



Pesticides Residues in Fresh Food of Plant Origin: Case Study in Indonesia

Agung Hendriadi, Sulistiyorini^{*)} and Miranti Reine Devilana

The Agency for Food Security, Ministry of Agriculture Indonesia, Indonesia

ARTICLE INFO

Keywords:

Active ingredients
 Food safety
 Fresh food of plant origin
 Pesticide
 Residue

Article History:

Received: February 7, 2020

Accepted: December 31, 2020

^{*)} Corresponding author:

E-mail: rinisulistiy@yahoo.com

ABSTRACT

The use of pesticides in fresh food of plant origin (FFPO) such as horticulture products is widely known. Such broad implementation of pesticide can result in a tremendous usage of pesticides and, afterward, in intolerable levels of pesticide residues in the products. In this work, we analyzed the pesticide residues in FFPO - which include fruits, vegetables, and rice - from some provinces in Indonesia. These products are taken from the market as samples for this analysis and they were not washed before the test. The test for pesticide residues uses two kinds of tests, which are: Rapid Test Kit that gives the qualitative result (presence or absence of active ingredients residual) without showing the amount of pesticide residue itself; and laboratory test that gives a quantitative result of pesticide active ingredients residual. Lab test data analysis shows that 98.58% of total samples from 26 provinces do not contain or have residues under MRLs so that it is stated as achieving food safety requirements. The pesticide residues include Organophosphate, Carbamate, Pyrethroid, Organochlorine, N-Phenylpyrazole, and Neonicotinoid groups of pesticide. Considering the effect of pesticide (residue) on human health and to environmental sustainability, efforts to control pesticide use need to be continued.

INTRODUCTION

Food is the most basic human need and its fulfillment is part of human rights. It was declared by FAO/WHO at the International Conference on Nutrition in Rome in 1992, that adequate, nutritious and safe food is the right of every human being. Safe food is food that is free from biological, chemical, and other contaminants that can disturb, harm, and endanger human health and does not conflict with the religion, beliefs, and culture of the community, to be able to live healthy, active, and productive lives. FAO/WHO also agreed that food safety is one of the components of food security. One of the most widely consumed food throughout the world is fruits and vegetables which are included in the Fresh Food of Plant Origin (FFPO) in the horticulture group.

According to Norton, Sanchez, Clarke-Harris, & Traoré (2003), there is a quick-rising in the production and export of horticultural products in

many developing countries. Data have shown that from 1970 to 2002, fruit and vegetable production in developing countries increased almost fourfold from 256 to 960 million metric tons, while exports more than triplicated from 1.9 to 6.5 million metric tons. The stimulus for a request for such high-value commodities include income increase, transportation costs decrease, and, in some cases, improved market access. Production for export is often fostered as a means of producing foreign exchange, boosting incomes to producers, and giving employment to the poor in a rural area. As for the importing countries, they get an advantage from bigger product stocks that generally have been limited and costly in the off-season.

In Indonesia, there were five seasonal vegetable commodities with the largest production in sequence, namely shallots (1.4 million tons), cabbage (1.44 million tons), large chili (1.21 million tons), potatoes (1.16 million tons), and

ISSN: 0126-0537 Accredited First Grade by Ministry of Research, Technology and Higher Education of The Republic of Indonesia, Decree No: 30/E/KPT/2018

Cite this as: Hendriadi, A., Sulistiyorini, & Devilana, M. R. (2021). Pesticides residues in fresh food of plant origin: Study case in Indonesia. *AGRIVITA Journal of Agricultural Science*, 43(2), 285–299. <https://doi.org/10.17503/agrivita.v43i2.2570>

cayenne pepper (1.15 million tons) in 2017 (BPS, 2019). Agricultural commodities have a strategic role in increasing foreign exchange earnings especially in the era of free trade of commodities between countries at present including horticultural commodities (Amilia, Joy, & Sunardi, 2016). In 2017, 17 (seventeen) types of seasonal vegetables were exported by Indonesia, namely shallots, garlic, kidney beans, cauliflower, potatoes, cabbage, turnips, carrots, spinach, beans, chili, mushrooms, long beans, cucumbers, chayote, eggplant, and tomatoes (BPS, 2019). The total value of vegetable exports in 2017 reached US \$ 14.48 million (BPS, 2019). The commodity that was the biggest contributor to foreign exchange was shallots with a net weight of 6.48 thousand tons and an export value of US \$ 8.81 million (BPS, 2019).

Horticultural commodities, especially fruits and vegetables, are products that are susceptible to pesticide residues. The physical characteristics of horticultural products which are perishable and bulky require visual quality requirements such as size, color, aroma, and freshness. Such conditions encourage excessive treatment of pesticides that have an impact on the vulnerability of these commodities to pesticide residues. In general, horticultural farmers, especially vegetables and fruits, tend to overuse pesticides to secure their products, even though conceptually pesticides are the last alternative in pest control (Amilia, Joy, & Sunardi, 2016; Miskiyah & Munarso, 2009). Farmers' hesitancy to the risk of crop failure and insufficient information about the pesticides they get is the reasoning factors for the high usage of pesticides in developing countries (Karunamoorthi, Mohammed, & Wassie, 2012; Popp, Pető, & Nagy, 2013; Veres et al., 2020). Besides, climate change can rise the use of active ingredients in pesticides by up to 60% (Koleva & Schneider, 2009). The cause for massive usage of pesticides is because they are more appraised by developing countries, especially in tropical regions, pursuing to join the global economy by supplying off-season fresh fruits and vegetables to countries in more moderate climates; thus, most of the developing countries are experiencing a shifting from an agrarian culture to newly industrialized society exploring for the economic prosperity driving to boosted consumption of such chemicals in agriculture (Abdou & El-Atta, 2018; Ecobichon, 2001).

Furthermore, based on the results of previous studies it is known that insecticide residues (which is one type of pesticide) in addition to being found in soil and water are also found in rice both at the farm level and at the market. In general, pesticide residues are still below the Maximum Residue Limits (MRLs), and only a few are above MRLs (FAO, 2005). Although the residual content in food is still below the MRLs, it is still important to pay attention for long-term use, especially the accumulative and biomagnification properties and their toxicity to the environment, human health, and soil microorganisms (Ardiwinata & Nursyamsi, 2012). It is in line with the statement by Aloizou et al. (2020) and Shattuck (2019) which mentioned the negative effect of low dose pesticide exposure in long-term/chronic conditions.

Even though pesticide usage in the agriculture and public health sector gives advantages, their usage also brings detrimental environmental and public health results. Concerns of the hazards of pesticides towards the environment and human health have been raised by many studies (Kim, Kabir, & Jahan, 2017). If pesticides are used improperly, they are potentially dangerous to humans, animals, other living organisms (Kaur, Mavi, & Raghav, 2019). Pesticides in plants, if systemic will be absorbed into plant tissues (leaves, fruit, branches, roots, skin, etc.). Possible food safety risks from pesticide residues are also a big issue for importers of fresh fruits and vegetables and a market-risk factor for exporters who may get their products restrained or refused if residues surpass tolerable limits. For example, Pan, Ren, & Luning (2021) stated that according to published data, there are 2473 food alert notifications in fruits and vegetables, which are alarmed about pesticide residues between 2015 and 2020 in Europe.

The utilization of pesticides should be cautious as they are toxins, considering the safety of operators, materials that are given pesticides as well as the surrounding environment (Karunamoorthi, Mohammed, & Wassie, 2012; Schreinemachers et al., 2017).

This study was driven by the Fresh Food Safety and Quality Control and Supervision activities carried out by the Agency for Food Security - Ministry of Agriculture. This is a form of Indonesian government support for food safety aspects as stipulated in Law number 18 of 2012 concerning Food

(Pemerintah Pusat, 2012). It was then detailed by Government Rule no. 86/2019 (Pemerintah Pusat, 2019) on Food Safety, which is a renewed version of Government Rule no. 28/2004 (Pemerintah Pusat, 2004), stating that the supervision for the fulfillment of requirement on food safety, quality, and nutrition for fresh food was conducted among other by the minister that administers government affairs in the agricultural sector, the governor, and/or the regent/mayor following their authority.

