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Analysis of Pesticide Residue Reduction Using Vinegar and Salt Solutions in Bird's Eye Chili (*Vigna sinensis L.*)

[1]Beni Hari Susanto*, [2]Ike Dian Wahyuni, [3]Misbahul Subhi
[1] Bachelor's Program in Environmental Health, STIKES Widyagama Husada Malang, Indonesia*; email: benyharisusanto1226@widyagamahusada.ac.id
[2] Bachelor's Program in Environmental Health, STIKES Widyagama Husada Malang, Indonesia
[3] Bachelor's Program in Environmental Health, STIKES Widyagama Husada Malang, Indonesia
*Corresponding

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Abstract
Introduction: *Inappropriate pesticide use in agricultural production may have adverse consequences, including the presence of pesticide residues on agricultural products.* ***Objective:*** *This study aimed to determine the most effective method for reducing pesticide residues in bird's eye chili (Vigna sinensis L.).* ***Method:*** *This was a descriptive quantitative study with a true-experimental approach using a pretest-posttest design with a control group. The study sample consisted of 5 kg of bird's eye chili (Vigna sinensis L.). The samples were collected after the farmer had conducted pesticide spraying three days before sample collection. The pesticide was applied at a dose of 10 mL mixed with 1 L of water, and spraying was performed for 30 minutes. Samples were collected in the morning from five sampling points, pooled into one composite sample, and then divided into five groups of 1 kg each.* ***Result and Discussion:*** *Data were analyzed using Cochran's Q test to evaluate the effectiveness of the pesticide-residue reduction treatments. The largest reduction was observed after treatment with a vinegar solution, with a reduction of 63.88%. Cochran's Q test yielded a value of 0.049 (<0.05), indicating a statistically significant difference in pesticide-residue reduction among treatments in bird's eye chili (Vigna sinensis L.).* ***Conclusion:*** *The source manuscript reports that the most effective treatment was soaking in hot water.*

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Introduction

Chilli (*Vigna sinensis L.*) also known as chilli pepper or hot pepper, is one of the most popular vegetables and spice crops from the solanaceae family, regarded as one of the most important vegetable crops globally (Barboza et al., 2022) It is used in a variety of daily culinary purposes, as fresh vegetable, dried chillies, masala powders, sauces, pickles, and more (Gupta et al., 2023). Worldwide, both green (as a vegetable) and dried chillies (as a spice) are utilized for their impressive flavor, pungency, and color (Bal et al., 2022). Chilli is a good source of vitamins A, C, B6, E, K, and minerals like calcium, magnesium, folate, potassium, thiamin, iron, and copper. The alkaloids capsaicin and capsaicinoids have high medicinal value and are utilized in many pharmaceutical preparations (Azlan et al., 2022). It has also gained significant importance due to its 'oleoresin' content, which allows for better distribution of color and flavor in foods (Gupta et al., 2023) Additionally, it exhibits significant antimicrobial and antioxidant properties, inhibiting bacteria and fungi growth during storage, thus extending shelf life (Vuerich et al., 2023). The strongest form of oleoresin is used in making hot sauces, and as flavoring agents in beverages and other culinary applications (Azlan et al., 2022) This has made chilli a popular spice with a wide range of commercial and therapeutic applications.

Chilli has high domestic demand and export potential. However, production and productivity are hampered by various biotic and abiotic factors. Major insect pests such as thrips, mites, whiteflies, fruit borers, and jassids are responsible for yield losses of 60–75 percent (Azlan et al., 2022). As the crop is susceptible to pests throughout the year, it receives higher pesticide load. Insecticides such as emamectin benzoate, fipronil, spirotetramat, and tolfenpyrad are approved for use in chilli by the Indian Government (Ali et al., 2022). Pesticides are toxic chemical compounds used to control pests affecting agricultural crops. Article 75 of Law of the Republic of Indonesia Number 22 of 2019 defines pesticides as chemical substances and other materials, as well as microorganisms and viruses, that may be used to eradicate or prevent pests or animals, weeds, or undesirable plants. Inappropriate pesticide use can endanger the health of farmers and consumers, adversely affect non-target microorganisms, and contribute to environmental contamination of soil and water (Ibrahim & Sillehu, 2022).The World Health Organization (WHO) has estimated that pesticide poisoning affects approximately 1-5 million agricultural workers each year, with up to 220,000 deaths. Approximately 80% of poisoning cases have been reported in developing countries; although these countries account for only 25% of global pesticide use, they account for approximately 99% of pesticide-related deaths (Ibrahim & Sillehu, 2022).

