Safety and Health at Work 15 (2024) 110–113

Contents lists available at ScienceDirect

Safety and Health at Work

journal homepage: www.e-shaw.net

Short Communication

Comparative Study of Heavy Metal Blood Serum Level Between Organic and Conventional Farmers in Eastern Taiwan

Mei-Hua Chung [1], Kuo-Hsiang Hung [1], Mi-Chia Ma [2], Mei-Yu Liu [3], Ru-Wei Lin [4,5,*]

[1] Graduate Institute of Bioresources, National Pingtung University of Science and Technology, Pingtung, Taiwan
[2] Department of Statistics, National Cheng Kung University, Tainan, Taiwan
[3] Department of Pathology and Laboratory Medicine, Taipei Veterans General Hospital Yuli Branch, Hualien, Taiwan
[4] Institute of Food Safety Management, National Pingtung University of Science & Technology Pingtung, Taiwan
[5] Department of Plant Industry, National Pingtung University of Science & Technology Pingtung, Taiwan

ARTICLE INFO

Article history:
Received 7 June 2023
Received in revised form
7 November 2023
Accepted 9 November 2023
Available online 13 November 2023

Keywords:
Fertilizers
Heavy Metals
Farmers

ABSTRACT

Numerous studies have indicated that organic fertilizers (OFer) might contain heavy metals (HMs) that present health risks to organic farmers (OFar). This study compared the concentrations of six HMs (Zn, Ni, Cd, Cu, Pb, Cr) in the blood of two distinct groups of farmers: 30 OFar from a designated organic area in eastern Taiwan, and 74 conventional farmers (CFar) from neighboring non-organic designated regions. The findings revealed that the OFar exhibited higher levels of Zn (1202.70 ± 188.74 μg/L), Cr (0.20 ± 0.09 μg/L), and Ni (2.14 ± 1.48 μg/L) in their blood compared to the CFar (988.40 ± 163.16 μg/L, 0.18 ± 0.15 μg/L, and 0.77 ± 1.23 μg/L), respectively. The disparities in Zn, Cr, and Ni levels were measured at 214.3 μg/L, 0.02 μg/L, and 1.37 μg/L, respectively. Furthermore, among the OFar, those who utilized green manures (GM) displayed significantly elevated blood levels of Zn (1279.93 ± 156.30 μg/L), Cr (0.24 ± 0.11 μg/L), and Ni (1.94 ± 1.38 μg/L) compared to individuals who exclusively employed chemical fertilizers (CFer) (975.42 ± 165.35 μg/L, 0.19 ± 0.16 μg/L, and 0.74 ± 1.20 μg/L), respectively. The differences in Zn, Cr, and Ni levels were measured at 304.51 μg/L, 0.05 μg/L, and 1.20 μg/L, respectively. As a result, OFar should be careful in choosing OFer and avoid those that may have heavy metal contamination.

Organic farming has experienced rapid growth in recent years, driven by an increased emphasis on health, sustainability, and the ecological friendliness of agricultural production systems [1]. Maksuda highlighted the fact that the global organic farming area tripled between 2011 and 2016, ultimately reaching 71.5 million hectares by 2018 [2]. OFar employ organic materials like manure, compost, GM, and agricultural waste to enhance the soil with trace elements and organic substances [3]. Compost, a prevalent organic fertilizer, can be produced from various organic waste sources, including livestock manure, crop residues, and other agricultural waste [4,5].

Numerous studies have demonstrated that organic farming might involve the utilization of organic fertilizers derived from agricultural waste that could potentially harbor HMs. These fertilizers have the potential to contribute to the gradual accumulation of HMs in the soil over time [6–8]. As HMs are non-biodegradable, they have the propensity to accumulate within animals and plants, thereby posing threats to ecosystems and human well-being [9]. The entry of HMs into the human body can occur through multiple pathways, with the most prevalent routes being ingestion, inhalation, and skin contact [10]. Consequently, farmers who operate in environments where HMs are present may encounter health risks.

