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Research Articles

Effect of fly ash and bottom ash application as mix growing media on heavy metals status in vegetables

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ABSTRACT

Coal fly ash-bottom ash (FABA) is still possible to be used directly as a mixture of soil with other growing media in small-scale agriculture. This study aimed to determine and identify the level of safety for the consumption of vegetable crops related to the adsorption of heavy metals due to the use of mixed FABA growing media. In this study, the proportion mixture of 6% FABA, 8,6% compost, and 8.6% fine coal (lignite) was applied. The proportion ratio between FABA and soil was 1:15. The FABA media application was prepared for chili, water spinach, spinach, caisim mustard, and moringa vegetables. The study was conducted without any control treatment without FABA on the same soil type. As an alternative control, vegetables from local farmers, local markets, and supermarkets surrounding the study site were taken. The experimental results showed that the application of FABA did not increase heavy metals content in vegetables. It can be concluded that vegetables grown on FABA media were safe and suitable for consumption in terms of acceptable daily intake of various heavy metals, except for As intake in water spinach and caisim mustard, which were recommended to be confirmed in further determination research.

Keywords: Acceptable daily intake; consumption safety; FABA; human toxicity

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INTRODUCTION

Coal burning not only produces energy and electricity but also produces waste in the form of fly ash and bottom ash (FABA). Coal burning for energy production produces approximately 5% ash content comprising 10-20% bottom ash and 80-90% fly ash. Coal consumption of the Indonesian electricity company (PLN) in 2021 amounted to 68.47 million tons, so that produced FABA was 3.42 million tons (PT PLN, 2021). The most FABA problem at the company is its abandoned volume and its storage management. FABA storage in landfills requires high operational costs, especially in monitoring its environmental impact and preventing the spread of pollution to the surrounding environment (Gajaje et al., 2021). FABA can raise problems in the environment as pollution in the air, water, and subsidence problems (Jambhulkar et al., 2018).

Many efforts have been made to utilize FABA. It has been used in various professional construction such as manufacturing concrete, filling structural, manufacturing stone brick, and construction roads (Wang et al., 2022). Although FABA contains heavy metals and other possibly poisonous microelements characteristics (Firman et al., 2020), however, the poisonous effect was found as not harmful. In agriculture, a low level of FABA application is considered safe (Chi et al., 2022). FABA conformance as a growing media mixture is equivalent with the soil as growing media, except carbon organic matter and nitrogen concentration, which were previously burned out during the energy generating process (Sonwani et al., 2023). The application of fly ash with a combined 10% dose with compost and fertilizer on bamboo shoots supported the higher yield, and the content of As, Cr, Cu, Mn, Ni, Pb, and Zn at permissible limits (Taupedi and Ultra, 2022). FABA contains macronutrients (K, Na, Ca, Mg) and micronutrients such as Fe, Cu, Zn, and Mn which are capable to support plants growth (Shakeel et al., 2019).

FABA application increases the soil pH (Panda & Biswal, 2018), thus it is considered for reclamation on acidic land. Land reclamation uses dolomite and limestone is relatively expensive and long-lasting in improving soil characteristics and releasing large amounts of CO_2 (Yao et al., 2015). FABA contains high calcium (Mohamed et al., 2023) that could be used as a replacement for calcitic and dolomitic liming. FABA application also increases soil aeration, percolation, and water retention; and the fly ash application enhances phosphate adsorption, and soil capacity to retent P on acidic land to neutral (Seshadri et al., 2014).

At the realization in the field of application, FABA is best done by reducing the effect of “dusting” which is heard containing nanoparticles that can interfere with the respiratory system on subchronic impact. Applications of FABA on a limited scale reduce those risks. However, when used on a large scale, it is already appropriate to use a variety of options that are suitable for the conditions of cultivation, either granulated with various agents granules such as tapioca or molasse (Agusta et al., 2020), pellet formulations (Arista et al., 2022), or slurry formulations based on weak acids or weak bases (Agusta et al., 2020).

