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The Effect of Weight Gain and Length of Stay of *Pistia stratiotes* on the Phytoremediation Ability of Tofu Liquid Waste and Its Utilization as a Source of Biology Learning

Rima Kholifatul Janah[1], Elly Purwanti[2], Lud Waluyo[3]

[,1,2,3]*Biology Education Study Program, FKIP, University of Muhammadiyah Malang, Jl. Raya Tlogomas No.246, Malang, 65144, East Java, Indonesia*

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ABSTRACT

Waste water from the process of making tofu causes environmental pollution because it has acidic and cloudy. The acidic nature of the tofu waste is a result of the process of adding vinegar to the clumping process. Therefore, it is necessary to treat waste before it is discharged into river bodies in order to reduce organic matter and suspended and dissolved solids in the waste water. One of the effective and low cost ways is the phytoremediation process. The water plant that can be used as a remediator is *Pistia stratiotes*. This study was to determine the interaction between variations weight and remained of *Pistia stratiotes* on the improvement of the quality tofu waste water and its use as a source of biology learning. The approach and type of this research are quantitative and true experiment. Sampling of waste water was carried out at the industrial center of making tofu as much as 70 liters in Pakunden Village, taking *Pistia stratiotes* from the swamps around the river flow of Kali Lahar, Blitar City. Sample testing was carried out at Jasa Tirta I, Malang. This study consisted of 10 treatment groups and 3 control groups with 3 repetitions with variations weight of 80 g, 90 g, 100 g, 110g, 120g and remained of 7 days and 14 days. The experimental design used in this experiment was a completely randomized design, the results of this study can be used as a source of information on Biology learning that has been adjusted to the 6 requirements of learning resources.

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INTRODUCTION

Tofu is very popular in all layers of the society because of its ease of procurement, low price, and high nutritional value (Tandian & Praptiningsih, 2013). The high market demand for tofu will increase and is driven by the ease of obtaining raw materials, resulting in increasing number of tofu-making small industries (Darmajana, 2012). The process of

Korespondensi Author: rima.kholifatul@gmail.com (Janah)
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making tofu has both positive and negative impacts. The positive impact of making tofu is the fulfillment of people's food needs, while the negative impact is liquid waste from the process of making tofu which causes environmental pollution Yudhistira, *et al*., (2016). One of the processes of making tofu that produces liquid waste is the remaining tofu water from the clumping process which, if discharged directly into river bodies, will cause pollution.

Tofu liquid waste is generally acidic and cloudy. The remaining organic matter causes the tofu liquid waste to become cloudy - the higher the suspended and dissolved solids content in the tofu liquid waste, the cloudier the liquid waste (Dina*, et al*., 2014). The acidic nature of the tofu waste is the result of the tofu-making process which includes the addition of vinegar (Vidyawati & Fitrihadjati, 2016; Nindra & Hartini, 2015). Waste treatment before being discharged into river bodies is very necessary in order to reduce organic matter and suspended and dissolved solids in the liquid waste, so as not to pollute the environment or water bodies. One of the effective ways with low cost is the phytoremediation process.

Plants that can be used in the phytoremediation process must have a high growth rate, live in a cosmopolitan habitat, be able to consume large amounts of water in a short time, be able to remediate pollutants, and be easy to maintain (Waluyo, 2018). Aquatic plants meet the criteria of plants that can be used as a phytoremediation process. Aquatic plants act as water aerators through the process of photosynthesis, regulate water flow, clean polluted streams through the sedimentation process, and absorb particles and minerals (Indah*, et al*., 2014).

Previous relevant research has been carried out by Disyamto, Kasman, Vidyawati related to the duration of plant phytoremediation to reduce organic pollutants and be able to bind suspended solids. Previous research by Disyamto*, et al.* (2014) made use of cat tail plant (*Thypa latifolia*) for phytoremediation of tofu waste by measuring the decrease in Biological Oxygen Demand (BOD). Research by Kasman*, et al.* (2018) made use of water jasmine plant (*Eichinodorus palaefolius*) for phytoremediation of tofu waste by measuring the rate of decrease in BOD, *Total Suspended Solid* (TSS), and fat. Research by Vidyawati & Fitrihadjati (2016) used water hyacinth plant (*Eichornia crassipers*) for phytoremediation of tofu waste by measuring the reduction of Nitrogen (N).