This study aimed to measure the levels of HMs such as Cd, Cu, Ni, Zn, Pd and Cr in the blood of OFar in this study were those who used OFer and no CFer, pesticides or herbicides. This study compared 30 OFar from a specific region in eastern Taiwan with 74 CFar from a neighboring area with similar geological conditions. The participants completed a questionnaire and provided a blood sample of 7ml for heavy metal testing using ICP-MS. The reference ranges for normal levels of HMs in blood were as follows: Cd < 5 μg/L, Cr ≦ 0.6

Mei-Hua Chung: https://orcid.org/0000-0003-0910-0502; Kuo-Hsiang Hung: https://orcid.org/0000-0002-2657-4390; Mi-Chia Ma: https://orcid.org/0000-0003-1949-3004; Mei-Yu Liu: https://orcid.org/0009-0009-4233-6200; Ru-Wei Lin: https://orcid.org/0000-0003-0852-4274
* Corresponding author. Department of Plant Industry, National Pingtung University of Science & Technology, Pingtung, Taiwan.
E-mail address: rwlin@mail.npust.edu.tw (R.-W. Lin).

2093-7911/$ – see front matter
https://doi.org/10.1016/j.shaw.2023.11.006

Table 1
Demographic data and heavy metal contents in blood

	All (n = 104)	CFar (n = 74)	OFar (n = 30)	p
Age (year)†	49.32 ± 13.76	49.72 ± 15.03	48.33 ± 10.13	0.855
Sex§, n (%)				0.044*
Male	78 (75.0)	60 (81.1)	18 (60.0)	
Female	26 (25.0)	14 (18.9)	12 (40.0)	
Education level, n (%)				0.175
No higher than junior high school	22 (21.5)	17 (23.6)	5 (16.7)	
High school	43 (42.2)	26 (36.1)	17 (56.7)	
University and above	37 (36.3)	29 (40.3)	8 (26.7)	
Alcohol, n (%)				0.264
Yes	67 (64.4)	45 (60.8)	22 (73.3)	
No	37 (35.6)	29 (39.2)	8 (26.7)	
Areca nut, n (%)				0.115
Yes	36 (34.6)	22 (29.7)	14 (46.7)	
No	68 (65.4)	52 (70.3)	16 (53.3)	
Smoking, n (%)				0.829
Yes	43 (41.3)	30 (40.5)	13 (43.3)	
No	61 (58.7)	44 (59.5)	17 (56.7)	
CFer, n (%)				<0.001***
Yes	73 (70.2)	73 (98.6)	0 (0.0)	
No	31 (29.8)	1 (1.4)	30 (100.0)	
OFer, n (%)				<0.001***
Yes	41 (39.4)	11 (14.9)	30 (100.0)	
No	63 (60.6)	63 (85.1)	0 (0.0)	
GM, n (%)				<0.001***
Yes	15 (14.4)	3 (4.1)	12 (40.0)	
No	89 (85.6)	71 (95.9)	18 (60.0)	
Living environment, n (%)				>0.999
near farmland	86 (82.7)	61 (82.4)	25 (83.3)	
downtown area	18 (17.3)	13 (17.6)	5 (16.7)	

*Significant (p-value < 0.05); ***Significant (p-value < 0.001) † using Mann-Whitney U test; § using Fisher's exact test.

μg/L, Pb < 10 μg/dL, Cu 700-1500 μg/L, Ni < 2.0 μg/L, Zn 700-1200 μg/L. The questionnaire encompassed demographic details, exposure history to pesticide and OFer, and environmental factors. The study adhered to the principles outlined in the Declaration of Helsinki and received approval from the Yuli Hospital IRB (IRB No. YLH-IRB-11001). All participants provided informed written consent.

This study used SPSS Version 17.0 (SPSS Inc., Chicago Illinois, USA) to perform descriptive and comparative analyses. The Fisher's exact test analyzed the categorical variables to compare the conventional and OFar on sex, educational level, alcohol consumption, betel areca nut, smoking, pesticide use, herbicide use, insecticide and herbicide use, organic fertilizer use, and living environment differences. The Mann-Whitney U test compared the median values of age and blood levels of Cd, Cu, Zn, Cr, Ni, and Pb between the two groups of farmers. The significance level was 0.05. A p-value less than 0.05 indicated a significant mean difference in heavy metal blood levels.