MATERIALS AND METHODS

Pesticide residue testing was carried out to measure the number of pesticides left in food. In these analyses, pesticide residue data were derived from samples of Fresh Food of Plant Origin (fruits and vegetables) taken from several provinces. Food samples taken from each region differ depending on the level of consumption, the level of production, and the intensity of pesticides used in the cultivation of certain plants. So there can be a difference in the number and kind of FFPO being sampled by provinces. Some examples of food ingredients used in this pesticide testing are rice, chili peppers, onions, tomatoes, long beans, cabbage, apples, oranges, and grapes. The foodstuffs to be tested were taken from markets and supermarkets located in each province, either nationally produced or imported. To obtain pesticide residue data, the tests conducted by each province in 2018 consisted of two types, namely Rapid Test and Laboratory Test. Rapid Test kits mainly used are G-9 devices; while the testing laboratory varied between provinces. In 2018, there were 27 and 26 provinces involved in the Rapid test and Laboratory Test respectively. The collected data from the Provincial government was then sent to and then compiled in the Agency for Food Security.

In this study, samples of FFPO have not washed before the testing; as this study intends to monitor the level of pesticide residue of FFPO in the market. This approach is different with pesticide monitoring program by other countries such as US Pesticide Data Program (PDP) whereas before the testing the samples were washed for 15 to 20 seconds with mildly flowing cold water as a consumer would do; as the data will be used among other for dietary risk assessments (USDA Agricultural Marketing Service, 2019).

Pesticide residues testing using a rapid test kit produces qualitative data because of the ability of this tool to detect the presence or absence of active pesticides (with a limit of detection/LOD of Carbamate 2 ppm and Organophosphate 0.5 ppm for G-9 Device), without showing the amount of pesticide residue itself. The Laboratory Test produces quantitative data in the form of residual pesticide active ingredients in the samples (fruits and vegetables) tested. Active Ingredients are synthetic chemicals or natural ingredients contained in Technical Materials or Pesticide Formulations which have toxic power or other biological effects on the target organism (Regulation of the Minister of Agriculture of the Republic of Indonesia No. 39/Permentan/SR.330/7/2015 on Pesticide Registration) (Kementerian Pertanian, 2015). Pesticide residue analysis in the lab was mostly using Gas Chromatography-Mass Spectrometry/GC-MS, while the rest was using Liquid Chromatography/LC. Data generated from this laboratory test was in the form of the amount of the active ingredient in each sample; however, few provinces report test results in the form of groups of pesticide active ingredients. This data was then compared to the standard for pesticide residues so that a conclusion is reached whether the fresh food tested meets the food safety requirements or not. References for food safety requirements include Regulation of the Minister of Agriculture of the Republic of Indonesia No. 55/Permentan/KR.040/11/2016 (Kementerian Pertanian, 2016) on Food Safety Supervision for Entry of Fresh Food from Plant Origin, Regulation of the Minister of Agriculture of the Republic of Indonesia No. 53/Permentan/KR. 040/12/2018 on Safety and Quality of Fresh Food from Plant Origin, Indonesian National Standard (SNI) 7317:2008 on Pesticide Maximum Residue Limits on Agriculture Product (BSN, 2008) and Codex Pesticides Residues in Food Online Database (Codex Alimentarius International Food Standards, 2020).

RESULTS AND DISCUSSION

A pesticide is a general phrase indicating some classes of insecticides, herbicides, fungicides, rodenticides, wood preservatives, garden chemicals, and household disinfectants that are utilized to either exterminate or guard against pests. The pest can be in the form of insects, plant

pathogens, weeds, mollusks, birds, mammals, fish, nematodes (roundworms), and microbes that oppose humans for food, damage property, or help bring or transmit diseases, or are seen as an aggravation. The most commonly used pesticides include insecticides, herbicides, fungicides, and rodenticides. The greatest utilization of pesticides is in the health sector and crops (Yadav et al., 2015). They are beneficial in public health for exterminating vectors of the disease, such as mosquitoes as well as in agriculture for killing pests damaging crops.

These pesticides vary in their physical, chemical, and identical characteristics from one class to another. There is three most widely known method of pesticides classification suggested by Drum (1980). This classification is still referenced by Kaur, Mavi, & Raghav (2019). The three methods of pesticide classes are classification based on (i) the mode of entry, (ii) pesticide function and the pest organism they exterminate, and (iii) the chemical composition of the pesticide. The pesticides that are analyzed in this study, as shown in the test result, are in the form of chemical composition (which is known as active ingredients/materials), refer to group iii. Classification based on the chemical composition and nature of active ingredients is the most usual and beneficial method of classifying pesticides. With refer to chemical composition, pesticides are classified into four main groups namely; organochlorines, organophosphorus, carbamates, and pyrethrin and pyrethroids (Büchel, 1983). Roberts & Karr (2012) stated that the coverage of pesticide types and products is wide-ranging and in their study, they describe other specific chemical groups that are in addition to the four groups mentioned earlier, namely: Neonicotinoids, N-phenyl pyrazole Insecticides, Phosphonates Herbicides, Chlorophenoxy Herbicides, Dipyridyl Herbicides, and Long-acting Anticoagulants. According to Sudarmo (1991), after being applied, pesticides if they can survive in the target field or the environment for a relatively long period it are said to be persistent. Amilia, Joy, & Sunardi (2016) states that based on their persistence, pesticides can be grouped into two groups, namely persistent and less persistent. Very persistent pesticides can leave residues very long and can accumulate in tissues through the food chain, for example, organochlorines, such as dichloro diphenyl trichlorethane (DDT), cyclodien, hexachlorocyclohexane (HCH), and endrin. Pesticides that are classified as less

persistent are effective against various types of targeted pests but easily degraded inside the soil, among others, are organophosphate groups, such as disulfoton, parathion, diazinon, azodrin, and 2-gophacide. The residual life of organophosphates and carbamates does not last long so chronic poisoning of the environment tends not to occur because environmental factors easily break down organophosphate and carbamate compounds into non-toxic components. Even though this compound is an acute poison so that safety factors are very important in its use (Hartini, 2014). Pan, Ren, & Luning (2021) stated that one of the major safety issues in food production is pesticide residue; particularly in fruits and vegetables that are susceptible to pest outbreak.

As the testing results of samples collected from various provinces, pesticide residue data of FFPO samples in 2018 were obtained. Types of FFPO tested included a variety of fruits and vegetables as well as rice either nationally produced or imported.

Pesticide Residue Analysis using Rapid Test Kit Result Data

The Rapid Test Kit in 2018 was conducted in 27 provinces. This test, which uses G-9 Device, can detect active ingredients of Carbamate groups up to 2 ppm and Organophosphate up to 0.5 ppm. The total sample tested using the Rapid Test Kit is 3.047 samples of FFPO. From the test, the following results are obtained:

1. Some 2,698 samples (88.55% of the total sample) did not show any pesticide residual of Carbamate and Organophosphate. According to the Reigart (1999), since the 1960s Organophosphate (OP) and carbamates insecticides have been extensively utilized for handling insects in the house and agriculture. Throughout this era, OP and carbamates largely substituted the usage of organochlorines because of apprehensions in the environmental and human health area of the later class. For the last 10 years (since 2002), chemical products in the OP and carbamate group have been inspected, which results in the next regulatory action with refers to human health apprehensions. Such arrangement can be seen in 2 widely used OPs with great acute toxicity: parathion (forbidden) and chlorpyrifos (no longer permitted for housing application).

Other OPs that continue commonly used include dichlorvos, acephate, methyl-parathion, and malathion. Malathion has rather poorer acute toxicity between the OPs and is registered for handling head lice (Ovide). While for carbamate, there is a popular example namely aldicarb, in which its application has generally been reduced by regulatory action because of its great toxicity. Carbamates that are widely used include carbaryl and pirimicarb (Roberts & Karr, 2012).

2. About 349 samples (11.45% of the total samples) showed residue of Carbamate/Organophosphate pesticides. The five commodities with the highest intensity detected by the 2 compounds of pesticides were: tomatoes (19.20%), Chillies (17.77%), grapes (7.45%), leeks (5.44%), and long beans (5.16%). Further information regarding the percentage of FFPO samples detected by the 2 compounds of pesticides compared to the total number of samples detected is shown in Fig. 1. Tomatoes were FFPO that are widely sampled

by 23 of the 27 provinces that reporting rapid test results.