Aquatic plants that may be used as remediators are *kapu-kapu* (*Pistia stratiotes*). *Pistia stratiotes* is a freshwater plant that is commonly found in the tropics by floating freely and adhering to mud. The fine hairs on the roots, and the long, dense roots of P. stratiotes enable the plant to absorb large amounts of water and bind organic pollutants and suspended and dissolved compounds (Wirawan*, et al.*, 2014). According to Indah*, et al.* (2014) *P. stratiotes* can reduce BOD, Chemical Oxygen Demand (COD), TSS, and pH as well as oil and fat content. This shows that *P. stratiotes* is a plant that is able to reduce pollutants that cause pollution in waste. Therefore, the researchers wanted to use the *P. stratiotes* plant as a remediator in the phytoremediation of tofu liquid waste by measuring the quality improvement of chemical parameters which include the value of Dissolved Oxygen (DO), pH, and levels of ammonia (NH3); and physical parameters include levels of Total Dissolved Solid (TDS) and TSS.

This research was conducted to overcome the problem of tofu liquid waste, reduce environmental pollution, and provide new knowledge for the community: that *P. stratiotes* can be an alternative waste treatment with low

cost. The results of the research are also expected to be used as a source of high school biology lessons in Basic Competency K.D 4.11 - Formulating ideas for solving problems of environmental changes that occur in the surrounding environment. Based on this review, the author wants to conduct research on the Effect of Weight Gain and Length of Stay of *P. stratiotes* on the Phytoremediation Ability of Tofu Liquid Waste and Its Utilization as a Source of Biology Learning.

METHOD

Research Approach and Design

This study uses a quantitative approach and the type of research carried out is using true experimental research. The research design used was a completely randomized design (CRD) with 10 treatments and 3 repetitions.

Research Location and Time

The research was conducted at Graha Sejahtera Residence Landungsari, Dau, Malang. Sample testing was carried out at Jasa Tirta I Jl. Surabaya No. 2A, Sumbersari, Lowokwaru, Malang. Sampling of liquid waste was carried out at the industrial center for making tofu, Pakunden Village, Sukorejo District, Blitar City, and taking P. stratiotes plants in the swamps around the Kali Lahar river flow in Blitar City. The study was conducted from February 2020 to April 2021.

Research Population

The population in this study is tofu liquid waste generated from the tofu industrial center in Pakunden Village, Blitar City.

Sampling technique

The sampling technique is done by non-random sampling (sampling without random) with quota sampling (sampling quota or a certain amount). There were 10 treatment groups and 3 control groups with 3 repetitions, with variations in weight of P. stratiotes 80 g, 90 g, 100 g, 110 g, 120 g and P. stratiotes plant length of stay 7 days and 14 days.

Tools and materials

The tools used in this study were 1 pack of label paper, 1 digital scale, 2 35 L black jerry cans, 2 measuring cups, 1 digital camera, 32 plastic buckets with a diameter of 40 cm, 32 black bottles 600 mL. The materials used in this study were 70 L of tofu liquid waste and 72 P. stratiotes or the equivalent of 5 kg.

Research Flow

The phytoremediation process of tofu liquid waste begins with acclimatization of P. stratiotes plants which is carried out for 4 days, the acclimatized P. stratiotes plants are transferred to plastic buckets that have been given tofu liquid waste without dilution of 1.5 L, Before and after after the treatment measure the research parameters, namely the decrease in physics and chemistry (TSS, TDS, DO, pH, NH3) in tofu liquid waste. The data collection instrument used in this study was the observation sheet.

RESULTS AND DISCUSSION

Research result

The average results of measurements of pH, NH3, DO, TDS, and TSS of tofu liquid waste can be seen in the following table. Based on Table 1, the lowest average pH value was 2.9 with treatment of 0 grams of P. stratiotes with a length of stay of 14 days, the highest pH level of 7.78 with treatment of 100 grams of P. stratiotes with a length of stay of 14 days and 110 grams of P. stratiotes with a length of stay of 14 days.

