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Lead Poisoning Risk for Dairy Cows in the Semi-Arid Region of Pernambuco, Brazil

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Abstract The lead (Pb) isotopes ^{206}Pb and ^{208}Pb are the final products of the radioactive decay of ^{238}U and ^{232}Th, respectively. Soils in the municipalities of Pedra and Venturosa, Brazil, present high levels of these radionuclides. We hypothesized that forage plants growing in these soils may take up high amounts of Pb and, consequently, intoxicate dairy cows. To test this, we quantified Pb concentrations in 23 forage samples from this region. Pb concentrations varied from 5 to 344 mg kg^{-1}. The highest values are one order of magnitude above the reported limit, therefore, indicating high risk of Pb contamination for dairy cows.

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Lead ingestion is one of the most frequently reported causes of poisoning for farm animals, especially for dairy cows. Usually, signs of lead toxicity in dairy cows include a depressed appearance, blindness, grinding of teeth, muscular twitching, snapping of eyelids, seizures, polioencephalomalacia, and hypernatremia (Neathery and Miller 1975; Cebra and Cebra 2004). Lead is considered the heavy metal of higher natural occurrence in soil, with concentrations varying from 1 to 200 μg g^{-1}, and is widely distributed in the earth's crust. Natural lead is a mixture of four stable isotopes: ^{208}Pb (51–53%), ^{206}Pb (23.5–27%), ^{207}Pb (20.5–23%) and ^{204}Pb (1.35–1.5%). ^{206}Pb and ^{208}Pb are the final products of the natural radioactive decay of ^{238}U and ^{232}Th, respectively (Jaworowski 1969).

Studies about the geology of the rural region at the state of Pernambuco (Brazil), identified 263 points with radioactive anomalies associated with uranium e thorium. According to the report of the Brazilian Nuclear Corporation (Nuclebras), there are high levels of natural uranium around the municipalities of Pedra and Venturosa, located in the Brazilian state of Pernambuco, where U_3O_8 concentration reaches up to 22,000 mg kg^{-1} (Costa et al. 1977). A recent study carried out in dairy farms in the cited municipalities found high concentrations of ^{238}U and ^{232}Th in rock and soil samples (Santos Jr et al. 2005; Santos Júnior et al. 2006). In soils with high levels of these radionuclides, lead may be easily absorbed by plants that are consumed by herbivores, such as dairy cows (Amaral et al. 1988). In the municipalities of Pedra and Venturosa, the main crops cultivated and used as forage for dairy cattle are prickly pear (*Opuntia ficus-indica*), buffel grass (*Cenchrus ciliares*) and napier grass (*Pennisetum*

purpureum). In this context, the aim of the present study was to quantify stable lead concentrations in cultivated forage species in dairy farms in the municipalities Pedra and Venturosa, Brazil, and to discuss the potential effects of stable lead intake on the health of dairy cows feeding from these forage species.

Materials and Methods

Twenty tree biomass samples of prickly pear, buffel grass and napier grass were collected during November 2007 in nine dairy farms located near the uranium and thorium anomalous area in the municipalities of Pedra and Venturosa. This region is characterized mainly by subsistence agriculture systems and, as a consequence, very few trucks pass through the dirt roads that connect the farms. Besides, there are no industries or paved roads in the areas where the farms are located, therefore there are no relevant sources of lead contamination other than the decay of ^{238}U and ^{232}Th. The selection criteria for the sampling points were the nearness of the farms to the occurrence of uranium. The farms chosen in the present study are also the major producers of milk in the studied region, which have a daily production of approximately 6,000 l.

For each sample, 3 kg of fresh cattle forage were collected. The dry material was obtained after heating the samples to 80°C during 48 h in a forced ventilation oven. After that, the material was weighed to obtain the dry mass and then taken to the furnace, where the temperature was raised gradually up to 300°C. After 48 h at this temperature the ashes were obtained (IRD 1983). Subsequently, 10 g of ashes were taken for acid digestion. The acid digestion procedure was based on the method developed by Akagi et al. (1995). Approximately 10 g of ashes from each sample was transferred into a volumetric flask of 50 ml, in which 1 ml of HNO_3, 1 ml of $HClO_4$, 1 ml of H_2SO_4 and 1 ml of high-purity water (18 MΩ) were added and heated to 90°C on a hotplate for 30 min. After cooling, the digested sample was completed to a volume of 50 ml with high-purity water. The extracts were then analyzed in triplicate.

The analyses were carried out by using a Varian AA220-FS atomic absorption spectrometer with a flow injection system. The precision and the accuracy of lead determination were checked using certified reference material (Trace elements in plants), from the Food Analysis Performance Assessment Scheme (FAPAS). The accuracy of the results was checked by running three replicates of the certified reference material. For the calculation of the detection limits and quantification, the Brazilian Agency of Sanitary Surveillance (ANVISA) definitions were used (ANVISA 2003).

Results and Discussion

The mean lead concentration found in each sample is shown in Table 1. We observed a high variability of lead concentration between the samples analyzed. Lead recovery was near 95% with a relative standard deviation of 2.5%. The detection limits and quantification for lead were 1 μg and 3 μg, respectively. Lead concentration in buffel grass and napier grass was consistently higher than the concentration in prickly pear. The highest values were observed in samples collected in the farms referred to as F-7 and F-8.