3. When viewed from the region/province from which the FFPO sample originates, it can be seen which regions/provinces have a high or low intensity of pesticide residue detected. Based on the analysis results on pesticide residue data using a Rapid Test Kit, it can be seen that the 5 provinces with the highest detected intensity of pesticides residue compared to their samples number, namely: Bengkulu (68.09% of this province samples), Riau (58.53%), Central Java (40.4%), East Nusa Tenggara (35.14%) and Jambi (34.21% of this province samples). The number of samples reported from each province varies, in which for the five provinces the total number of samples for each rapid test is 47, 41, 146, 37, and 114. Detailed analysis result of pesticide residue on FFPO using the Rapid Test Kit in various regions/provinces can be seen in Fig. 2.

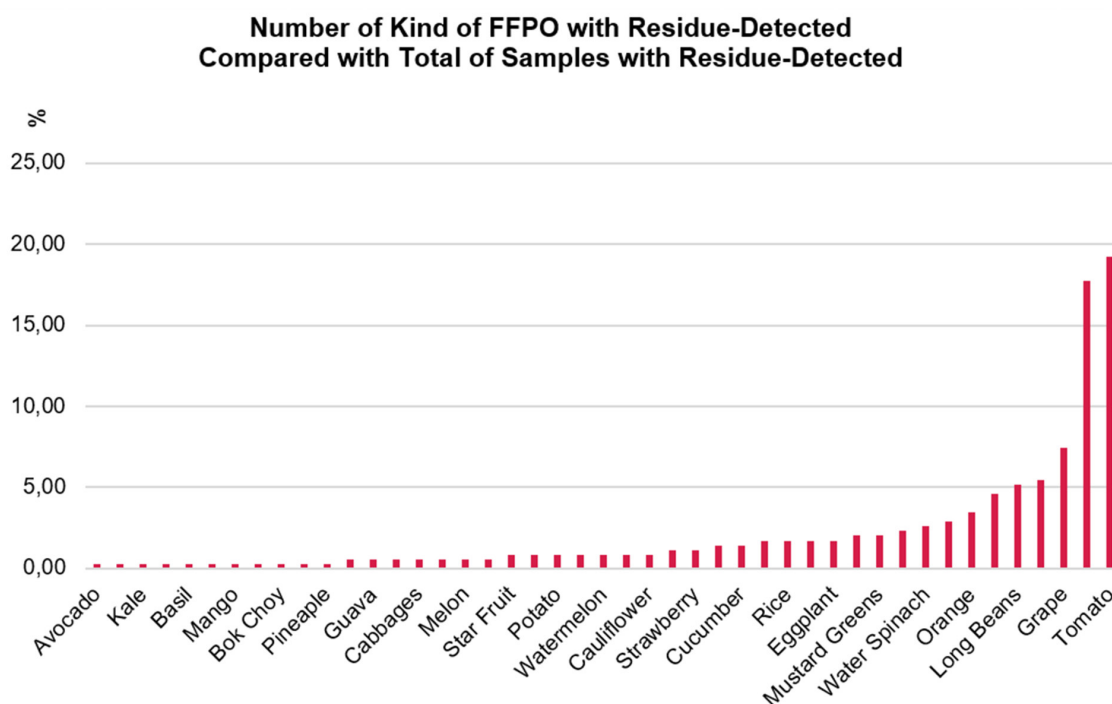


Fig Kind of FFPO Sample

Fig. 1. Number of samples that contain pesticide: Carbamates and Organophosphates (Rapid Test Kit Result in 2018)

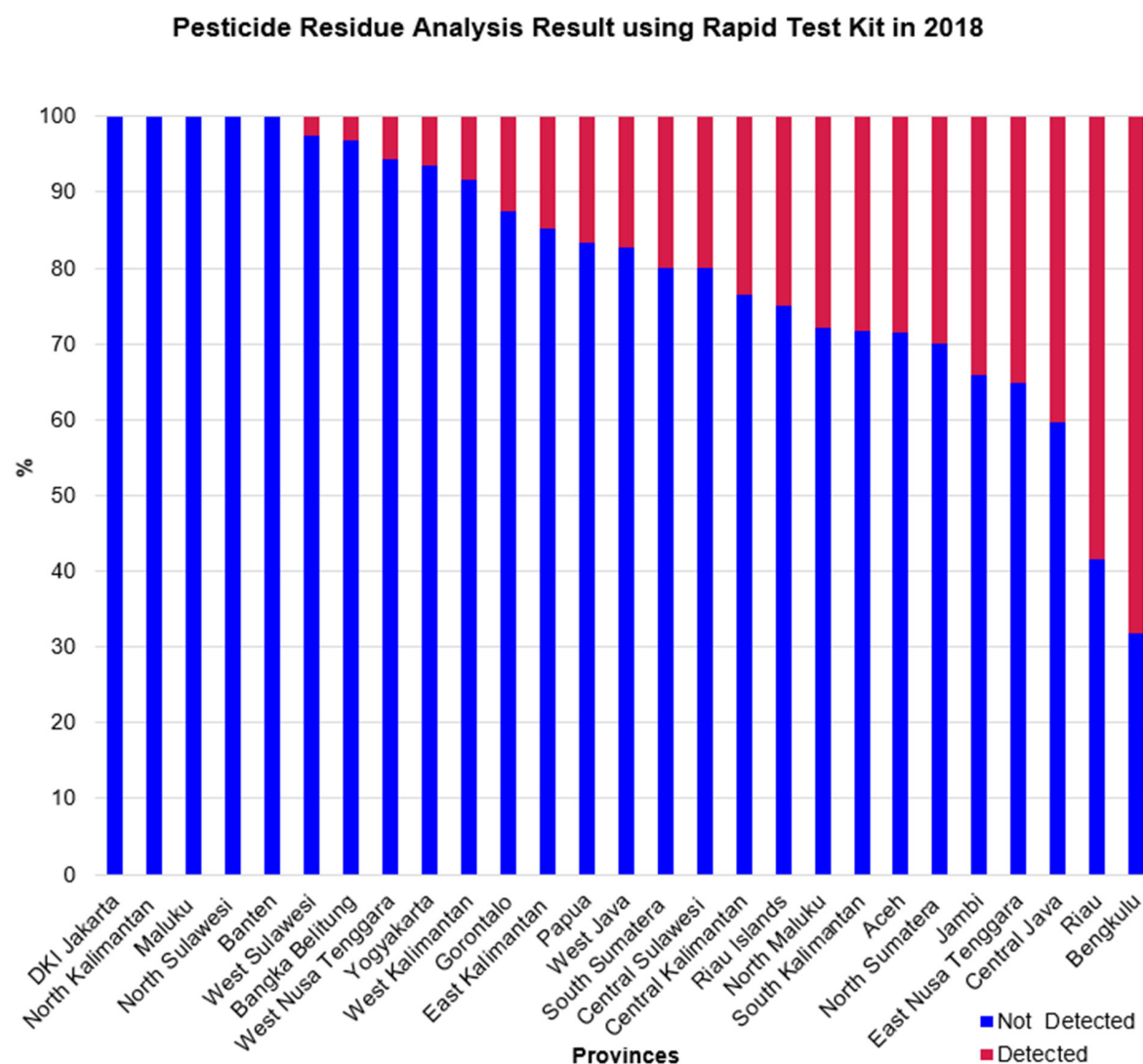


Fig. 2. Result of Rapid Test Kit for fresh food of plant origin in 27 provinces

Pesticide Residue Analysis using Laboratory Test Result Data

Pesticide residues testing in the laboratory were coming from 635 samples of 26 provinces on 8 major islands in Indonesia, namely Sumatra (Aceh, North Sumatra, Riau Islands, Bangka Belitung, Riau, West Sumatra, Jambi, South Sumatra, Lampung); Kalimantan (East Kalimantan, West Kalimantan, South Kalimantan, North Kalimantan); Java (Banten, West Java, Central Java, East Java); Bali; Sulawesi (North Sulawesi, South Sulawesi, Central Sulawesi, West Sulawesi, Gorontalo); Maluku; North Maluku and Papua. The result data is shown in Table 1.

Table 1. Data of Laboratory Test result for pesticide residues in 2018

Conclusion	Number of Samples	
	Number	%
Accepted (A)	626	98.58
Not Accepted (NA)	9	1.42
Total	635	100.00

Remarks: Percentage is the comparison between each number of Accepted and Not Accepted Samples with number of total samples

Table 1 shows that based on the results of pesticide residue testing in the laboratory using Gas Chromatography or Liquid Chromatography, most of the samples (98.58%) are showing no residues or still within the Maximum Residue Limits (MRLs) so that they are declared as meeting food safety requirements (Accepted). As mentioned earlier, samples of FFPO were not washed before the testing; as this study intends to monitor the level of pesticide residue of FFPO in the market. The MRLs of pesticides are used to determine the level of safety of agricultural products to protect the public from health risks posed (Putri, Sunarti, & Suhartini, 2016).