Table 1 shows the results of Fisher's exact test for categorical variables and two groups of farmers: conventional and organic. The p-value of gender was less than 0.05, indicating a significant difference in the proportions of female farmers between the two groups. Specifically, organic farming had a higher proportion of women than conventional farming. Out of the 30 OFar, none utilized CFer. Conversely, among the 74 CFar, 62 solely relied on CFer, 8 employed a combination of chemical and OFer, 3 incorporated CFer, OFer, and GM, and one individual refrained from using any fertilizers. Additionally, 12 OFar integrated GM into their practices. These patterns reveal noteworthy disparities in the utilization of CFer, OFer, and GMs between the organic and conventional farmer groups ($p < 0.001$).

The test results revealed that OFar exhibited higher levels of Zn, Ni, and Cr in their blood compared to CFar (Table 2). The mean concentrations for Zn, Ni, and Cr were measured as 1202.70 ± 188.74 μg/L, 2.14 ± 1.48 μg/L, and 0.20 ± 0.09 μg/L, respectively, for OFar, while they were 988.40 ± 163.16 μg/L, 0.77 ± 1.23 μg/L, and 0.18 ± 0.15 μg/L for CFar ($p < 0.001$ for Zn and Ni; $p = 0.028$ for Cr).

Furthermore, the utilization of OFer and GM was linked to elevated levels of Zn, Cr, and Ni in the blood of farmers (refer to Table 2). Farmers who incorporated OFer demonstrated notably higher average levels of Zn and Ni (1166.77 ± 184.73 vs. 974.36 ± 164.23 μg/L, $p < 0.001$; 1.83 ± 1.55 vs. 0.73 ± 1.19 μg/L, $p < 0.001$) in comparison to those who didn't use them. Similarly, farmers who adopted GM exhibited higher mean levels of Zn, Cr, and Ni (1235.51 ± 199.62 vs. 1018.98 ± 178.29 μg/L, $p < 0.001$; 0.22 ± 0.10 vs. 0.18 ± 0.14 μg/L, $p = 0.017$; 1.92 ± 1.63 vs. 1.04 ± 1.38 μg/L, $p = 0.035$) than those who didn't employ such practices.

To comprehend the disparities in heavy metal concentrations within the blood of farmers who exclusively employ CFer, solely utilize OFer, or use a combination of organic and green fertilizers, we conducted additional analyses. Our findings revealed that farmers who exclusively employ OFer exhibit heightened levels of HMs in their bloodstream. Specifically, Zn and Ni levels in their blood are notably elevated in comparison to farmers who exclusively employ CFer (1151.22 ± 194.80 vs. 975.42 ± 165.35 μg/L, $p = 0.001$; 2.27 ± 1.56 vs. 0.74 ± 1.20 μg/L, $p < 0.001$).

Similarly, farmers who incorporate both organic and green fertilizers demonstrate elevated levels of Zn, Cr, and Ni in their blood, as opposed to those who solely relied on CFer (1279.93 ± 156.30 vs.