In the preliminary study, various mixing media using FABA have been tested. The application of FABA as growing media with a composition of 6% FABA, 8.6% compost, and 8.6% fine coal (lignite) showed the best result on plant growth of various vegetables in agriculture areas close to PT. Indonesia Power, a state electric generating company. The mix media ratio of FABA with soil at proportion 1:15, plus NPK-fertilizer in a proportion of 0.4% of total media weight is recommended. Nevertheless, safety aspect of FABA application on vegetables is not evaluated yet. This study aimed to determine and identify the level of safety for the consumption of vegetable crops related to the adsorption of heavy metals due to the use of mixed FABA growing media. Here, chili, water spinach, spinach, caisim mustard, and moringa vegetables are evaluated and safety levels based on the provisions of the Acceptable Daily Intake (ADI) and Estimate Daily Intake (EDI) of WHO-FAO (1993) and WHO (1996) are discussed.

MATERIALS AND METHODS

Research site

The research was conducted from March to August 2022 at the nursery house of PT. Indonesia Power Suralaya PGU on Jl. Ex PLTU Suralaya Complex (5°54'02.6"S 106°01'50.4" E), Banten Province, Indonesia. Vegetable samples observed included chili (*Capsicum annuum* L.), water spinach (*Ipomoea aquatica* Forssk.), spinach (*Amaranthus sp.* L), caisim mustard (*Brassica rapa* L. subsp. *Parachinensis*), and moringa (*Moringa oleifera* Lam.) which were planted with and without FABA application (non-FABA). Non-FABA vegetable samples were obtained from KWT’s cultivation of Pandan Lestari, supermarkets, and local markets. The location of KWT Pandan Lestari was Lingkungan Kubang Saron Belumbang, Tegalratu Urban Village, Ciwandan Cilegon Sub-district (6°01'18.0"S 105°59'06.6" E). The supermarket was the Transmart Cilegon (6°00'24.8"S 106°02'33.8" E), and the local market was the traditional market Kranggot Cilegon (6°01'06.0"S 106°03'48.5" E).

Research design

The growing media with FABA application at nursery house of PT. Indonesia Power Suralaya PGU is placed in plastic pots. In a pot, media composed of fine coal (lignite) 1.5 kg, soil 13.5 kg, fly ash 0.5 kg, bottom ash 0.5 kg, and compost 1.5 kg. The total weight of the entire medium was 17.5 kg (1.0 kg FABA+1.5 kg compost+1.5 kg fine coal+13.5 kg soil). FABA: 1 kg in 17.5 kg = 6%; Compost: 1.5 kg in 17.5 kg = 8,6%; Fine coal: 1.5 kg in 17.5 kg = 8.6%. The proportion of FABA and soil (soil+compost)= 1.0 kg : (13.5 kg+1.5 kg) = 1:15.

Vegetable samples were taken on the edible part, i.e., the part of stems and leaves for water spinach, spinach, caisim mustard and moringa, while the portion of fruit for chili, about 100 g of sample were taken. Heavy metal content in the edible part of the vegetables was analyzed 3 times as replication. The observed heavy metals included Hg, Fe, Cd, Ni, Pb, As, Cr, Sn, Zn, and Mn. The extraction for heavy metals analyses used HNO_3 and $HClO_4$ and the measurement used ICP-AES Shimadzu 9820 series.

Furthermore, vegetable products were identified for their consumption safety level related to heavy metal absorption based on WHO's Acceptable Daily Intake (ADI) and Estimate Daily Intake (EDI) based on daily product consumption (WHO-FAO, 1993) and (WHO, 1996). The calculation formula was as follows: ADI = bC x Bw; ADI = acceptable daily intake (mg kg^{-1} day^{-1}); bC = Quality standard value of each metal that is allowed to enter the body according to JECFA (mg kg^{-1} day^{-1}); BW = body weight (kg $capita^{-1}$).

Estimate Daily Intake (EDI) was calculated as follows: $EDI = \frac{C\ x\ dC}{bW}$; EDI = Estimated value of heavy metals that enter each day (mg kg^{-1} day^{-1}); C = Concentration of heavy metals in vegetables (mg kg^{-1}); dC = intake rate per day (g $day^{-1}capita^{-1}$); bW = body weight (kg $capita^{-1}$).