From 635 samples tested in the laboratory, there were 63 samples (9.92%) FFPO that have pesticide residues of Organophosphate, Carbamate, Pyrethroid, Organochlorine, N-Phenylpyrazole, or Neonicotinoid groups of pesticide, which included: chili, tomatoes, rice, onion, eggplant, lettuce, apple, orange, corn, papaya, banana, pumpkin, mustard greens, cauliflower, beans, dragon fruit, bitter

melon (*pare*), pear, grapes, longan (*kelengkeng*), strawberries, cabbage and leeks (*onclang*) as described in Fig. 3. This result is under further development regarding the testing method for pesticide active ingredients (Sulfuryl Fluoride – kind of fumigants) that needs to be renewed.

From the analysis on 63 FFPO samples with pesticide residues, there were 24 active ingredients of those mentioned 6 groups of pesticides. The active ingredients with the highest frequency found in the sample are the group of Organophosphate (23.81%). Other active ingredients found in the sample are Deltamethrin, Permethrin, Cypermethrin (a group of Pyrethroids), etc. as shown in Fig. 4.

Of the 63 samples with pesticide residue, 54 samples or 85.71% of detected samples have residues below the maximum threshold so that they were declared to meet food safety requirements. The remaining 9 samples out of the 63 samples or 1.42% of the whole 635 samples have residues above MRLs with detail as shown in Fig. 5

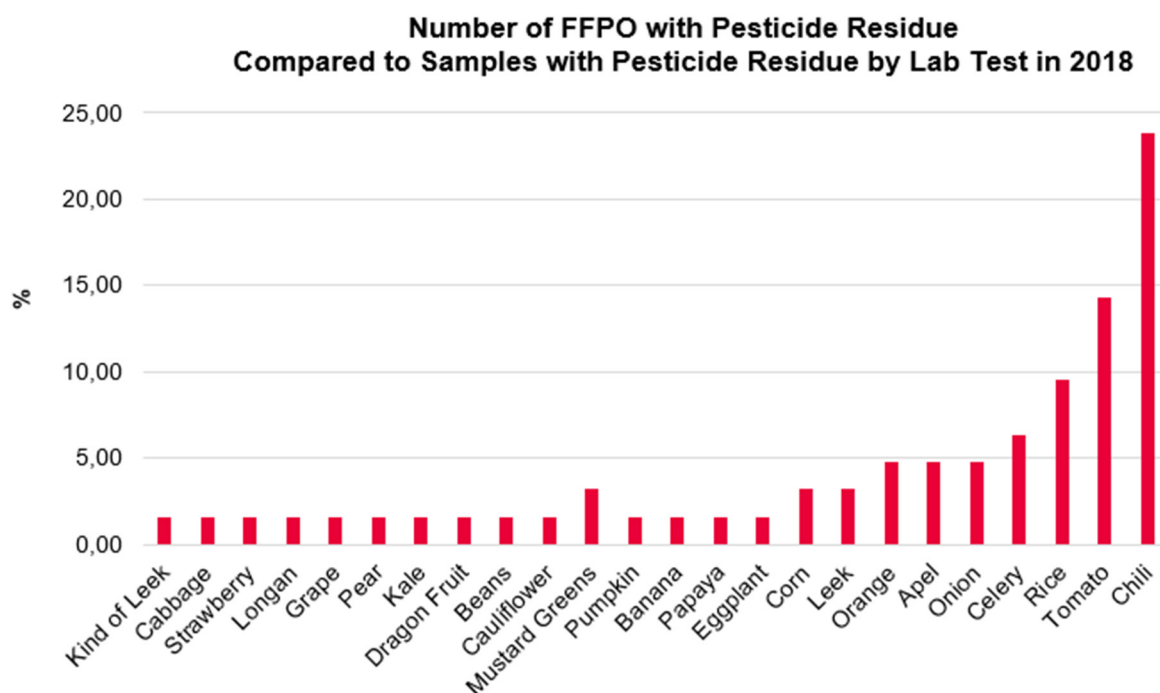


Fig. 3. Number of FFPO samples compared to samples with pesticide residues from 26 provinces based on Laboratory Test in 2018