Pesticide application to crops may leave residues on the plants, in the soil, and in the surrounding environment. Human consumption of produce containing pesticide residues may have adverse long-term health effects. Pesticide residues that accumulate in soil may also affect soil organisms and subsequently influence crops grown in that soil (Maulana et al., 2023). When pesticide residues enter the food chain, their toxic properties may contribute to various health problems, including cancer, mutations, congenital abnormalities, and AIDS (Chemically Acquired Deficiency Syndrome), among others (Ulvia et al., 2025). Nevertheless, synthetic pesticides are considered effective and efficient because they can control pests, weeds, and diseases that interfere with plant growth, thereby increasing production. Their use may also reduce labor, time, and costs. Spraying three to four times per year may control pests, weeds, and diseases that impair plant growth (Dewi et al., 2025). Reported that pesticides have contaminated nearly all environmental compartments, with residues detected in soil, air, surface water, and groundwater. Pesticide contamination presents substantial risks to the environment and non-target organisms, ranging from beneficial soil microorganisms to insects, plants, fish, and birds. Recent studies indicate that the environment is chronically contaminated with pesticides and that the level of biocide contamination has increased rapidly (Mali et al., 2023). According to (Muarif, 2025), facilities for monitoring pesticide residue levels in vegetables in Indonesia remain inadequate. Vegetable samples collected from seven major vegetable-producing areas in West Java, Central Java, and East Java were reported to contain residues of several insecticides, including DDT, aldrin, diazinon, dieldrin, fenitrothion, phenthoate, and chlorpyrifos.

As there is not much dataset available for the insecticides as combi-products on chilli which are being frequently used by growers, so it is crucial to produce residue data and continue with the risk assessment studies for such insecticides. When food items are consumed raw by the consumers, decontamination of insecticide residues from the food commodities is also a major concern for their safety as there are chances of pesticide residue exposure to the consumer. So, several decontamination methods are assessed for commodities in order to eliminate pesticide residues and minimize exposure risks to the consumer. Washing of vegetables and fruits, soaking in acid/salt/alkali solution for a specific period of time, use of oxidizing agents and use of various washes available in the market has been applied and found effective for the removal of insecticide residues from several food commoditie (Roy & Shil, 2025) Across the dataset, reductions ranged from 0.0% to >94.0% for rinsing (median=30.2%), 0.6% to >99% for water soaking (median=33.7%), 0.2% to >99.0% for baking soda soaking (median=50.9%), and 8.6% to >99.0% for vinegar/acetic acid soaking (median=54.2%). While plain water washing was effective in multiple studies, baking soda or vinegar/acetic acid soaking showed more than a 15.0% greater median average reduction across studies. However, the high solution concentrations commonly studied may limit generalizability to typical household use. Pesticide physico-chemical properties, washing method, and produce characteristics were the most frequently reported factors impacting pesticide reduction (Factor-Litvak et al., 2026)

Observations among vegetable farmers indicated that pesticide application did not always follow the instructions provided on pesticide labels. Farmers applied pesticides approximately 3-6 times during a single growing season, depending on the type of pest. On this basis, pesticide residues were expected to be present on citrus fruits. Bird's eye chili (*Vigna sinensis L.*). Intended for consumption are generally washed only with clean water, either under running water or by soaking. Therefore, this study aimed to determine whether the treatment was effective in reducing pesticide residues in bird's eye chili (*Vigna sinensis L.*).

Methods

This study used a descriptive quantitative design with a true-experimental approach and a pretest-posttest control-group design. The study population consisted of bird's eye chili (*Vigna sinensis L.*) obtained from a farmer was used as the study sample. Samples were selected using a non-probability purposive sampling technique. Experimental treatments for pesticide-residue reduction were conducted at the Environmental Health Laboratory, STIKES Widyagama Husada Malang, while pesticide residue testing was performed at the Pesticide and Fertilizer Testing Laboratory in Surabaya, East Java. Data were obtained from laboratory measurements before and after treatment, tabulated, and compared between pre-treatment and post-treatment measurements. Each treatment was applied for the same duration of 7 minutes.