Table 1. Average results of measurement of tofu liquid waste

No.	Treatment	Treatment parameters				
		pH	NH_3 (mg/L)	DO (mg/L)	TDS (mg/L)	TSS (mg/L)
1.	A0B0	3,4	3,02	0,7	4661	1471
2.	A0B1	3,2	3,30	0,7	4633	1465
3.	A0B2	2,9	3,89	0,6	4668	1460
4.	A1B1	7.4	0,44	1,91	2773	883
5.	A1B2	7,67	0,45	4,02	1435	435
6.	A2B1	7,43	0,48	2,04	2666	1127
7.	A2B2	7,77	0,43	4,86	1299	423
8.	A3B1	7,57	0,47	2,81	2463	1009
9.	A3B2	7,87	0,45	4,88	1067	381
10.	A4B1	7,47	0,45	3,45	2054	785
11.	A4B2	7,87	0,47	4,97	993	364
12.	A5B1	7,5	0,43	3,98	1769	564
13.	A5B2	7,77	0,46	5,02	986	322

The lowest NH3 level was 0.43 mg/L with treatment of 90 grams of Pistia stratiotes with a length of stay of 14 days and 110 grams of Pistia stratiotes with a length of stay of 7 days, the highest NH3 level of 3.89 mg/L with treatment of 0 grams of Pistia stratiotes with a long stay 14 days. The lowest DO level was 0.46 mg/L with treatment of 0 grams of Pistia stratiotes with a length of stay of 14 days, the highest DO level was 5.02 mg/L with treatment of 120 grams of Pistia stratiotes with a length of stay of 14 days. The lowest TDS level was 986 mg/L with treatment of 120 grams of Pistia stratiotes with a length of stay of 14 days, the highest level of TDS was 4668 mg/L with treatment of 0 grams of Pistia stratiotes with a length of stay of 14 days. The lowest TSS level was 322 mg/L with treatment of 120 grams of Pistia stratiotes with a length of stay of 14 days, the highest level of TSS was 1471 mg/L with treatment of 0 grams of Pistia stratiotes with a length of stay of 0 days.

Interaction of Pistia stratiotes Plant Weight and Length of Stay on Improvement of Tofu Liquid Waste Content

The average results showed that the variation in plant weight had an effect on improving the quality of tofu liquid waste, the heavier the plant, the better the improvement in the quality of the liquid waste. Plant weight will affect the number of plants and the number of roots, the more roots the higher the absorption that occurs. Vidyawati & Fitrihadjati (2016) mentions that in the phytoremediation process there is a process of absorption of organic substances contained in tofu liquid waste by plant roots.

Interaction of Pistia stratiotes Plant Weight and Length of Stay on Tofu Liquid Waste Content Improvement

The average of the results showed that the variation in plant weight had an effect on improving the quality of tofu liquid waste, the heavier the plant, the better the improvement in the quality of the liquid waste. Plant weight will affect the number of plants and the number of roots, the more roots the higher the absorption that occurs. Vidyawati & Fitrihadjati (2016) stated that in the phytoremediation process there is a process of

absorption of organic substances contained in tofu liquid waste by plant roots.

The absorption of organic pollutants is influenced by the root system and plant metabolism. P. stratiotes has fibrous roots and many branches making it easier to absorb organic pollutants dissolved in water. P. stratiotes will produce certain compounds to bind organic pollutants dissolved in water to be drawn to the roots. The process of breaking down organic pollutants before they are absorbed by plants is assisted by water microorganisms that live in plant roots. Djo*, et al*. (2017) mentions that the role of microorganisms that live in plant roots is very large, where these microorganisms will break down large organic compounds in water into smaller compounds so as to facilitate root absorption. Apsari*, et al.* (2018) states that the process of capturing pollutants by plants is called phytostabilization. Organic pollutants contained in wastewater enter the roots through capillary pores in the root fibers or the smallest root branches, water containing pollutants will diffuse into the root hairs, then will pass through the cells into free space through the membrane, and by osmosis enter into the plant plasma membrane. Menurut Hamzah & Pancawati (2013) The process of absorption or absorption of pollutants in the roots is called rhizofiltration. Organic pollutants that have accumulated in the roots will then enter the stems through transport vessels (xylem), which will then be forwarded to the leaves. In the leaves there will be a process of processing organic pollutants using substances that are needed by plants. Pollutant treatment process according to Astuti & Indriatmoko (2018) is a process used to reduce harmful compounds into simple compounds that not only occur in leaves but also occur in stems and roots. In addition, if P. stratiotes absorbs too many toxic molecules, the toxic molecules will accumulate in old leaves so that the amount of harmful pollutants in the body is reduced.