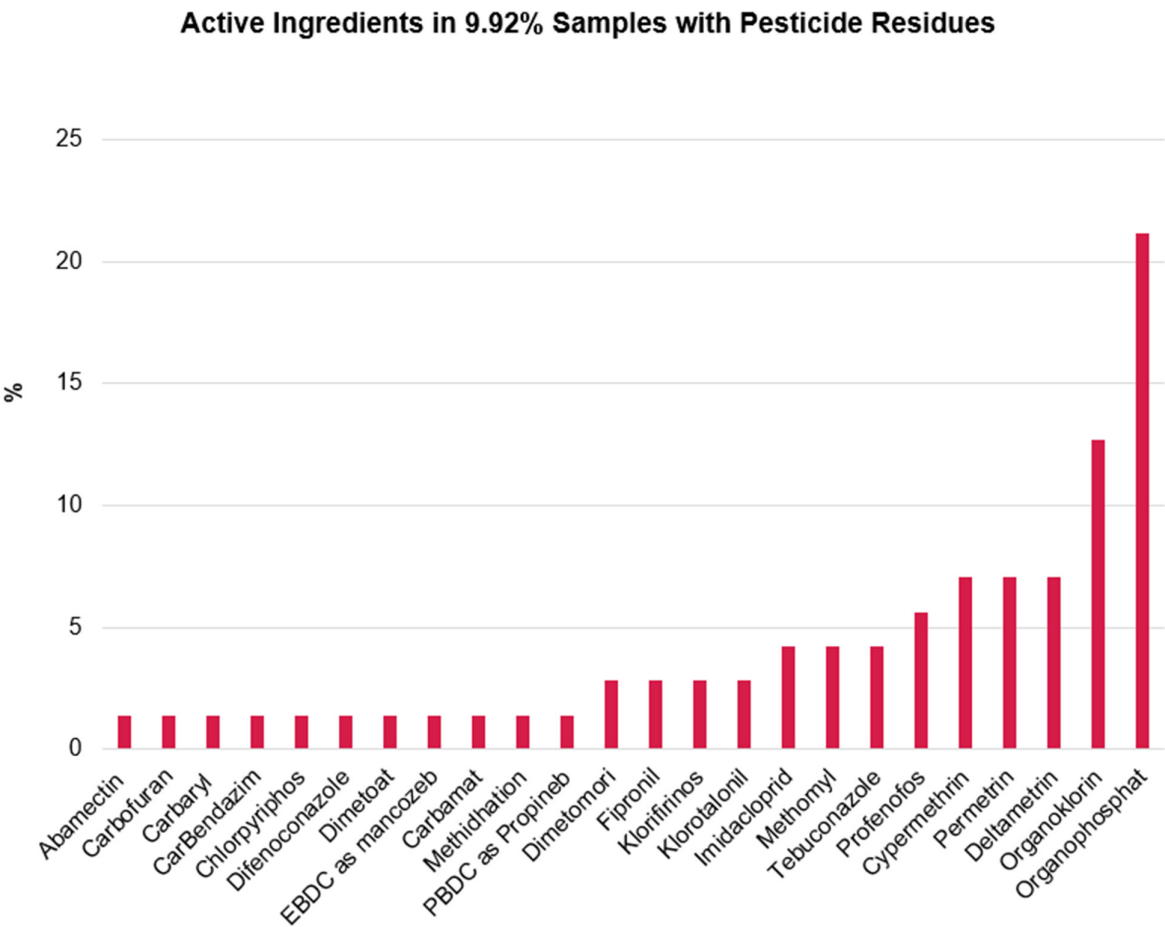


Fig. 4. Active ingredients in 9.92% samples with pesticide residues in 2018

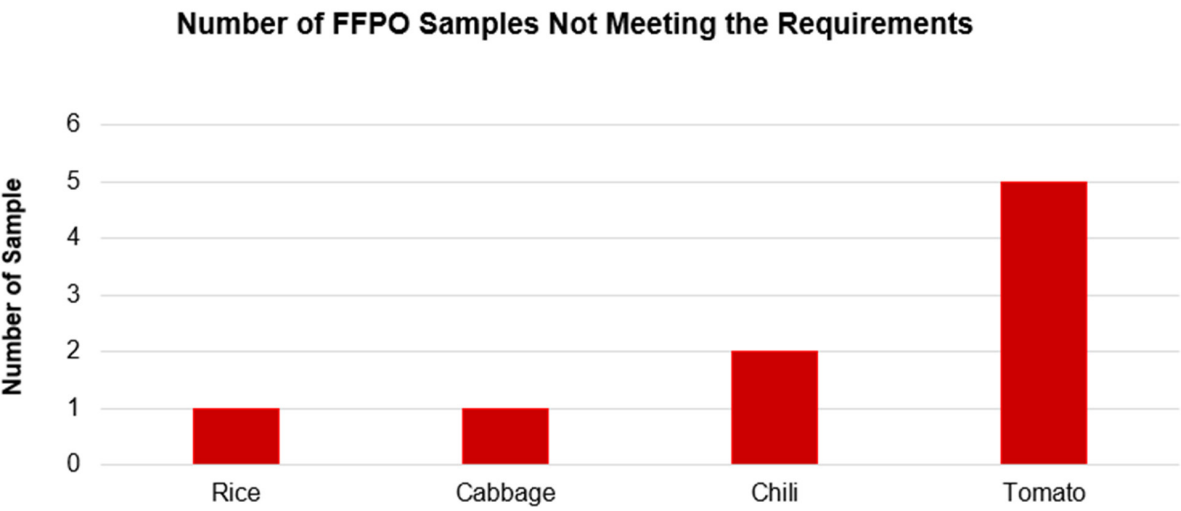


Fig. 5. Samples of FFPO that contained pesticide residue not meeting requirement

From the Lab Test results, it appeared that tomato was the FFPO sample that had the most pesticide residues, followed by chili, cabbage, and rice.

1. There were 9 samples of tomato (from 63 samples with pesticide residue) which were detected to contain one or more of 3 active ingredients of pesticides, namely: Organophosphate, Chlorpyrifos, Profenofos, Permethrin, Abamectin. Five samples of tomato were detected to have Carbofuran - part of Carbamate Group - (0.2 mg/kg) and Organophosphate type pesticides that exceed the MRL so it did not meet existing requirements. The MRL for Carbofuran in tomatoes regulated in SNI 7313: 2008 is 0.1 mg/kg. Based on the 2013 Annual Reports of the European Food Safety Authority (European Food Safety Authority, 2015), tomatoes are one of the highest contaminated vegetables with pesticides whereas various residues being repeatedly identified. For example, in 2013, from 1,451 analyzed samples of tomatoes, 49% were clean of pesticide residues, and

51% were discovered with one or various pesticides incalculable concentrations. Fig. 6 gives information on active ingredients of pesticide residues in 9 tomato samples.

2. As shown in Fig. 7, a number of 15 chili samples (from 63 samples) with pesticide residues, were detected to contain Difenoconazole (6.67% of 15 samples), EBDC as mancozeb (6.67%), Fipronil (6.67%), Imidacloprid (6.67%), Carbamate (6.67%), Organophosphate (26.67%), PBDC as Propineb (6.67%), Profenofos (20%) and Cypermethrin (33.33% of 15 samples). There are two chili samples each containing active ingredients of pesticides exceeding MRLs, namely Fipronil (0.063 mg/kg) and Imidacloprid (0.48 mg/kg), so they do not meet food safety requirements. According to SNI 7313: 2008 concerning the Maximum Limit of Pesticide Residues, MRLs of Fipronil and Imidacloprid are 0.05 mg/kg and 0.1 mg/kg respectively. Fipronil is part of the N-Phenylpyrazole Insecticide Group while Imidacloprid is part of the Neonicotinoids Group (Roberts & Karr, 2012).