Determination of water content is carried out by the thermogravimetric method or by an oven, which is based on the difference in weight before heating and after heating. Oven using a temperature of 80 ^{o}C, until the sample weight is constant (fixed). Analysis of heavy metal content comprised parameters Hg, Cd, Cu, Ag, Ni, Pb, As, Cr, Sn, Zn, and Mn in vegetable products.

Measurement of soil pH, EC (Electrical Conductivity), and TDS (Total Dissolved Substance) were carried out using a pH meter, EC meter, and TDS meter. Soil samples were taken as much as 5 grams then added 25 mL of distilled water. The soil was stirred until all the soil was mixed, after which the tool was placed in the solution until all the tool sensors touched the solution. The observation was continued with measurements of Ca^{2+}, Na^{+}, and TDS. Analysis of heavy metal content comprised Hg, Cd, Cu, Ag, Ni, Pb, As, Cr, Sn, Zn, and Mn. This analysis was carried out at the Testing Laboratory, Department of Agronomy and Horticulture.

Data analysis

Data was analysis using the t-test in SAS software. Data was presented in tabular was processed using Microsoft Excel.

RESULTS AND DISCUSSION

Heavy metals content in fly ash, bottom ash, and planting media

Based on total heavy metals content, coal fly ash and bottom ash from PT. Indonesia Power Suralaya PGU is not categorized as hazardous waste (B3 waste), either category 1 (TK-A) or category 2 (TK-B) according to Government Regulation No. 22 of the Year 2021 (Table 1). FABA, mix media, and soil used for the experiments both with FABA or without FABA application, showed clearly to be categorized as non-B3 waste and passed the C-category of B3 waste for the total heavy metal content of Ni, Pb, Cd, As, and Hg. However, FABA, mixed growth media and the soil without FABA application showed variability in the content of Zn with mostly lower than the C-category threshold (TK-C) and Cu mostly higher than the C-category threshold (TK-C). The total content on Cr and Mo did not pass the threshold C-category at FABA, soil used, and the mix media. The bottom ash (BA) sample for the Cr parameter is categorized as non-B3 waste while for the other 10 parameters, it only acts as a base layer. The content of heavy metals on fly ash for all parameters was higher than on bottom ash. This phenomenon is supported by Firman et al. (2020) regarding the content of heavy metals in fly ash and bottom ash.

Table 1. Heavy metal content of fly ash, bottom ash, FABA, and non-FABA planting media.

Category/ Vegetable species	Total heavy metal content in the soil media[z]										
	Fe (%)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Cd (ppm)	Cr (ppm)	As (ppm)	Mo (ppm)	Hg (ppm)
TK-A[y]	-	-	15000	3000	12000	6000	400	2000	2000	4000	300
TK-B[y]	-	-	3750	750	3000	1500	100	500	500	1000	75
TK-C[y]	-	-	120	30	60	300	3	1	20	40	0.3
Fly ash (FA)	2.79	531.3	125.32	35.95	55.82	15.74	1.46	19.7	6.33	113.72	<0.005
Bottom ash (BA)	2.10	412.1	26.28	20.10	36.24	4.79	1.31	6.2	1.00	51.23	<0.005
M. oleifera (no-FABA)	5.67	1031.0	97.45	87.49	22.02	69.34	1.52	48.8	<0.005	168.76	<0.005
C. annuum (no-FABA)	3.15	809.5	180.20	54.47	60.21	42.48	1.43	12.8	<0.005	117.72	<0.005
Amaranthus (no-FABA)	4.02	356.2	76.88	34.82	2.12	35.66	1.25	0.1	<0.005	219.47	<0.005
I. aquatica (no FABA)	3.70	992.5	98.10	74.79	18.82	26.50	1.40	36.8	<0.005	120.17	<0.005
M. oleifera (FABA)	5.97	1085.0	64.89	102.63	29.85	42.74	1.28	57.3	<0.005	157.73	<0.005
C. annuum (FABA)	5.04	1113.7	86.17	139.87	27.27	42.77	1.27	40.9	<0.005	134.09	<0.005
Amaranthus sp. (FABA)	5.01	958.0	59.63	95.28	29.38	37.56	1.29	38.6	<0.005	119.68	<0.005
I. aquatica (FABA)	4.72	1026.0	53.03	98.37	23.56	29.64	1.29	35.5	<0.005	119.85	<0.005
B. rapa (FABA)	5.04	914.8	51.71	98.21	19.06	27.18	1.28	21.0	<0.005	116.40	<0.005
No-FABA x mix media with FABA	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns

Note: [z]At the end of the experiment (August 2022); [y]Justification for TKA-TKB-TKC based on Indonesian Government Regulation no 22 of 2021; ns = not significant, * significant based on t-test p<0.05

Chemical characteristics of growing media

The application of FABA for the mixed growing media increased soil pH by 1.0 units. FABA growing media had a higher pH value (pH 7.3) compared to non-FABA media (pH 6.3) (Table 2). FABA had an alkaline characteristic and contributed significantly to macro- and micronutrients in the soil for the plants. FABA was capable of increasing soil pH and capable to improve soil moisture capacity (Noviardi, 2013). The application of mixed FABA with dolomites at the rate of 5 tons ha^{-1} could increase soil pH by 0.6 units (Ilham et al., 2020). An increase in soil pH in the soil could improve payload negative soil through the mechanism of deprotonation of H^+ in clay minerals (Priatmadi et al., 2014).

FABA additions as granules in the rate of 8 ton ha^{-1} on mineral soils increased the pH starting in the week 4th for at least for 4 months after soil application due to the contribution of the significant content of Ca and Mg in the FABA (Agusta et al., 2021). Soil EC, TDS, Ca^{2+}, Na^+, and NO_3^- on FABA growing media were not significantly different (Table 2). It indicates that the presence or absence of FABA had no contribution to a decrease or an increase in the measured parameters until 3 months of plant growing time. The electrical conductivity (EC) in FABA soil media of 180.8 µs cm^{-1} and the value in non-FABA media of 197.3 µs cm^{-1} is justified as negligible since its EC value is <2000 µS cm^{-1}. Plants growing on soils with EC values > 4000 µS cm^{-1} will be stunted (Gupta et al., 2011).

Table 2. Chemical characteristics of FABA and non-FABA[z] growing media.

Media type	pH	EC ($\mu S\ cm^{-1}$)	TDS (ppm)	Na^+ (ppm)	Ca^{2+} (ppm)	NO_3^- (ppm)
FABA	7.3	180.8	92.1	463.2	450.0	100.7
Non FABA	6.3	197.3	97.7	625.0	501.0	105.7
Results	*	ns	ns	ns	ns	ns

Note: [z]based on solubility in water with a ratio of soil: water = 1:5; ns = not significant, * significant based on t-test $p<0.05$

The Na^+ concentration in the FABA-mixed media was 463.2 ppm (Table 2), which is equivalent to 2.01 me 100 g^{-1}. In non-FABA media, the Na^+ concentration is 625 ppm, which is equivalent to 2.72 me 100 g^{-1}. Based on the classification of Na^+ in the soil, both values are classified as high. A value of 0.1-0.3 me 100 g^{-1} falls into the low category, while 0.4-0.7 me 100 g^{-1} falls into the medium category. A higher Na content in the soil is not appropriate for the soil's physical properties because it will cause clay dispersion, which can lead to blockage and the formation of crusts in the soil nests, resulting in decreased soil permeability and increased soil density. However, in some plants, Na might be exchangeable with K to increase cell turgor (Gupta et al., 2011); in low K^+ concentration in rice, Na^+ application increases rice grain production. Moreover, some C4 plants require Na^+ to survive. In the present study, the nitrate (NO_3^-) content of FABA and non-FABA growing media was 100.7 ppm and 105.7 ppm, respectively, with no statistically significant difference (Table 2).