Results and Discussion

1. Result

Sample Collection and Experimental Treatment

Before sample collection, the farmer had sprayed the crop three days earlier. The pesticide dose was 10 mL mixed with 1 L of water, and spraying was conducted for 30 minutes. Samples were collected in the morning from five sampling points, combined into one composite sample, and then divided into five groups, each containing 1 kg of sample. The samples were subsequently transported to the laboratory for pesticide-residue reduction treatments.

Pesticide Residue Test Results in the Control Group (No Treatment)

Table 1

Pesticide Residue Levels in the Control Group

Treatment	Diazinon	Dimethoate
K1 (Control)	2.2461 mg/kg	0 mg/kg

As shown in Table 1, diazinon pesticide residue was detected in the control sample of bird's eye chili (*Vigna sinensis L.*) at 2.2641 mg/kg. In contrast, dimethoate residue was not detected.

Pesticide Residue Test Results After Treatment With Vinegar Solution

Pesticide residues in bird's eye chili (*Vigna sinensis L.*) were analyzed after soaking in a vinegar solution for 7 minutes. The results are presented below.

Table 2

Pesticide Residue Levels After Soaking in Vinegar Solution

Treatment	Diazinon	Dimethoate
K2 (Vinegar solution)	0.8113 mg/kg	0 mg/kg

Based on Table 2, soaking bird's eye chili (*Vigna sinensis L.*) in vinegar solution at pH 3.71 reduced the measured diazinon residue level to 0.8113 mg/kg. Dimethoate residue was not detected. According to the Regulation of the Minister of Agriculture Number 24 of 2011, the maximum residue limit for humans is 0.015 mg/kg; therefore, the pesticide residue level after the running-water washing treatment did not meet the required standard.

Pesticide Residue Test Results After Soaking in Salt Solution

Pesticide residues in bird's eye chili (*Vigna sinensis L.*) were analyzed after soaking in a salt solution for 7 minutes. The results are presented below.

Table 3

Pesticide Residue Levels After Soaking in Salt Solution

Treatment	Diazinon	Dimethoate
K3 (Salt solution)	1.4578 mg/kg	0 mg/kg

Based on Table 3, soaking bird's eye chili (*Vigna sinensis L.*) in salt solution at pH 6.27 reduced the measured diazinon residue level to 1.4578 mg/kg. Dimethoate residue was not detected. According to the Regulation of the Minister of Agriculture Number 24 of 2011, the maximum residue limit for humans is 0.015 mg/kg; therefore, the pesticide residue level after soaking in salt solution did not meet the required standard.

Effectiveness Analysis

Treatment effectiveness in reducing pesticide residues was calculated using the following equation:

$$E = \frac{C0 - C1}{C0} X\ 100\%$$

Where (Sitompul et al., 2013):
E = effectiveness
C_0 = concentration before treatment
C_1 = concentration after treatment

Table 4
Effectiveness of Pesticide-Residue Reduction

Treatment	Diazinon reduction	Interpretation	Dimethoate reduction	Interpretation
Control (no treatment)	0%	Not effective	0%	Not detected
Vinegar solution	63.88%	Not effective	0%	Not detected
Salt solution	35.09%	Moderately effective	0%	Not detected

Based on Table 4, washing bird's eye chili (*Vigna sinensis L.*) with vinegar solution for 7 minutes resulted in a 63.88% reduction in pesticide residues. Soaking in salt solution for 7 minutes resulted in a 35.09% reduction.

Statistical Hypothesis Testing

Cochran's Q test was used to assess whether there was a difference in the effectiveness of pesticide-residue reduction among treatments in bird's eye chili (*Vigna sinensis L.*). A significance value of $p < 0.05$ was interpreted as indicating a statistically significant difference among variables, whereas $p > 0.05$ was interpreted as indicating no statistically significant difference.

Table 5
Cochran's Q Test for the Effectiveness of Pesticide-Residue Reduction

Variables	*p-value*	Interpretation
K1 – Control K2 – Vinegar-solution washing K3 – Salt-solution soaking	0.049	There was an effect on pesticide-residue reduction in bird's eye chili (Vigna sinensis L.).

Criterion: $p < 0.05$, $\alpha = 0.05$

Based on the Cochran's Q test, the significance value was p = 0.049 (<0.05), indicating that the alternative hypothesis (H1) was supported and that the treatments had a significant effect on pesticide-residue reduction in bird's eye chili (*Vigna sinensis L.*).

