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The cadmium and lead content of the grain produced by leading Chinese rice cultivars

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ABSTRACT

The cadmium (Cd) and lead (Pb) content in both white and wholemeal flour milled from 110 leading rice cultivars was assessed. The white flour Cd content ranged from <0.0025 to 0.2530 mg/kg (geometric mean (GM) = 0.0150 mg/kg), while its Pb content ranged from <0.0250 to 0.3830 mg/kg (GM = 0.0210 mg/kg). The *indica* types took up higher amounts of Cd and Pb than did the *japonica* types. Although the heavy metal content of wholemeal flour tended to higher than that of white flour, nevertheless 84.5% (Cd) and 95.4% (Pb) of the entries were compliant with the national maximum allowable concentration of 0.2000 mg/kg of each contaminant. An analysis of the Cd content in the white flour of three *indica* type cultivars grown in two consecutive years at two locations indicated that Cd content may be significantly affected by the conditions prevailing in the growing season.

1. Introduction

The two heavy metals cadmium (Cd) and lead (Pb) are potentially damaging both to crop productivity and to human health (Zhang et al., 1997). A large proportion of the arable land in China has experienced Cd contamination, due to industrial activity (Liu, Probst, & Liao, 2005), the use of untreated mining wastewater for irrigation (Yang, Lan, Wang, Zhuang, & Shu, 2006), or soil acidification (Wang, Jiang, Rao, & He, 2009). The main source of Pb contamination is the use of tetraethyl lead in automotive fuel (Burguera, Burguera, & Rondon, 1988). Once absorbed into the human body, both Cd and Pb are highly persistent. Over-exposure to Cd, for example, can induce emphysema and osteoporosis, culminating in irreversible damage to the lungs, kidneys and bones (Godt et al., 2006; Satarug et al., 2003). Pb is a strong neurotoxin, particularly for children (Cheng et al., 2006). Although plants do not generally take up Pb very effectively, the Pb content of the grain of rice crops grown in Pb-polluted soil can reach an alarmingly high level (Chen, Sun, Liu, & Zhou, 2008; Liu et al., 2003; Rooney, Mclaren, & Cresswell, 1999). Because of its prominence in the Asian diet, rice represents a leading source of dietary Cd and Pb (Moon et al., 1995; Naseri, Rahmahikhah, Beigygloo, & Ranjbar, 2014; Shimbo, Zhang, Watanabe, Higashikawa, & Ikeda, 2001), particularly in certain parts of China (Chen, Gong, Zhou, & Liu, 2013; Chen, Zheng, Tu, & Zhu, 1999; Cheng, Zhao, et al., 2006; Cheng, Zhang, et al., 2006; Luo, Wang, Xu, & Chen, 2014; Qian, Chen, Zhang, Chen, & Li, 2010; Sun et al., 2010; Tang et al., 2014; Wu, Luo, Deng, Teng, & Song, 2014; Zhai et al., 2008; Zhan, Wei, & Niu, 2012; Zhang, Zhang, Zhong, & Jiang, 2014; Zheng et al., 2005). In 2002, a survey carried out by the Chinese Ministry of Agriculture Rice Product Quality Inspection and Supervision Center showed that 10% of rice samples contained over the national maximum allowable concentration (MAC) of 0.2000 mg/kg Cd; in some samples, the level rose as high as 1.00 mg/kg (Yang et al., 2006). Among some 269 *japonica* rice seed lots sampled from the Yangtze River delta, 4.1% contained above the Cd MAC, and 15.2% above the Pb MAC (Cheng et al., 2006). Zhen, Cheng, Pan, and Li (2008) have reported that 10% of samples obtained from public markets exceeded the MAC for Cd. In contrast, Qian, Chen, Zhang, Chen, and Li (2010) claimed that in a set of >700 refined (white) flour samples, the vast majority contained below the Cd and Pb MACs, while Wang, Song, Yin, and Xu (2014) showed that mean levels of Cd and Pb in 300 rice samples collected in Jiangsu province lay below the MAC. The conclusion is that the extent of both Cd and Pb contamination is uncertain. Nothing is known regarding the interaction of Cd and Pb and cooking and eating quality.

Rice cultivars have been classified into a number of subspecies, of which the two most prominent are *indica* and *japonica*. The former type is grown mainly in the southern lowland areas of China, while the latter prevails in the North, as well as in a number of upland regions in the South. Here a set of both *indica* and *japonica*

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Chinese cultivars was analyzed, the criterion for inclusion being only that they were grown on a minimum of 10^4 Mu (equivalent to 6.67 KHa). The sampling locations were chosen to include regions which had reported above the MAC for Cd (Guangdong, Hunan, Sichuan, Fujian, Liaoning, Jiangsu, Anhui and Zhejiang) (Liu, Li, Li, Jin, & Pan, 2006; Zhan, Wei, & Niu, 2012). The samples were taken directly from the field, rather than from local markets to ensure an accurate location database. The objectives of this study were to assess the level of both Cd and Pb in milled from a nationwide collection of rice, to compare this with the equivalent in wholemeal flour and to document the effect on grain Cd and Pb content of the cropping location. The study also set out to survey the variation in the Pb and Cd content of the grain of some leading Chinese rice cultivars, and to establish a database of relevance to the international rice market.

2. Materials and methods

2.1. Rice samples

Grain from 110 (70 *indica* type and 40 *japonica* type) cultivars was obtained from paddy-grown crops produced across all of the major Chinese production regions both in 2012 and 2013 (Fig. 1). The *indica* grain was harvested from plants grown in either Zhejiang (18 samples), Hunan (11), Guangxi (7), Jiangxi (7), Guangdong (6), Anhui (5), Fujian (4), Sichuan (4), Yunnan (4), Hubei (2), and Chongqing (2) provinces, while the *japonica* grain was grown in Heilongjiang (11), Jiangsu (6), Zhejiang (6), Liaoning (4), Jilin (4), Henan (3), Shandong (3), Ningxia (2) and Hubei (1) provinces. Following the classification of the Chinese rice production areas, southern China (Guangdong, Guangxi and Fujian), growing exclusively *indica* types, falls into Zone I; central China (Hubei, Hunan, Jiangxi, Anhui, Zhejiang and Jiangsu), where both *indica* and *japonica* types are grown, falls into Zone II; south-western China (Sichuang, Chongqing and Yunnan), where similarly both *indica* and *japonica* types are grown, into Zone III; and northern China (Shangdong, Henan, Heilongjiang, Ningxia, Liaoning and Jilin), where only *japonica* types are grown, into Zone IV. The three *indica* cultivars Yueyou9311, Yliangyou1 and Zhongzheyou1 were collected from two sites located in either Jiangxi or Hunan in both years. After harvest, the grain was divided into 140 g lots and air-dried to a moisture content of ~12%, then de-hulled using a Model THU-35A Testing Husker (Satake Engineering Co. Ltd., Hiroshima, Japan) and milled using a McGill Miller No. 2 (Seedburo Equipment Co., Chicago, IL, USA). A Cyclotec 1093 sample mill (Foss Tecator AB, Höganäs, Sweden) was used to produce both white and wholemeal flour fine enough to pass through a 0.42 mm screen.

Fig. 1. A geographical map of sampling area.