The Ca^{2+} FABA value of 450.0 ppm (Table 2), is equivalent to 2.25 me 100 g^{-1}, while for non-FABA it was 501.0 ppm which is equivalent to 2.51 me 100 g^{-1}. This value is included in the low class based on the classification of Ca^{2+} in the soil. In general, Ca^{2+} values of 2-5 me 100 g^{-1} are included in the low class, 6-10 me 100 g^{-1} is categorized in the medium class, and 11-20 me 100 g^{-1} is categorized in the high class. However, even though the exchangeable-Ca^{2+} content is low, it will not show deficiency symptoms, because symptoms begin to appear if the exchangeable-Ca^{2+} content is <1 me 100g^{-1} (Management, 2002).

Heavy metal concentration in the vegetables

The concentration of heavy metals in spinach and water spinach leaves due to FABA application was not affected, on the contrary, the concentration of Pb in the leaf decreased slightly from 19.5 ppm to 16.8 ppm in spinach and from 15.4 ppm to 14.5 ppm in water spinach (Table 3). The slight concentration increase of Zn from 44.89 ppm to 51.74 ppm and Cu from 17.65 ppm to 24.57 ppm in chili is supposed less considered on human health impact since the daily consumption of chili is much less than the daily consumption of other vegetables, which averagely 153 g (Kalmpourtzidou et al., 2020).

The concentrations of Fe, Mn, Zn, Cu, Ni, Cd, Cr, As, Mo, and Hg in spinach were not affected by the application of FABA, but there was a decrease in Pb concentration from 19.5 ppm to 16.8 ppm (Table 3). The FABA application reduced the Fe concentration of chili from 95.26 ppm to 67.41 ppm and the Mn concentration from 63.03 to 38.17 ppm. Further, FABA increased the concentration of chili from 44.89 ppm to 51.7 ppm and the Cu concentration from 17.65ppm to 24.57 ppm, but the increase had little effect on human health as the daily consumption of chili was much less than the average daily intake of other vegetables of 153 g (Kalmpourtzidou et al., 2020).

In water spinach, the application of FABA reduced the concentration of Pb from 15.40 ppm to 14.50 ppm, while other heavy metals it was not affected (Table 3). The Fe content of the mustard has been significantly increased due to the use of FABA as a mixer of the plant medium from 545 ppm to 2186 ppm. In moringa, the addition of FABA as a growing medium does not result in an increase or decrease in the concentration of heavy metals. Zn, Cd, and Mo concentrations are decreasing, which may support their security status from vegetable consumption, nevertheless, the ADI value of Fe consumption is not mentioned by WHO-FAO (1993) nor WHO (1996). However, our study results were not similar compared to the results of another previous study (Akoji et al., 2022) that the average concentrations of Pb, Mn, Cd, and Ni on all plant samples were higher than the permissible limit, while Cd was higher only on spinach samples.

Table 3. Concentration of heavy metals of various vegetables with and without FABA application in the growing media.

Vegetable species	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Cd (ppm)	Cr (ppm)	As (ppm)	Mo (ppm)	Hg (ppm)
Amaranthus (no-FABA)	971.1	432.5	145.90	25.33	42.05	19.5	8.61	20.64	14.47	18.33	<0.005
Amaranthus (FABA)	2497^{ns}	150.6 ^{ns}	134.70^{ns}	21.69^{ns}	40.8^{ns}	16.8*	5.23^{ns}	24.02^{ns}	11.16^{ns}	13.13^{ns}	<0.005^{ns}
C. annuum (no-FABA)	95.26	63.03	44.89	17.65	17.15	13.1	3.90	10.02	8.15	12.58	<0.005
C. annuum (FABA)	67.41*	38.17*	51.74*	24.57*	14.98^{ns}	13.3^{ns}	3.54^{ns}	8.33^{ns}	7.54^{ns}	12.93^{ns}	<0.005^{ns}
I. aquatica (no FABA)	738.1	807.3	160.10	38.01	30.76	15.4	3.89	12.05	7.27	12.59	<0.005
I. aquatica (FABA)	543.9^{ns}	241.9^{ns}	100.1^{ns}	51.68^{ns}	33.87^{ns}	14.5*	3.68^{ns}	12.97^{ns}	9.49^{ns}	12.5^{ns}	<0.005^{ns}
B. rapa (no-FABA)	545.9	137.0	187.60	30.05	37.02	14.0	3.53	15.37	5.19	17.67	<0.005
B. rapa (FABA)	2187.0*	129.6^{ns}	110.80*	25.26^{ns}	38.17^{ns}	12.8^{ns}	3.26*	22.17^{ns}	10.22^{ns}	12.05*	<0.005^{ns}
M. oleifera (no-FABA) ^{z}	509.7	137.4	69.25	29.73	36.71	13.9	3.46	35.03	8.74	20.24	<0.005
M. oleifera (FABA)^{z}	362.4	178.8	74.36	28.01	38.21	13.9	3.40	27.22	14.03	20.46	<0.006
TDI (mg^{-1} kg bW^{-1} day^{-1})	-	-	0.692	0.002	0.009	0.04	0.007	0.004	0.002	0.077	0.005