Table 2
Heavy metal contents in blood for different independent variables

Heavy metal	Organic farming ($n = 30$)	Conventional agriculture ($n = 74$)	p†
Cd (μg/L)	0.65 ± 0.40	0.68 ± 0.48	0.755
Cu (μg/L)	864.50 ± 151.69	872.12 ± 166.58	0.821
Zn (μg/L)	1202.70 ± 188.74	988.40 ± 163.16	<0.001***
Cr (μg/L)	0.20 ± 0.09	0.18 ± 0.15	0.028*
Ni (μg/L)	2.14 ± 1.48	0.77 ± 1.23	<0.001***
Pb (μg/dL)	1.73 ± 0.57	1.62 ± 0.55	0.344
Heavy Metal	No CFer (n = 31)	CFer (n = 73)	p
Cd (μg/L)	0.64 ± 0.40	0.69 ± 0.48	0.943
Cu (μg/L)	858.53 ± 152.78	874.75 ± 166.18	0.609
Zn (μg/L)	1193.20 ± 192.96	989.49 ± 164.01	<0.001***
Cr (μg/L)	0.20 ± 0.09	0.18 ± 0.15	0.025*
Ni (μg/L)	2.07 ± 1.50	0.78 ± 1.24	<0.001***
Pb (μg/dL)	1.71 ± 0.57	1.62 ± 0.55	0.479
Heavy Metal	OFer (n = 41)	No OFer (n = 63)	p
Cd (μg/L)	0.61 ± 0.38	0.71 ± 0.50	0.767
Cu (μg/L)	870.29 ± 145.73	869.67 ± 172.49	0.915
Zn (μg/L)	1166.77 ± 184.73	974.36 ± 164.23	<0.001***
Cr (μg/L)	0.18 ± 0.08	0.19 ± 0.16	0.215
Ni (μg/L)	1.83 ± 1.55	0.73 ± 1.19	<0.001***
Pb (μg/dL)	1.69 ± 0.53	1.63 ± 0.57	0.472
Heavy Metal	GM (n = 15)	No GM (n = 89)	p
Cd (μg/L)	0.51 ± 0.29	0.70 ± 0.47	0.251
Cu (μg/L)	896.43 ± 160.56	865.45 ± 162.40	0.429
Zn (μg/L)	1235.51 ± 199.62	1018.98 ± 178.29	<0.001***
Cr (μg/L)	0.22 ± 0.10	0.18 ± 0.14	0.017*
Ni (μg/L)	1.92 ± 1.63	1.04 ± 1.38	0.035*
Pb (μg/dL)	1.77 ± 0.41	1.63 ± 0.57	0.167
Heavy Metal	Near Farmland (n = 86)	Downtown Area (n = 18)	p
Cd (μg/L)	0.68 ± 0.46	0.61 ± 0.43	0.764
Cu (μg/L)	870.28 ± 161.50	868.16 ± 167.52	0.686
Zn (μg/L)	1045.57 ± 205.96	1072.40 ± 141.52	0.325
Cr (μg/L)	0.20 ± 0.14	0.15 ± 0.08	0.036*
Ni (μg/L)	1.16 ± 1.40	1.21 ± 1.67	0.532
Pb (μg/dL)	1.67 ± 0.56	1.54 ± 0.54	0.240
Heavy Metal	Only Using CFer (n = 62)	Only Using OFer (n = 18)	p
Cd (μg/L)	0.71 ± 0.50	0.74 ± 0.43	0.345
Cu (μg/L)	872.73 ± 172.17	851.09 ± 146.17	0.519
Zn (μg/L)	975.42 ± 165.35	1151.22 ± 194.80	0.001**
Cr (μg/L)	0.19 ± 0.16	0.17 ± 0.06	0.467
Ni (μg/L)	0.74 ± 1.20	2.27 ± 1.56	<0.001***
Pb (μg/dL)	1.64 ± 0.57	1.73 ± 0.65	0.623
Heavy Metal	Only Using CFer (n = 62)	Using OFer & GM (n = 12)	p
Cd (μg/L)	0.71 ± 0.50	0.50 ± 0.30	0.246
Cu (μg/L)	872.73 ± 172.17	884.58 ± 164.04	0.719
Zn (μg/L)	975.42 ± 165.35	1279.93 ± 156.30	<0.001***
Cr (μg/L)	0.19 ± 0.16	0.24 ± 0.11	0.013*
Ni (μg/L)	0.74 ± 1.20	1.94 ± 1.38	<0.001**
Pb (μg/dL)	1.64 ± 0.57	1.73 ± 0.45	0.390
Heavy Metal	Only Using OFer (n = 18)	Using OFer & GM (n = 12)	p
Cd (μg/L)	0.74 ± 0.43	0.50 ± 0.30	0.095
Cu (μg/L)	851.09 ± 146.17	884.58 ± 164.04	0.465
Zn (μg/L)	1151.22 ± 194.80	1279.93 ± 156.30	0.039*
Cr (μg/L)	0.17 ± 0.06	0.24 ± 0.11	0.095
Ni (μg/L)	2.27 ± 1.56	1.94 ± 1.38	0.632
Pb (μg/dL)	1.73 ± 0.65	1.73 ± 0.45	0.787

* Significant ($p < 0.05$)
** Significant ($p < 0.01$)
*** Significant ($p < 0.001$).
† Using Mann-Whitney U test.