2. Discussion

Experimental Analysis

During experimental sample preparation, samples were collected from five sampling points and divided into five groups. The samples were collected two days after pesticide spraying. Based on observations and interviews, farmers sometimes used pesticide doses that were consistent with recommendations and sometimes used doses that were not. Farmers often estimated the amount of pesticide to be applied; for example, one bottle cap of pesticide was mixed with 1 L of water, whereas in another practice two bottle caps of pesticide were mixed with four buckets of water and then used for four plots or four crop rows. Spraying was carried out in the morning and lasted approximately 30-50 minutes. According to (Phopin et al., 2022), insecticide-dose selection among farmers is associated with farmers' perceptions of potential risk, leading them to adapt to environmental conditions perceived as unfavorable. Farmers also tend to use a calendar-based spraying schedule because insecticides are regarded as insurance for crop yield; consequently, insecticides may be applied routinely and in quantities exceeding the limits stated on pesticide labels.

According to (Pramhesti et al., 2024), pesticides sprayed onto crops may no longer be evenly distributed by the time they reach the target area. Under such conditions, pesticide application may cause crop injury or death. Other processes that may occur after spraying include runoff, in which pesticide droplets fall from the plant canopy and potentially contaminate the environment; volatilization, in which a pesticide changes from a liquid to a gaseous form and is lost to the atmosphere; photodecomposition, in which light breaks down the pesticide into inactive forms; adsorption to soil particles; leaching by rainfall into deeper soil layers, which may ultimately contaminate groundwater and river water; chemical reactions that convert pesticide molecules into inactive or non-toxic forms; and degradation by soil microorganisms.

Reduction of Pesticide Residues With Vinegar Solution

Following treatment with vinegar/acetic acid solution (C2H4O2) at pH 3.71 for 7 minutes, the pesticide residue level decreased from 2.2461 mg/kg before treatment to 0.8113 mg/kg after treatment, corresponding to a 63.879% reduction in diazinon residue and categorized in the source manuscript as moderately effective. Dimethoate residue was not detected in bird's eye chili (*Vigna sinensis L.*). The acidic properties of vinegar solution may influence pesticide residue levels. More strongly acidic conditions may produce greater pesticide-residue reduction; however, they may also affect the taste of the produce.

These findings are consistent with (Rizkina et al., 2021), who used a qualitative Rapid Test Kit (RTK) method and reported that washing long beans with an acidic solution (C2H4O2) reduced pesticide residues by 46.99%. However, soaking may alter the taste of vegetables. (Rusydan et al., 2025). also reported that acetic acid solution (C2H4O2) has a high capacity to reduce pesticide residue levels. Under acidic conditions (pH 3), diazinon undergoes photolytic decomposition, producing simpler compounds, including 2-isopropyl-4-methyl-6-pyrimidinol (IMP) and thiophosphonate, followed by the formation of $SO4^{2-}$ ions. The hydrolysis and photolysis products have been identified as reducing pesticide residues and producing compounds with lower toxicity. A pH below 3 may therefore result in greater pesticide-residue reduction. Nevertheless, after treatment with vinegar solution, the produce should be rinsed thoroughly with clean water.

Reduction of Pesticide Residues With Salt Solution

Following soaking in salt solution (NaCl) at pH 6.27 for 7 minutes, the pesticide residue level decreased from 2.2461 mg/kg before treatment to 1.4578 mg/kg after treatment, corresponding to a 35.096% reduction in diazinon residue and categorized in the source manuscript as not effective. Dimethoate residue was not detected in bird's eye chili (*Vigna sinensis L.*). Salt may contribute to acid-base neutralization. These acid-base conditions may facilitate the breakdown of hydrolyzed chemical compounds. Hydrolysis changes the chemical form of organic molecules when they react with alkaline water, producing compounds associated with OH (hydroxide) groups.

Conclusion

Before treatment, diazinon pesticide residue was detected in the control sample of bird's eye chili (*Vigna sinensis L.*) at 2.2641 mg/kg, whereas dimethoate residue was not detected. After treatment with vinegar solution, the measured diazinon residue level was 0.8113 mg/kg. After soaking in salt solution, the measured diazinon residue level was 1.4578 mg/kg. Dimethoate was not detected in either treatment group. However, all post-treatment residue levels remained above the Maximum Residue Limit (MRL) specified in the Regulation of the Minister of Agriculture Number 24 of 2011. The vinegar-solution treatment was reported to provide a moderately effective pesticide-residue reduction of 63.88%.

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