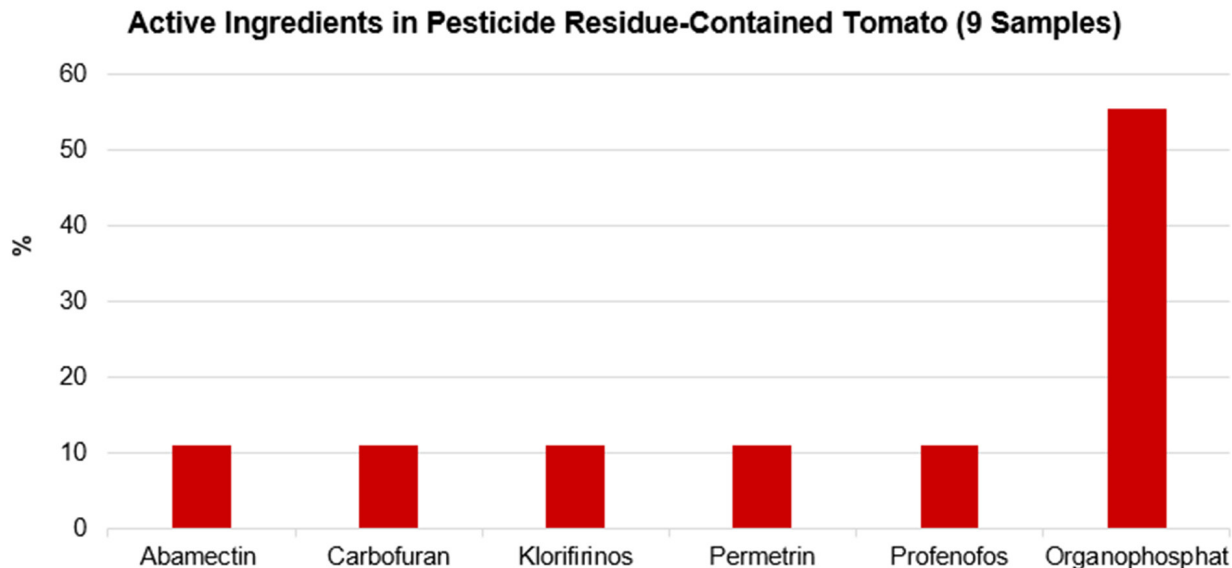


Fig. 6. Active ingredients of pesticide residue in tomato

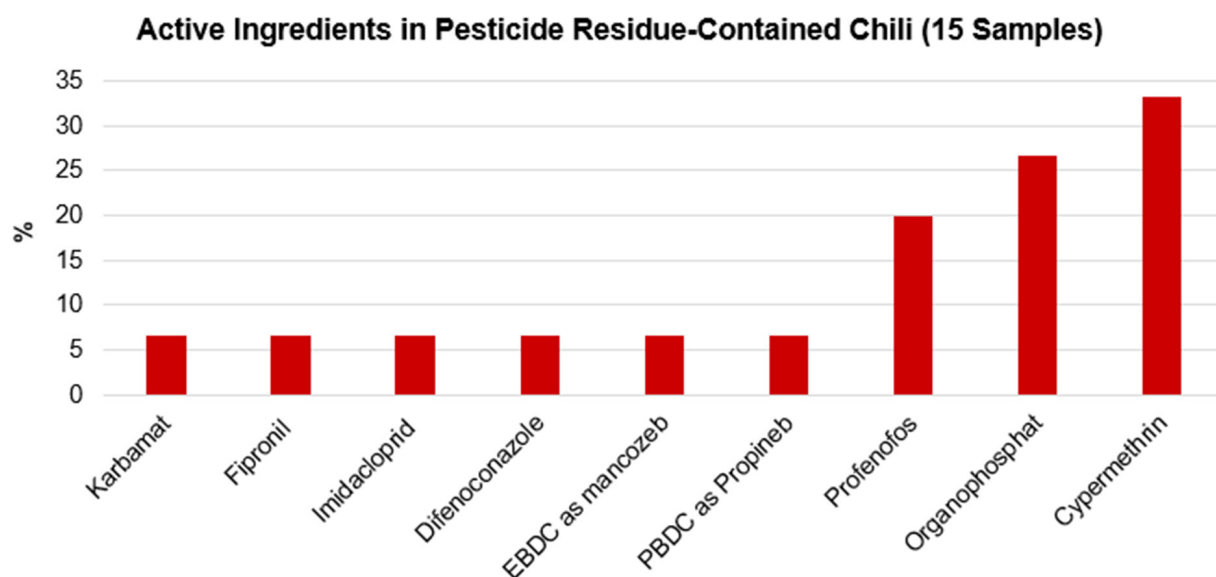


Fig. 7. Active ingredients of pesticide residue in chilli

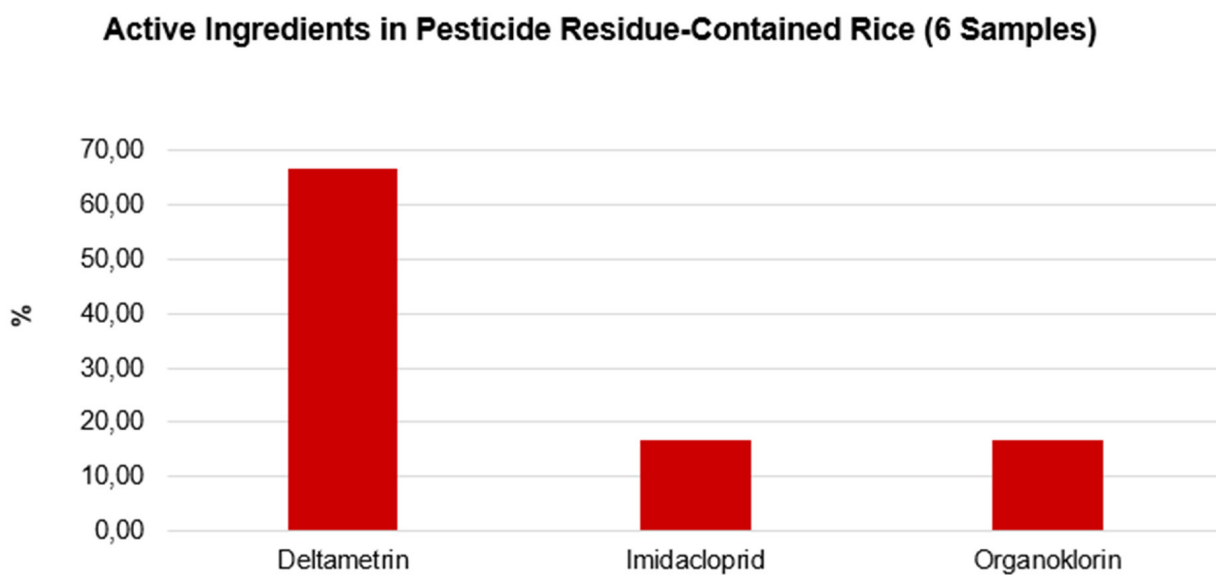


Fig. 8. Active ingredients of pesticide residue in rice

3. Of the 63 FFPO samples with pesticide residues, 6 of them are rice. There are active ingredients Deltamethrin (0.05 mg/kg) and Imidacloprid (0.012 mg/kg) detected in rice; while these two compounds have not been regulated in Permentan 53 of 2018; one of them is regulated in SNI in which MRL for Imidacloprid is 0.1 mg/kg. When viewed from Codex Standards,

Deltamethrin in cereal seeds has MRL of 2 mg/kg and 0.05 mg/kg for Imidacloprid. With refer to Codex MRL Standard for cereal grains, these pesticides' active ingredients in rice are still within the limits permitted by Codex, so that the samples are declared as meeting food safety requirements. Deltamethrin (Pyrethroids Group) is found to be the most frequent active

ingredient in rice with pesticide residue (4 of 6 samples or 66.67%). According to Yu et al. (2014), Deltamethrin, which is part of a pyrethroid insecticide, is counted as rather small toxicity compared to other insecticides. Deltamethrin is now applied for handling insect pests in stowed products such as grains. Meanwhile, Pyrethroids are one of the most regularly used pesticides because they often substitute for limited or forbidden insecticides of housing and agricultural application (Rosita, Donatella, & Cinzia, 2016). There is 1 rice sample with Organoclorin content exceeding the MRL so that it did not meet food safety requirements. Fig. 8 gives information on the active ingredients of pesticide residues for 6 rice samples.

4. Another 1 sample of FFPO that is not meeting the requirement is cabbage which test result only shows the level of Organophosphate (not the detailed active ingredients) that exceeds 0.05 mg/kg. The MRL 0.05 mg/kg is selected based on the lowest MRL value for the Organophosphate Group that can be used in cabbage according to existing regulations/standards

Pesticides are poisonous to target pests, but when misused, the poisonousness can spread to non-target organisms such as useful insects, humans, and animals as well as the environment (Kaur, Mavi, & Raghav, 2019; Kiwango, Kassim, Kimanya, 2018). Pesticides in plants, if systemic will be absorbed into plant tissues (leaves, fruit, branches, roots, skin, etc.). The pesticide can be toxic to the main plant until the plant dies or growth is disturbed. Pesticides will always leave residue on plants. This residue is needed to be able to kill the pests, but several certain pesticides (which are classified as very persistent) leave pesticide residues long enough on plants so that it is likely to be consumed by herbivores or humans. (Hartini, 2014). Exposure of pesticide residues from food intake is the main source of pesticide exposure followed by breathing and dermal contact. Vegetables with pesticide residues under MRLs, if ate raw constantly and in great quantities can trigger health problems for consumers (GEMS/Food & Codex Committee on Pesticide Residues, 1997). Contact or exposure to pesticide residues through food intake is presumed to be five times significantly

higher than other types of contact such as from air or drinking water (Juraske, Mutel, Stoessel, & Hellweg, 2009). As fruits and vegetables are primarily eaten raw or semi-processed, they are predicted to impound higher pesticide residue levels compared to other food groups of vegetable origin such as bread and other food products with cereal processing provision (Hlihor, Pogăcean, Rosca, Cozma, & Gavrilescu, 2019). Pesticide residues in vegetables are influenced by usage dosage, the occurrence of spraying, and usage time (Alegantina, Reini, & Lastari, 2005; Sapbamrer & Hongsibsong, 2014).

Contact to pesticide residues causes health effects that differ with the characteristics of the pesticide and the method of action (Kariathi, Kassim, & Kimanya, 2017). Unsuitable usage of pesticides brings consequences worldwide or local, transient or permanent, or short-term (acute) or long-term (chronic). The greatest dangerous consequences encompass devastation of non-target pest organisms (earthworm, pollinator, and predators), demise in biological diversity, microbial diversity, and soil biomass or community structure. These ecological losses due to pesticide application are economically or socially important (Kiwango, Kassim, Kimanya, 2018). Also, Costa et al. (2020) state that the latest study reviews the present knowledge relating cancer and neurodegenerative diseases to dysregulation of microRNA network because of pesticide exposure.

According to Hartini (2014), reducing levels of pesticide residues in food can be done through several approaches, namely physical and chemical. Pesticide residues in agricultural products can be reduced by washing the product with water (Putri, Sunarti, & Suhartini, 2016) which flows several times, then soaked in water for one hour. According to Bouchard et al. (2011) and Kariathi, Kassim, & Kimanya (2017), the example of treatments that can affect pesticide residues extensively in vegetables include washing, peeling, and cooking. Such processes usually decrease pesticide in the vegetables so that lowering the risk of human contact with these residues (GEMS/Food & Codex Committee on Pesticide Residues, 1997). Ahmed, Randhawa, Yusuf, & Khalid (2011) state that to reduce the risk of pesticides on human health, diverse processing processes can be effectively operated on fruits and vegetables. It is also known that handling vegetables with acidic and alkaline

solutions can also effectively reduce pesticide residues. Keikotlhaile, Spanoghe, & Steurbaut (2010) shows that while washing and peeling can reduce pesticides residue; baking, boiling, canning, and juicing indicated both reduction and increases of pesticide residue levels as regards to open systems may result in water loss during heating by evaporation, thereby concentrating the pesticide residues if they are not destroyed by heating. Moreover, the results of such activities on pesticide residues were originated from studies at the laboratory level which may not show the actual situation at the community level; so that it underlines the necessity for examining the results at the community level (Kiwango, Kassim, Kimanya, 2018). Referring to the resulting study as mentioned above, it is important to wash FFPO, especially in running water before it is consumed.