Wijayanti*, et al.* (2019) Plants will store toxic materials in old tissues such as old leaves and easily peeling bark, which plants need to reduce the concentration of toxic materials in the plant body.

The average result of the study shows that variations in length of stay affect the quality of tofu liquid waste, the longer the stay lasts, the higher the improvement in the quality of the liquid waste which can be seen from the results of the study. The results showed that the improvement in the quality of tofu liquid waste on the 7th day did not meet the class II water quality standards based on the 1991 Government Regulation. Meanwhile, on the 14th day it showed that the improvement in the quality of the tofu liquid waste almost met the class II water quality standards based on the 1991 Government Regulation. Research conducted by Yuni*, et al.* (2014) states that the longer time used in the phytoremediation process affects the absorption of organic pollutants in liquid waste by plants. The absorption of organic pollutants on day 7 was very large, this resulted in P. stratiotes being at a saturation point, so that on day 14 the plant leaves looked yellow and withered. Fauziyah*, et al*. (2020) states that the saturation point is the maximum time limit that plants can tolerate in absorbing pollutants, so that it can inhibit the process of absorption of pollutants. Indah*, et al.* (2014) adding a yellowish color to the leaves is a result of the absorption of organic pollutants, resulting in wilting and death of the leaves.

Based on the research that has been done regarding the interaction difference between the variation of P. stratiotes plant weight and length of stay on the quality of tofu liquid waste there is an interaction. The absorption of organic matter in water is influenced by the length of stay, the type of plant, and the

weight of the plant used (Caroline & Moa, 2015). In addition to plant weight and length of stay, another possible factor that causes interactions between the two variables in the absorption process of organic molecules dissolved in tofu wastewater is the temperature in the research environment. Research conducted by Ana *, et al.* (2013) mentions that environmental temperature also plays a role in the process of absorption of pollutants by plants. When the ambient temperature is in accordance with the conditions desired by the P. stratiotes plant, the process of absorption of organic pollutants will also take place optimally. Puspitasari & Irawanto (2016) added that the ambient temperature controls the biological reactions that occur in plants. If the ambient temperature decreases, the absorption rate will decrease, and vice versa if the ambient temperature increases, the absorption process rate will increase because plant metabolism increases so that the absorption process is more effective.

The following is a discussion of the effect of P. stratiotes administration and length of stay on improving pH, NH3, DO, TDS, and TSS.

1. Nilai pH

All average pH values in tofu liquid waste after being treated have met the Government Regulation of the Republic of Indonesia No.28 of 2001 Water Quality Standard Class II with a minimum pH value of 6 with a maximum pH of 9. The pH value at a length of stay of 14 shows a much higher average number compared to the mean on day 7. According to Novita*, et al.* (2019), changes in pH in water are caused by the role of plants and microorganisms in plant roots. Microorganisms in plant roots play a role in the decomposition of organic matter dissolved in water. Meanwhile, plants will take CO_2 dissolved in water in the form of H_2CO_3 to reduce H^+ compounds, so that H^+ compounds are reduced and cause the water to become more alkaline.

Adack (2013), added that the liquid waste left over from making tofu can cause disturbance to aquatic organisms. So that the acidic nature of tofu liquid waste needs to be controlled so as not to pollute the waters.

2. NH3 levels

All average levels of NH3 in tofu liquid waste have met the class II water quality standard based on Government Regulation of the Republic of Indonesia No. 28 of 2001 with a maximum NH3 value of 2. NH3 levels at the length of stay 14 indicate an average number that is much lower than the average on day 1. 7. According to Vidyawati & Fitrihadjati (2016), changes in NH3 in water are caused by an increase in the pH number. The reduction of NH3 from tofu liquid waste is assisted by nitrosomonas bacteria, where NH3 will be degraded to nitrite or nitrate which will then be absorbed by plants through plant roots.