Note: ^{Z}No t-test was not conducted due to no samples from supermarket nor local markets were found; ns = not significant, * significant based on t-test p<0.05 on the same vegetable species

Consumption safety

Human health can be disturbed by the presence of unwanted heavy metals and metalloids such as Hg, As, Pb, Cd, and Cr, which can increase illness and even fatality (Rai et al., 2019). The main source of heavy metal exposure in humans is through consumption, and there is growing concern regarding risk-related health potency issues due to the presence of several heavy metal contaminants in plants (Pigłowski, 2018).

Metal footprint could preserve considerably its positive effects, but mostly are toxic for many living organisms (Tóth et al., 2016). Although Cd, mercury (Hg), lead (Pb), arsenic (As), chromium (Cr), selenium (Se), nickel (Ni), and zinc (Zn) are present as trace minerals in plants, human consumption as a consequence is inevitable, which its intake is varied depending on the amount and frequency of food consumption (Mitra et al., 2022). Acceptable Daily Intake (ADI) is generally defined as the total maximum amount of ingredients and chemicals to which somebody could be exposed, every day for a period of a long time, usually without suffering the damaging effect (Mathiyalagan and Mandal, 2020). ADI is stated in milligrams of ingredients, as seen in food, per kilogram of body weight per day (mg kg^{-1}day^{-1}) (Chilakapati & Mehendale, 2014)). The concept of ADI was introduced by the Joint (FAO/WHO) Expert Committee on Food Additives (JECFA) in 1961. Estimate Daily Intake (EDI) is defined as a score that estimates the metal incoming weight of in body every day. Tolerable Daily Intake (TDI) is the total maximum temporary something substance in milligrams per kilogram of body weight that can be consumed in a day without causing harm to health (Marini et al., 2021).

Table 4 shows the EDI simulation based on estimation of common vegetables consumption by Southeast Asian people at an average of 153 g day^{-1} (Kalmpourtzidou et al., 2020) and an average body weight of 60 kg (Putri et al., 2021). The evaluated vegetables grown with or without FABA applications exhibited no security issues on heavy metals including Zn, Pb, Cd, Mo, and Hg. Fe and Mn are not mentioned in the recommendation data of WHO (1996).

Table 4. Estimated Daily Intake (EDI) of heavy metals on vegetable consumption*.

