International Journal of Agricultural and Environmental Information Systems
Volume 13 • Issue 1

Factors Affect the Sorption and Degradation of and Rostenedione in Three Typical Agricultural Soils From Different Regions

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ABSTRACT

Androstenedione is a natural steroid hormone and endocrine disruptor. Batch and laboratory microcosm experiments and studies were conducted to investigate its adsorption and degradation in three soils: the Freundlichparameter Kf of androstenedione in the tested soils. Cattle manure dissolved organic matter (DOM) at 20 mg C·L−1 and decreased androstenedione sorption in the three soils. Degradation rate positively correlated with content clay and silt, while negatively with content of sand under the same conditions. Soil moisture significantly affected the persistence of androstenedione in red soil and black soil, whereas there was no significant difference in alluvial soil. Androstenedione half-life increased, ranging from 2.04d to 17.33d, under soil temperatures of 20°C, 10°C, and freeze-thaw cycles between +10°C and−10°C. Androstenedione degradation was inhibited in black soil at -10°C. Androstenedione degradation was significantly affected by soil texture and environmental factors, and manure DOM inhibited androstenedione sorption in three soils and can increase its transport to water sources.

KEYWORDS

Androstenedione, Degradation, Manure, Sorption

0 INTRODUCTION

The effects of natural steroid hormones in animal feces or sewage on physiological mechanisms of wild animals and humans have become a hot research topic in the environmental field (Leet et al., 2011; Ferrey et al., 2015; Zhang et al., 2021). Masculinized fish was found in the androstenedione-containing river receiving mill effluents, and the androstenedione has been revealed to cause androgenic effects on female mosquitofish (Jenkins et al., 2003). It is also frequently detected in wastewaters and concentrated animal feeding operations (CAFOs) lagoons worldwide in the following research (Chang et al., 2011; Liu et al., 2012; Bartelt-Hunt et al., 2011). Recently, potential environmental contamination risk with androstenedione caused by application of animal manure to fields has become a concern (Yost et al.,

DOI: 10.4018/IJAEIS.298655 *Corresponding Author

2014; Bartelt-Hunt et al., 2012; Zhang et al., 2019). Up to 800 $ng \cdot L^{-1}$ of androstenedione has been measured in livestock wastewater lagoons (Bartelt-Hunt et al., 2011). China has a total population of 7.6×10^9 livestock, including 100 million cattle, 660 million pigs and 650 million poultry (Liu et al., 2012). Yang et al. (2021) reported that androstenedione accumulates in the soil with long-term fecal application. Chinese researchers believed that androstenedione excreted by animals is worth notice and may pose potentially high risks to sensitive organisms in the receiving environment (Liu et al., 2012; Zhang et al., 2015; Huang et al., 2019).

Steroid hormones cannot degrade during composting completely (Zhang et al., 2019). After agricultural application, steroid hormones in animal manure were easily absorbed in soils and sediments owing to organic matter interactions (Lima et al., 2012; Ong et al., 2012). Kim et al. (2007) also confirmed that androstenedione adsorbed in soils within several minutes followed by a slow adsorption process. Due to its high adsorption by soils, the androstenedione thus has relatively low potential to migrate in soils (Yuan et al., 2020). The livestock grazing with direct access to the earth's surface water resulted in elevated androstenedione concentrations of up to 44 $ng \cdot L^{-1}$ in agricultural watersheds (Kolodziej et al., 2007). In a simulated rainfall field experiment (Mansell et al., 2011), six steroid hormones, including androstenedione, were detected in the runoff from a steer feedlot. Arnon et al. (2008) suggested that interactions between hormones and manure lead to enhanced soil transport, to depths of 32 m below a dairy-farm waste lagoon. Stump et al. (2010) proved that dissolved organic matter (DOM) from cattle manure decreased 17β-estradiol sorption on soils. Lucas and Jones (2006) reported that sheep urine enhances leaching through soil columns. Although it is reported that DOM may inhibit photodegradation of sex hormones (Young et al., 2013), there is no sufficient information available on the effect of manure DOM on androstenedione sorption.

The effect of manure waste on the degradation of steroid hormones has come into focus (Prateret al., 2015; Zitnick et al., 2011). Jacobsen et al. (2005) investigated how swine feces or municipal biosolids temporarily restrained the mineralization and dissipation of testosterone, but did not extend the residence time in soil. However, Lucas and Jones (2006) reported that addition of cattle and sheep waste to soil accelerated the degradation of estrone and 17β-estradiol. Degradation kinetics of steroid hormones is affected by soil temperature and moisture as well as amendment with manure (Yang et al., 2010). For example, the degradation rate of 17β-estradiol increased (10% to 20%) with increasing soil moisture (Xuan et al., 2008). However, there was no significant impact of soil moisture (ranging from 7% to 39%) on testosterone dissipation rates (Lorenzen et al., 2005). A temperature dependence of degradation has also been reported for testosterone and 17β-estradiol (Lorenzen et al., 2005; Xuan et al., 2008). The adsorption and degradation are important processes affecting the amount of the residue of the androstenedione in soils. Most studies (Sangster et al., 2015; Gravert et al., 2021) have studied the processes and influencing factors of the adsorption or degradation separately. Additionally, Salvia et al. (2014) explored the degradation of steroid hormones by two different traits of soils and confirmed that the rate of degradation depended on the soil. In fact, the adsorption of the androstenedione may affect its degradation in environmental media, but little attention has been paid to it due to limited investigation (Zhong et al., 2021). Our innovation lies in the comprehensive study of the factors affecting both the adsorption and degradation processes.

This study systematically investigated the sorption and degradation of androstenedione in typical Chinese soils. First, sorption properties for androstenedione were studied with a batch technique under biologically controlled conditions, and the influence of manure DOM on the sorption of androstenedione was also characterized. Second, the degradation rates of androstenedione in typical sterilized and unsterilized soils were investigated, and the effects of soil temperature, moisture and DOM from animal manure were also quantitatively examined.