From the on-farm side, among the methods to decrease pesticide residues is to adapt the distance/frequency of pesticide spraying according to its class as the degradation period of Organophosphate and Carbamate in the environment is about 2 weeks, then the spraying frequency/distance of this group is every once in 2 weeks. Kaur, Mavi, & Raghav (2019) suggests users of pesticides especially farmers to decrease the effects of pesticides by reducing their utilization or by substituting them with bio-pesticides. One of the answers for pesticide residue problems is offered by Nacorda, Vasquez, Lador, Mora-Garcia (2019) and Norton, Sanchez, Clarke-Harris, & Traoré (2003) through Integrated Pest Management (IPM) which is a scheme that counts on biological, cultural, and other less chemically laborious methods for pest management. IPM schemes have been worked out for some horticultural commodities in developing countries to diminish residues and deliver pre-inspection documentation. Such schemes ask for cooperation between the public and private sectors and between exporters and importers. Kim, Kabir, & Jahan (2017) suggest natural bio-control agents for agricultural purposes. Moreover, Yuantari, Widianarko, & Sunoko (2015) stated that related stakeholders such as academics can help through community service programs such as information dissemination/socialization of pesticide hazards so that farmers' knowledge about the dangers of pesticides will increase and farmers will be wiser in using pesticides. The public and private sectors such as government

agencies, NGOs, and manufacturers are supposed to do significantly better work into research, product development, product testing, and registration, and execution of pesticide usage plans, while promoting public education regarding pesticides (Kim, Kabir, & Jahan, 2017).

CONCLUSION

Analysis results of pesticide residues on FFPO samples show that based on lab tests most of the samples (98.58%) are still within MRLs. The Rapid Test shows that 88.5% of samples do not detect Organophosphate and Carbamate residue. Some 635 samples (9.92%) of total lab test samples indicate pesticide residues that cover 24 active ingredients. Considering the effect on human health and environmental sustainability, efforts to control pesticide use need to be continued.

ACKNOWLEDGEMENT

This research is supported by The Agency for Food Security, especially the division which conducts control activities for fresh food safety of plant origin. We express our sincere appreciation to the personnels who performed their work in food safety control including through sampling, so that we can use the data for this research. We also express our gratitude to all the reviewers who have contributed their expertise and time to review the manuscript.

REFERENCES

- Abdou, K. A., & El-Atta, H. M. A. (2018). Epidemiology of pesticides in developing countries. *Advances in Clinical Toxicology*, 3(1), 1–8. <https://doi.org/10.23880/act-16000128>
- Ahmed, A., Randhawa, M. A., Yusuf, M. J., & Khalid, N. (2011). effect of processing on pesticide residues in food crops - A review. *Journal of Agricultural Research*, 49(3), 379-390. Retrieved from https://apply.jar.punjab.gov.pk/upload/1374741403_92_543__2931--4013-1_%2810%29.pdf
- Alegantina, S., Reini, M., & Lastari, P. (2005). Penelitian kandungan organofosfat dalam tomat dan slada yang beredar di beberapa jenis pasar di DKI Jakarta. *Media Penelitian Dan Pengembangan Kesehatan*, 15(1), 44–49. Retrieved from <http://ejournal.litbang.kemkes.go.id/index.php/MPK/article/view/1143>

- Aloizou, A.-M., Siokas, V., Vogiatzi, C., Peristeri, E., Docea, A. O., Petrakis, D., Dardiotis, E. (2020). Pesticides, cognitive functions and dementia: A review. *Toxicology Letters*, 326, 31–51. <https://doi.org/10.1016/j.toxlet.2020.03.005>
- Amilia, E., Joy, B., & Sunardi, S. (2016). Residu pestisida pada tanaman hortikultura (Studi kasus di Desa Cihanjuang Rahayu Kecamatan Parongpong Kabupaten Bandung Barat). *Agrikultura*, 27(1), 23–29. <https://doi.org/10.24198/agrikultura.v27i1.8473>
- Ardiwinata, A. N., & Nursyamsi, D. (2012). Residu pestisida di sentra produksi padi di Jawa Tengah. *Pangan*, 21(1), 39–58. Retrieved from <https://jurnalpangan.com/index.php/pangan/article/view/103>
- Bouchard, M. F., Chevrier, J., Harley, K. G., Kogut, K., Vedar, M., Calderon, N., ... Eskenazi, B. (2011). Prenatal exposure to organophosphate pesticides and IQ in 7-year-old children. *Environmental Health Perspectives*, 119(8), 1189–1195. <https://doi.org/10.1289/ehp.1003185>
- BPS. (2019). *Statistik tanaman sayuran dan buah-buahan semusim Indonesia 2018*. Jakarta, ID: Badan Pusat Statistik. Retrieved from <https://www.bps.go.id/publication/2019/10/07/9c5de09c805bc38302ea1c/statistik-tanaman-sayuran-dan-buah---buah-semusim-indonesia-2018.html>
- BSN. (2008). *SNI 7313:2008*. Indonesia. Retrieved from <http://www.chilealimentosinodata.cl/uploads/rules/indonesia-batas-maksimum-pestisida.pdf?v1.6>
- Büchel, K. H. (1983). *Chemistry of pesticides*. Minnesota: Wiley. Retrieved from https://books.google.co.id/books/about/Chemistry_of_Pesticides.html?id=HGJtjgzkRQwC&source=kp_book_description&redir_esc=y
- Codex Alimentarius International Food Standards. (2020). 158 - *Glyphosate*. Rome, IT. Retrieved from http://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/pesticide-detail/en/?p_id=158
- Costa, C., Teodoro, M., Rugolo, C. A., Alibrando, C., Giambò, F., Briguglio, G., & Fenga, C. (2020). MicroRNAs alteration as early biomarkers for cancer and neurodegenerative diseases: New challenges in pesticides exposure. *Toxicology Reports*, 7, 759–767. <https://doi.org/10.1016/j.toxrep.2020.05.003>
- Drum, C. (1980). *Soil chemistry of pesticides*. USA: PPG Industries Inc. Retrieved from [https://scholar.google.com/scholar_lookup?title=Soil Chemistry of Pesticides&publication_year=1980&author=C. Drum](https://scholar.google.com/scholar_lookup?title=Soil+Chemistry+of+Pesticides&publication_year=1980&author=C.+Drum)
- Ecobichon, D. J. (2001). Pesticide use in developing countries. *Toxicology*, 160(1), 27–33. [https://doi.org/10.1016/S0300-483X\(00\)00452-2](https://doi.org/10.1016/S0300-483X(00)00452-2)
- European Food Safety Authority. (2015). The 2013 European Union report on pesticide residues in food. *EFSA Journal*, 13(3), 4038. <https://doi.org/10.2903/j.efsa.2015.4038>
- FAO. (2005). *Control of pesticide use and Maximum Residue Limits(MRLs) of pesticides*. Retrieved from [http://www.fao.org/waicent/faoinfo/food-safety-quality/cd_hygiene/cnt/cnt_fr/sec_3/docs_3.1/Pesticide Use & MRLs.pdf](http://www.fao.org/waicent/faoinfo/food-safety-quality/cd_hygiene/cnt/cnt_fr/sec_3/docs_3.1/Pesticide+Use+MRLs.pdf)
- GEMS/Food & Codex Committee on Pesticide Residues. (1997). *Guidelines for predicting dietary intake of pesticide residues (revised)*. Switzerland: World Health Organization. Retrieved from <https://www.who.int/foodsafety/publications/pesticides/en/>
- Hartini, E. (2014). Kontaminasi residu pestisida dalam buah melon (Studi kasus pada petani di Kecamatan Penawangan). *Jurnal Kesehatan Masyarakat*, 10(1), 96–102. Retrieved from <https://journal.unnes.ac.id/nju/index.php/kemas/article/view/3075>
- Hlihor, R.-M., Pogăcean, M. O., Rosca, M., Cozma, P., & Gavrilescu, M. (2019). Modelling the behavior of pesticide residues in tomatoes and their associated long-term exposure risks. *Journal of Environmental Management*, 233, 523–529. <https://doi.org/10.1016/j.jenvman.2018.11.045>
- Juraske, R., Mutel, C. L., Stoessel, F., & Hellweg, S. (2009). Life cycle human toxicity assessment of pesticides: Comparing fruit and vegetable diets in Switzerland and the United States. *Chemosphere*, 77(7), 939–945. <https://doi.org/10.1016/j.chemosphere.2009.08.006>
- Kariathi, V., Kassim, N., & Kimanya, M. (2017). Risk of exposures of pesticide residues from tomato in Tanzania. *African Journal of Food Science*, 11(8), 255–262. <https://doi.org/10.5897/AJFS2016.1527>
- Karunamoorthi, K., Mohammed, M., & Wassie, F. (2012). Knowledge and practices of farmers with reference to pesticide management: Implications on human health. *Archives of Environmental &*