Putra*, et al.* (2011) stated that nitrite and nitrate are used by plants for the growth process. The bigger or more plants, the higher the absorption that occurs. NH3 is a non-ionic compound that is toxic, therefore it needs to be controlled. Azizah & Humairoh (2015) added that excessive amounts of NH3 will cause death in aquatic organisms, whereas if it enters the human body it will cause poisoning.

3. DO level

Not all the average DO levels in tofu liquid waste complied with Government Regulation of the Republic of Indonesia No. 28 of 2001 with a minimum DO value of 4 mg/L, 5 samples met Government Regulation of the Republic of Indonesia No. 28 of 2001 namely A1B2, A2B2, A3B2, A4B2, A5B2. DO levels at the length of stay 14 showed a much higher average than the average on day

7. According to Cahyanto, *et al.* (2018) DO is dissolved oxygen in water, the higher the DO level in the water, the lower the contamination in water. The increase in DO from tofu liquid waste is produced by plants. Simatupang, *et al.* (2015) added that the oxygen produced from the photosynthesis process will be released into the air and will diffuse into the water resulting in increased dissolved oxygen levels. Wulandari & Niken (2013) stated that dissolved oxygen plays an important role in waters, oxygen plays a role in the process of reduction and oxidation of organic and inorganic materials. Dissolved oxygen will be used by microorganisms in the water to help the decomposition process of organic and inorganic molecules so that the absorption of organic pollutants will take place optimally.

4. TDS level

Not all the average TDS levels in tofu liquid waste meet the class II water quality standards according to Government Regulation of the Republic of Indonesia No. 28 of 2001 because the TDS level that must be owned is at least 1000 mg/L. treatments that meet class II water quality standards, namely A4B2 and A5B2. The level of TDS at the length of stay of 14 shows an average number which is much lower than the average on day 7, this is in accordance with the class II water quality standard according to Government Regulation of the Republic of Indonesia No. 28 of 2001. TDS or dissolved solids in water causes turbidity in the water. Ahmad & Adiningsih (2019) TDS or dissolved solids is very closely related to water turbidity, turbidity is not only disturbing for aquatic biota but also makes water unproductive, namely blocking sunlight for photosynthesis, and if there are a lot of suspended solids in the water it will result in very cloudy water. According to Hokoyoku, *et al.* (2017) TDS absorption can take place well due to the ability of the plant roots used to bind residues suspended in wastewater.

Kustiyaningsih & Irawanto (2020) added that the process of reducing TDS involves microorganisms, microorganisms in plant roots will decompose organic and inorganic molecules into simpler compounds making it easier for roots to absorb. Agustinus, *et al.* (2014) stated that microorganisms have their own time in breaking down organic molecules in water so that the rate of decline will be slow.

5. TSS Level

All average levels of TSS in tofu liquid waste do not meet class II water quality standards according to Government Regulation of the Republic of Indonesia No. 28 of 2001 because the TSS level that must be owned is at least 50 mg/L. TSS levels at the length of stay 14 showed a much lower mean number than the average on day 7. Penyerapan padatan tersuspensi berkaitan erat dengan panjang akar. The absorption of suspended solids is closely related to root length. According to Rahadian, *et al.* (2017) the longer and denser the plant roots, the more suspended solids the roots can bind. However, the binding of suspended solids carried out by P. stratiotes was not optimal, which was still above the prevailing water quality standard.

Ruhmawati, *et al.* (2017) stated that the process of reducing TSS involves microorganisms present in plant roots which then decompose organic and inorganic molecules into simpler compounds. Sitompul, *et al.* (2013) stated that microorganisms that live in roots will multiply and when TSS measurements are taken, microbes will also be counted as suspended solids in water. So that the amount of suspended solids present at the time of measurement does not decrease due to the presence of several counted microbes.

Utilization of Research Results as Biology Learning Resources

The research process and results can be used as a learning resource by considering the meaning of research as a learning resource. The interaction between educators (teachers) and students (students) requires a supporting component. One important component that supports the process of interaction between educators and students is the availability of learning resources. Suratsih (2010) stated that the requirements of research results to be used as learning resources include clarity of potential, conformity with goals, clarity of goals, clarity of information disclosed, and clarity of exploration. The following will describe the requirements regarding the utilization of the effect of weight gain and length of stay of P. stratiotes on the phytoremediation ability of tofu liquid waste and its use as a learning resource.