975.42 ± 165.35 μg/L, $p < 0.001$; 0.24 ± 0.11 vs. 0.19 ± 0.16 μg/L, $p = 0.013$; 1.94 ± 1.38 vs. 0.74 ± 1.20 μg/L, $p < 0.001$).

Intensive animal farming often incorporates Cu and Zn into animal feed to promote growth and prevent diseases. This results in elevated levels of these metals in OFer obtained from chicken and pig manure. The excessive and prolonged use of such fertilizers can make Pb to increase concentrations of Zn, Cr, and Cu in the soil [11,12]. However, high and continuous rates of fertilization can also result in higher total concentrations of Cd, Zn, Cr, and Cu in the soil, while levels of Pb, Ni, or As remain unchanged [13]. Li et al. (2019) reported that the average concentration of HMs in manure followed the sequence of Zn > Cu > Cr > Ni > Pb > Cd [14].

Previous research has indicated that sewage sludge compost and pig manure compost contained higher concentrations of Zn, Cu, and Cr compared to standard quality-controlled OFer. These studies have also shown that OFer can contribute to the increased accumulation of Ni and Zn in rice [15,16], as well as higher levels of Zn and Cr in wheat grains [17,18]. The elevated levels of Zn, Cr, and Ni discovered in the blood of farmers who use GM might be linked to the presence of these HMs in the composted plants. Therefore, the addition of organic waste should be undertaken with caution [19].

There are numerous sources of OFer, and based on the information presented in Table 2, the blood Cr levels of farmers utilizing OFer did not exhibit an elevated trend, unlike the Cr levels observed in the blood of OFar employing GM. As a result, OFar should be particularly careful when deciding on the specific type of organic fertilizer to utilize.

Cu content typically registers higher in organic compost and manure compared to other fertilizers. Nonetheless, OFar do not exhibit higher blood Cu levels than CFar in the scope of this study. This could be attributed to the fact that CFar also employ copper-based fertilizers and fungicides, which may result in increased Cu exposure for them (Table 2).

Furthermore, farmers residing in close proximity to agricultural fields exhibit significantly elevated blood levels of Cr (0.20 ± 0.14 vs. 0.15 ± 0.08 μg/L, $p = 0.036$) compared to those living in urban areas (refer to Table 2). Environmental factors could potentially influence the levels of HMs found in the blood of these farmers. However, since the proportion of farmers residing in urban areas does not significantly differ between the organic and conventional groups (as indicated in Table 1), the living environment does not appear to be a confounding factor.

Zn is essential for cell growth, immune function, and metabolism. During the COVID pandemic, many articles have indicated that Zn plays a role in antiviral and antibacterial responses. Zn deficiency has also been associated with anorexia, skin disorders, mood instability, irritability, and depression. However, prolonged excessive Zn intake can Pb to a significant decrease in blood Cu levels, anemia, leukopenia, compromised immunity, and weight loss [20]. As indicated in Table 2, the Zn content in the blood of OFar is 1202.70 ± 188.74 μg/L. However, for farmers using GM, the Zn content in their blood is even higher, measuring 1235.51 ± 199.62 μg/L, which exceeds the standard limit of 1200 μg/L. This suggests a potential risk of heavy metal-related health issues among organic farmers.

Our conclusion is that the blood levels of HMs in organic farmers in eastern Taiwan align with numerous studies demonstrating the accumulation of HMs in organic compost and manure. Therefore, it is advisable for organic farmers to carefully consider their choices of OFer.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgments

Thanks to Yuli agricultural association for assisting in recruiting volunteers and providing a venue, and Professor Jian-Kang Chao for conducting hygiene education for the volunteers.

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