The main radioactive anomaly of ^{238}U and ^{232}Th occurs in F-7 (Santos Jr et al. 2005, 2006). According to these authors, the high levels of ^{238}U and ^{232}Th found in the soils of F-8 were originated from the weathering of the anomalous rock outcrop within the neighbour F-7. As mentioned before, since there are no anthropogenic sources of Pb in the study area, the radioactive isotopes ^{238}U and ^{232}Th are very likely the only sources of lead in the soils of this region.

Table 1 Mean concentration of Pb in vegetables samples

Farm identification	Forage	Concentration (mg kg^{-1} DM[a])
F-1	Bufell grass	110 ± 20
F-1	Napier grass	140 ± 27
F-1	Prickly pear	7 ± 2
F-1	Prickly pear	15 ± 5
F-2	Bufell grass	87 ± 13
F-2	Prickly pear	17 ± 8
F-3	Bufell grass	200 ± 40
F-3	Bufell grass	250 ± 54
F-3	Prickly pear	20 ± 9
F-3	Prickly pear	45 ± 15
F-4	Prickly pear	10 ± 3
F-5	Bufell grass	38 ± 10
F-5	Prickly pear	12 ± 3
F-5	Prickly pear	25 ± 7
F-6	Prickly pear	21 ± 5
F-7	Bufell grass	344 ± 42
F-7	Prickly pear	67 ± 24
F-7	Prickly pear	58 ± 12
F-7	Prickly pear	5 ± 1
F-8	Bufell grass	289 ± 17
F-8	Bufell grass	277 ± 9
F-8	Prickly pear	79 ± 10
F-9	Bufell grass	45 ± 7

[a] Dry matter

[b] Standard deviation (95% of confidence at a 0.05 significance level)

Other studies in the literature have reported similar values of Pb in forage dry matter. For example, Lemos et al. (2004) found a maximum lead concentration of 245 mg kg^{-1} in the dry matter of forage samples collected in farms near the city of Campo Grande, in the Brazilian state of Mato Grosso do Sul. According to these authors, the pastures analyzed were contaminated by waste material from a lead battery recycling industry. It was observed that the value of 245 mg kg^{-1} in the dry forage matter reported by Lemos et al. (2004) is within the range of concentrations presented in the present study (Table 1). Similarly, studies conducted by Yoon et al. (2006), who quantified Pb in forage plants cultivated in an urban area contaminated by lead from automobile battery located in northeastern Jacksonville, Florida, USA, showed concentrations of this element ranging from 2.0 to 1183 mg kg^{-1} of dry matter.

Studies conducted by Strojan and Phillips (2002) showed a rapid absorption of lead by dairy cows when they are fed with forage contaminated by this element. These authors showed that, depending on the amount of lead ingested by dairy cows through forage ingestion, there may be intoxication and even death of the animals. Due to the elevated toxicity of lead to dairy cows, the National Research Council established a limit of tolerance of this element at 30 mg kg^{-1} of dry forage (National Research Council 1980). In Brazil, a maximum level of lead in forage consumed by dairy cows has not yet been established.

Approximately 61% of the samples in Table 1 presented lead concentrations higher than 30 mg kg^{-1} dry matter. According to a study conducted by Hammond and Aronson (1964), the daily ingestion of 300 mg of Pb in the total diet for a period of 60 days is fatal to cows. According to Silva et al. (2004), in the semi-arid region of Pernambuco dairy cows consume an average of 5 kg of dry matter per day, derived from different forage species. Based on this average consumption, it was therefore possible to estimate the amount of Pb ingested per day for dairy cows in the area of the present study. For this, we multiplied by 5 the values presented in Table 1. These results are presented in Table 2.

It is observed in Table 2 that most of the estimated values of Pb content in the potential daily diet of dairy cows fall within the range of 500–1,720 mg, which is much higher than the limit of 300 mg reported in the literature. It is important to mention that the forage samples from those farms located on the mineralization areas of uranium and thorium showed the highest natural concentrations of stable Pb. From the toxicological point of view, this is very important because serious cases of poisoning could occur in dairy cattle farms in the cities of Pedra and Venturosa. In fact, some farmers have reported health problems of dairy cows in this region in which the symptoms match those of Pb intoxication. However, since there is no scientific information to support this statement, we suggest the conduction of studies with the adequate methodology to test this hypothesis.

Table 2 Potential daily Pb ingestion by dairy cows through the consumption of three forage species in farms located in the municipalities of Pedra and Venturosa, PE, Brazil

Farm identification	Forage	Pb content (mg)
F-1	Bufell grass	550
F-1	Napier grass	700
F-1	Prickly pear	35
F-1	Prickly pear	75
F-2	Bufell grass	435
F-2	Prickly pear	85
F-3	Bufell grass	1,000
F-3	Bufell grass	1,250
F-3	Prickly pear	100
F-3	Prickly pear	225
F-4	Prickly pear	50
F-5	Bufell grass	190
F-5	Prickly pear	60
F-5	Prickly pear	125
F-6	Prickly pear	105
F-7	Bufell grass	1,720
F-7	Prickly pear	335
F-7	Prickly pear	290
F-7	Prickly pear	25
F-8	Bufell grass	1,445
F-8	Bufell grass	1,385
F-8	Prickly pear	395
F-9	Bufell grass	225

[a] Based on the consumption of 5 kg of dry matter

[b] Standard deviation (95% of confidence at a 0.05 significance level)

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