1) The clarity of potential is the clarity of a problem in the object expressed in teaching and learning activities. Based on the 2013 curriculum, the effect of weight gain and length of stay of P. stratiotes on the quality of tofu liquid waste. The addition of weight and length of stay of P. stratiotes plants is able to improve the quality of tofu liquid waste because plants are able to absorb organic pollutants dissolved in wastewater so that P. stratiotes can be used as a remediator that can be used as a source of student learning. The statement is in accordance with KD. 4.11 Formulate ideas for solving problems of environmental changes that occur in the surrounding environment which are displayed in the form of information media.
2) Conformity with learning objectives, the intended conformity is the results of research in accordance with the basic competencies contained in the 2013 curriculum in the Environmental Change chapter/material, namely KD. 4.11 Formulate ideas for solving problems of environmental changes that occur in the surrounding environment which are displayed in the form of information media, with one of the learning objectives which reads that students can determine waste management and are able to carry out environmental conservation efforts. Students are able to formulate solutions to problems that occur in the surrounding environment by using P. stratiotes as an example of a plant that can be used as a remediator in the phytoremediation process.
3) The target material and designation, is the clarity of the target of observation (object) and target allocation (subject). The target object in this study was the effect of plant weight and length of stay of P. stratiotes on improving the quality of tofu liquid waste, while the target subjects in this study were high school students, where students would get new information about the waste treatment process with P. stratiotes as a process remediator. phytoremediation which is adjusted to the material "Waste and its Processing" and KD used by KD. 4.11 Formulate ideas for solving problems of environmental changes that occur in the surrounding environment.
4) The information to be disclosed relates to facts that can be revealed to be used as concepts and principles in the use of learning resources. The facts that can be revealed in this study are as follows:
    a) The addition of weight and length of stay of P. stratiotes has the potential to improve the quality of tofu wastewater due to its ability to absorb organic pollutants in water.

b) The heavier the plant and the length of stay of the plant, the greater the improvement in the quality of the tofu liquid waste, the best plant weight is 120 g with a residence time of 14 days.

5) Clarity and exploration guidelines. The application of the results of this study to students must consider the time, cost, effort, and abilities of students. So that students can learn and analyze the process of adding weight and length of stay of P. stratiotes to the quality of tofu liquid waste simply by observing the pH value, color and turbidity of wastewater, smell of wastewater. The results of this study will later be used as discussion material which will be modified in the form of handouts that can be used by high school students in class X semester 2. Clarity of exploration includes observation, discussion, and making or drawing conclusions.
6) Clarity of acquisition. The results of the study are expected to provide benefits and can be used as a learning resource based on the following aspects of the learning objectives:
   a) Cognitive aspect, adding insight and information about the effect of weight gain and length of stay of P. stratiotes on improving the quality of tofu liquid waste.
   b) The affective aspect can be achieved by students through a simple practicum by increasing the weight and length of stay of P. stratiotes plants in tofu liquid waste, which is then carried out by simple observations including pH values, color and turbidity, and odors.
   c) Psychomotor aspects, obtained by students through a thorough, honest, diligent, and thorough attitude when doing a simple practicum by adding weight and length of stay of P. stratiotes plants in tofu liquid waste, which is then carried out simple observations including pH levels, color and cloudiness, and odor.

CONCLUSION

Based on the results of the study, it can be seen that there is an interaction between the addition of weight variations of *P. stratiotes* and length of stay on the quality of tofu liquid waste (pH, NH_3, DO, TDS, TSS). The temperature of the research environment also plays a role in the absorption of plants - when the ambient temperature is high, the rate of absorption of pollutants will also be high. The best interaction in this study was the addition of 120 g of *P. stratiotes* for 14 days with the highest pH of 7.77, the lowest NH_3 of 0.46 mg/L, the highest DO of 5.02 mg/L, the lowest TDS of 986 mg/L. L, and the lowest TSS was 322 mg/L. However, these results are still not in accordance with the class II water quality standard according to the Government Regulation of the Republic of Indonesia No. 28 of 2001 since the TSS level must be a minimum of 50 mg/L.

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