, it is known that during the pyrolysis and or pyrosynthesis process, both the quantity and the composition of the PAHs produced vary depending on the type and size of the pyrolyzed material, temperature of combustion, time the molecules remain in the gaseous state and the oxygen concentration (Vieira et al., 2010).

Before drying, the corn grains (wet) have already been contaminated by PAHs, however, this can occur through environmental pollution, air particles, soil, water, among others, as well as fruits, meats and vegetables (Rey-Salgueiro et al., 2008). Among the 12 samples analyzed before drying, B(j)F with a value of 0.2850 μg/kg was detected in only one, demonstrating that the contamination by this compound occurred in a small part of the grain lot.

During the 64th meeting, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) concluded that 13 PAHs are proven to be carcinogenic and genotoxic (World Health Organization, 2005). All PAHs found in corn grains in this present work are classified as carcinogenic and genotoxic. JECFA evaluated the toxicological effect of B(a)P and identified carcinogenicity as the most expressive characteristic. The degree of carcinogenicity of this compound for humans has been evidenced by its classification as a carcinogen since 1985 by the International Agency for Research on Cancer (2012).

B(a)P was considered for several years as a marker of the presence of PAHs in foods, however, a new evaluation by the European Food Safety Authority (EFSA) concluded that only this compound is not an adequate marker, therefore, it was adopted a system of 4 PAHs: [B(a) A; Chrysene, B(a)P and B(b)F] as an indicator of the presence of PAHs in food (Commission of the European Communities, 2011). The European Community Regulation (CEC) No. 835/2011, defined the maximum allowed level of 1.0 μg/kg for B(a)P and also this same threshold for the sum of the 4 PAHs, detected in processed foods on the basis of cereal (European Food Safety Authority, 2008).

The average concentration of the sum of the 4 PAHs detected in the corn grains after drying, was higher than the maximum values allowed for the category of cereal-based processed products and foods for babies and children, according to the European Union Law No. 835/2011 (Commission of the European Communities, 2011) (Table 3).

The presence of PAHs detected in dried corn grains using a direct-fired furnace can cause contamination of derivative products produced from this raw material, such as corn oil. Molle et al. (2017) evaluated 22 corn oil samples from the Brazilian market and found 13 PAHs ranging from 2.61 to 30.98 μg/kg.

There are several studies on the occurrence of PAHs in different types of products, including smoked meat sausages (Mirbod et al., 2022), corn grains (Resende et al., 2022; Silva et al., 2018; Lima et al., 2017), soybeans (Quequeto et al., 2022), grilled meat (Siddique et al., 2021), canola, sunflower and corn oils (Molle et al., 2017), infant milk and cereals (Rey-Salgueiro et al., 2009), yerba mate (Vieira et al., 2010), toasted bread (Rey-Salgueiro et al., 2008).

Table 3. Sum of the four PAHs determined in the corn grain after drying.

Compounds	B(a)A	Chr	B(b)F	B(a)P	Sum
PAH level (µg/kg)	1.3548	0.7206	0.6928	0.5801	3.3483

For the children's scenario, if we use only B(a)P as a parameter for the evaluation of contamination, the mean values detected in this study would be in accordance with the European Union Law No. 835/2011 (Commission of the European Communities, 2011). However, children who eat the same quantity of processed corn-based products (biscuit, bread, cake, among others) as the adults per day, are subject to a greater risk of exposure to PAHs, due to their lower body mass, as well as the developing organs and tissues that are more susceptible to the toxic effects of certain chemicals (Iwegbue et al., 2010).

Thus, the dangers caused by PAHs to human health have already been shown and these compounds deserve extreme attention in the field of food safety, as the growing concern with the presence of contaminants makes this a topic of great interest and relevance not only for researchers in this area, but also for the population in general.

4 Conclusion

The dryer showed an average efficiency of 83.61% for drying corn grains, which is considered satisfactory for systems that use a direct fired furnace. The average consumption of wood chips was 0.3932 kg of chips per kg of evaporated water. The specific energy consumption to remove 1.0 kg of water was 7,389.35 kJ.

Differences were found in the grains after dry for the characteristics of one-thousand grain mass, apparent specific mass, germination and electrical conductivity. However, for the industrial purpose of the grains, the quality has not been impaired.

Drying with a direct fired furnace using wood chips caused PAH contamination in corn grain. However, the conditions used during the drying process, as well as the fuel characteristics, alleviated the potential for contamination by PAHs.

The average concentrations of PAHs in corn grains were higher than the maximum values allowed by the European Union legislation.

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