- Occupational Health*, 67(2), 109–116. <https://doi.org/10.1080/19338244.2011.598891>
- Kaur, R., Mavi, G. K., & Raghav, S. (2019). Pesticides classification and its impact on environment. *International Journal of Current Microbiology and Applied Sciences*, 8(3), 1889–1897. <https://doi.org/10.20546/ijcmas.2019.803.224>
- Keikothlaile, B. M., Spanoghe, P., & Steurbaut, W. (2010). Effects of food processing on pesticide residues in fruits and vegetables: A meta-analysis approach. *Food and Chemical Toxicology*, 48(1), 1–6. <https://doi.org/10.1016/j.fct.2009.10.031>
- Kementerian Pertanian. (2015). Peraturan Menteri Pertanian tentang pendaftaran pestisida. Indonesia. Retrieved from http://perundangan.pertanian.go.id/admin/file/Permentan_39-2015_Pendaftaran_Pestisida.pdf
- Kementerian Pertanian. (2016). Peraturan Menteri Pertanian tentang pengawasan keamanan pangan terhadap pemasukan pangan segar asal tumbuhan. Indonesia. Retrieved from <https://paralegal.id/peraturan/peraturan-menteri-pertanian-nomor-55-permentan-kr-040-11-2016/>
- Kim, K.-H., Kabir, E., & Jahan, S. A. (2017). Exposure to pesticides and the associated human health effects. *Science of The Total Environment*, 575, 525–535. <https://doi.org/10.1016/j.scitotenv.2016.09.009>
- Kiwango, P. A., Kassim, N., & Kimanya, M. E. (2018). Pesticide residues in vegetables: Practical interventions to minimize the risk of human exposure in Tanzania. *Current Journal of Applied Science and Technology*, 26(1), 1–18. <https://doi.org/10.9734/CJAST/2018/38976>
- Koleva, N. G., & Schneider, U. A. (2009). The impact of climate change on the external cost of pesticide applications in US agriculture. *International Journal of Agricultural Sustainability*, 7(3), 203–216. <https://doi.org/10.3763/ijas.2009.0459>
- Miskiyah, & Munarso, S. J. (2009). Kontaminasi residu pestisida pada cabai merah, selada, dan bawang merah (Studi kasus di Bandung dan Brebes Jawa Tengah serta Cianjur Jawa Barat). *Jurnal Hortikultura*, 19(1), 101–111. Retrieved from <http://ejurnal.litbang.pertanian.go.id/index.php/jhort/article/view/780>
- Nacorda, E. R., Vasquez, P. P. G., Lador, R. P., & Mora-Garcia, C. (2019). Assessment of agrochemical use among rice field farmers in municipalities surrounding Lake Mainit, Philippines. *International Journal of Development and Sustainability*, 8(9), 633–644. Retrieved from <https://isdsnet.com/ijds-v8n9-09.pdf>
- Norton, G., Sanchez, G., Clarke-Harris, D., & Traoré, H. K. (2003). *Food safety in food security and food trade case study: Reducing pesticide residues on horticultural crops*. Washington, DC. Retrieved from https://www.researchgate.net/publication/5055680_Case_study_reducing_pesticide_residues_on_horticultural_crops
- Pan, Y., Ren, Y., & Luning, P. A. (2021). Factors influencing Chinese farmers' proper pesticide application in agricultural products – A review. *Food Control*, 122, 107788. <https://doi.org/10.1016/j.foodcont.2020.107788>
- Pemerintah Pusat. (2004). Peraturan Pemerintah (PP) tentang keamanan, mutu dan gizi pangan. Indonesia. Retrieved from http://perundangan.pertanian.go.id/admin/p_pemerintah/PP-28-04.pdf
- Pemerintah Pusat. (2012). Undang-undang (UU) tentang Pangan. Indonesia. Retrieved from <https://peraturan.bpk.go.id/Home/Details/39100>
- Pemerintah Pusat. (2019). Peraturan Pemerintah (PP) tentang Keamanan pangan. Indonesia. Retrieved from <https://peraturan.bpk.go.id/Home/Details/129230/pp-no-86-tahun-2019>
- Popp, J., Pető, K., & Nagy, J. (2013). Pesticide productivity and food security, A review. *Agronomy for Sustainable Development*, 33(1), 243–255. <https://doi.org/10.1007/s13593-012-0105-x>
- Putri, G. G., Sunarti, & Suhartini. (2016). Ketinggian lokasi dan residu pestisida pada tomat: Studi di Kota Batu dan Kabupaten Tulungagung. *Berita Kedokteran Masyarakat*, 32(5), 157–164. <https://doi.org/10.22146/bkm.6922>
- Reigart, J. R. (1999). *Recognition and management of pesticide poisonings*. USA: U.S. Environmental Protection Agency. Retrieved from https://books.google.co.id/books?id=RIUqzgEACAAJ&dq=Recognition+and+Management+of+Pesticide+Poisonings&hl=en&sa=X&ved=2ahUKEwiiy_7d-8LvAhUwlbcAHbcKDWoQ6AEwA3oECAIQAQ
- Roberts, J. R., & Karr, C. J. (2012). Pesticide exposure in children. *Pediatrics*, 130(6), e1765–e1788. <https://doi.org/10.1542/peds.2012-2758>
- Rosita, G., Donatella, F., & Cinzia, N. (2016). Accumulation of damage due to lifelong exposure to environmental pollution as dietary target in aging. In M. Malavolta & E. Mocchegiani (Eds.), *Molecular Basis of Nutrition and Aging* (pp. 177–

- 188). San Diego: Academic Press. <https://doi.org/10.1016/B978-0-12-801816-3.00013-3>
- Sapbamrer, R., & Hongsibsong, S. (2014). Organophosphorus pesticide residues in vegetables from farms, markets, and a supermarket around Kwan Phayao Lake of Northern Thailand. *Archives of Environmental Contamination and Toxicology*, 67(1), 60–67. <https://doi.org/10.1007/s00244-014-0014-x>
- Schreinemachers, P., Chen, H., Nguyen, T. T. L., Buntong, B., Bouapao, L., Gautam, S., ... Srinivasan, R. (2017). Too much to handle? Pesticide dependence of smallholder vegetable farmers in Southeast Asia. *Science of The Total Environment*, 593–594, 470–477. <https://doi.org/10.1016/j.scitotenv.2017.03.181>
- Shattuck, A. (2019). Risky subjects: Embodiment and partial knowledges in the safe use of pesticide. *Geoforum*. <https://doi.org/10.1016/j.geoforum.2019.04.029>
- Sudarmo, S. (1991). *Pestisida*. Yogyakarta: Kanisius. Retrieved from https://scholar.google.com/scholar?hl=id&as_sdt=0,5&cluster=6515394352539694684
- USDA Agricultural Marketing Service. (2019). *Pesticide data program annual summary reports*. Retrieved from <https://www.ams.usda.gov/reports/pdp-annual-summary-reports>
- Veres, A., Wyckhuys, K. A. G., Kiss, J., Tóth, F., Burgio, G., Pons, X., ... Furlan, L. (2020). An update of the Worldwide Integrated Assessment (WIA) on systemic pesticides. Part 4: Alternatives in major cropping systems. *Environmental Science and Pollution Research*, 27(24), 29867–29899. <https://doi.org/10.1007/s11356-020-09279-x>
- Yadav, I. C., Devi, N. L., Syed, J. H., Cheng, Z., Li, J., Zhang, G., & Jones, K. C. (2015). Current status of persistent organic pesticides residues in air, water, and soil, and their possible effect on neighboring countries: A comprehensive review of India. *Science of The Total Environment*, 511, 123–137. <https://doi.org/10.1016/j.scitotenv.2014.12.041>
- Yu, C., Li, Y., Zhang, Q., Zou, N., Gu, K., Li, X., & Pan, C. (2014). Decrease of pirimiphos-methyl and deltamethrin residues in stored rice with post-harvest treatment. *International Journal of Environmental Research and Public Health*, 11(5), 5372–5381. <https://doi.org/10.3390/ijerph110505372>
- Yuantari, M. G. C., Widianarko, B., & Sunoko, H. R. (2015). Analisis risiko pajanan pestisida terhadap kesehatan petani. *Jurnal Kesehatan Masyarakat*, 10(2), 239–245. <https://doi.org/10.15294/kemas.v10i2.3387>