Species sample	Moisture content (%)	EDI (mg day^{-1} person^{-1})										
		Fe**	Mn**	Zn	Cu	Ni	Pb	Cd	Cr	As	Mo	Hg***
Amaranthus (no-FABA)	85.88	21.00	9.34	3.15	0.55	0.91	0.42	0.19	0.45	0.31	0.40	<0.3
Amaranthus (FABA)	84.21	60.30	3.64	3.25	0.52	0.99	0.40	0.13	0.58	0.27	0.32	<0.3
C. annuum (no-FABA)	83.93	0.47	0.31	0.22	0.09	0.09	0.07	0.02	0.05	0.04	0.06	<0.3
C. annuum (FABA)	88.42	0.24	0.14	0.19	0.09	0.05	0.05	0.01	0.03	0.03	0.05	<0.3
I. aquatica (no FABA)	91.26	9.87	10.80	2.14	0.51	0.41	0.21	0.05	0.16	0.10	0.17	<0.3
I. aquatica (FABA)	89.93	8.38	3.73	1.54	0.80	0.52	0.22	0.06	0.20	0.15	0.19	<0.3
B. rapa (no-FABA)	92.46	6.30	1.58	2.17	0.35	0.43	0.16	0.04	0.18	0.06	0.20	<0.3
B. rapa (FABA)	91.49	28.50	1.69	1.44	0.33	0.50	0.17	0.04	0.29	0.13	0.16	<0.3
M. oleifera (no-FABA)	80.14	15.50	4.17	2.10	0.90	1.12	0.42	0.11	1.06	0.27	0.62	<0.3
M. oleifera (FABA)***	80.16	11.00	5.43	2.26	0.85	1.16	0.42	0.10	0.83	0.43	0.62	<0.3
TDI (mg kg^{-1} day^{-1})**		-	-	0.692	0.002	0.009	0.036	0.007	0.004	0.002	0.077	0.005
Acceptable daily intake (mg per 60 kg bW^{-1} day^{-1})		-	-	41.5	0.11	0.55	2.14	0.42	0.23	0.13	4.62	0.3

Note: *Based on vegetable consumption 153 g day^{-1}. *C. annuum* intake is about 31 g day^{-1}; **TDI is not mentioned in WHO-FAO (1993), WHO (1996), and (Abdel-Kader & Mourad, 2022); ***trace value under limit detection on the concentration in the vegetable

Consumption daily intake covering Tolerable Daily Intake (TDI) and Acceptable Daily Intake (ADI) exposes the value 41.54 mg Zn, 0.11 mg Cu, 0.55 mg Ni, 2.14 mg Pb, 0.42 mg Cd, 0.23 mg Cr, 0.13 mg As, 4.62 mg Mo and 0.30 mg Hg (Table 4). Daily consumption of spinach and leaves exceeded the acceptable daily intake limit for heavy metals Cu, Ni, Cr, and As; and it has nothing to do with the cultivation system whether it uses FABA or not. Pb concentration in water spinach increased in the FABA media, but this did not affect the ADI limit of water spinach in Pb. The intake of Cu heavy metals from water spinach and caisim mustard exceeded the ADI with or without the application of FABA. Although the use of FABA did not increase the concentration of As in water spinach and caisim mustard, it turned out that the daily intake of As in water spinach and caisim mustard exceeded the ADI limit when the growing media was supplemented with FABA. On the other side, consumption of chili was relatively lower than other vegetables, the role of consuming the ADI value of heavy metals had no significant value. The daily intake of heavy metals through vegetables or other food sources is still experienced and can continuously accumulate in the body. Cu, Ni, Cr, and As contents in spinach, mustard greens, water spinach, and moringa were not influenced by FABA application in growing media. On average, daily heavy metals intake per person using the present simulation was 0.264 mg Ni, 0.0609 mg Cd, 0.0375 mg Cr, 0.0203 mg As, 0.1320 mg Mo, and 0.01422 mg Hg.

CONCLUSIONS

The application of FABA in soil growing media 1:15 did not influence the metal concentration of chili, water spinach, spinach, caisim mustard, and moringa, except As concentration in water spinach and mustard, which are recommended to be confirmed in further research. Daily consumption of spinach and moringa leaves will exceed the Acceptable Daily Intake limits for heavy metals of Cu, Ni, Cr, and As, however, FABA application did not increase the concentration of heavy metals in spinach and had no effect on consumer heavy metal intake. The Pb concentration in water spinach increased from 13.4 ppm to 15.25 ppm in FABA media, but this did not affect the ADI limit for water spinach in Pb, with consumption values remaining below the WHO threshold. Cu heavy metal intake from water spinach and caisim mustard exceeded the ADI with or without FABA application. Vegetables grown in FABA-supplemented media had no effect on Cu intake. Although the use of FABA did not increase the concentration of As in water spinach and caisim mustard, it is probable that the daily intake of As in water spinach and caisim mustard exceeded the ADI limit when the vegetables were grown in media with FABA.

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