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Application of fermented product feed to growth performance of fish: a review

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ABSTRACT

Aquaculture activities cannot be separated from the availability of artificial feed, even 70% of the total production cost is spent on feed, so the availability of good feed, in terms of quality and quantity, is an effort to maintain the success of aquaculture activities. Feeds with high protein have relatively higher prices because some of their raw materials still rely on imports from other countries. The solution to this problem is to use alternative feed ingredients that have good nutritional content, are easy to obtain and do not compete with humans. Organic waste originating from food scraps and agricultural industry residues has considerable potential. However, it is necessary to have a fermentation process as an effort to improve the nutrition and quality of these materials. The purpose of this paper is to determine the extent of utilization of fermented organic waste as fish feed ingredients that can help improve fish growth performance.

Introduction

Fish feed in aquaculture is the most important thing that determines the success of aquaculture activities. Maintaining the availability of good feed, in terms of quality and quantity is an effort to maintain the success of cultivation (Sandra et al., 2019). The good quality feed has a relatively higher price, one of the things that cause the high price of feed is that some of the feed ingredients used in the manufacturing process are still imported from other countries which affect production costs and also has an impact on the selling price of the product which is quite high. If the price of feed used is too high, it will have an impact on the cost of aquaculture activities as well. The costs incurred for the availability of feed in aquaculture reaches 60-70% of the total production costs (Andriani et al, 2016). One of the efforts to reduce feed costs in fish farming is by making fish feed by utilizing available alternative feed ingredients.

Alternative feed ingredients that have the potential to become fish feed ingredients are agricultural waste and food waste. Kasapidou et al. (2015) explained that 30% of agricultural industrial waste has the potential to be used as a raw material for making feed and will create a zero-waste situation. Food waste also has the potential to be used as fish feed because it contains sufficient nutrients to be utilized (Anasih et al., 2021). There is a unique similarity between agricultural wastes and food waste is the high crude fiber content. The high crude fiber in feed will be a problem for the digestibility of feed, because crude fiber is a nutrient that is difficult to digest by fish and will affect digestibility and feed efficiency (Hepher, 1998). The solution to reducing crude fiber content in agricultural waste and food waste is the fermentation process.

Fermentation is a process of changing the composition of chemical compounds with complex structures into simpler structures by utilizing the work of enzymes produced from microbial secondary metabolites (Pamungkas, 2011; Andriani et al, 2016). The fermentation process on feed ingredients can improve the quality of ingredients,

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increase feed digestibility, and create flavors and aromas favored by fish (Andriani et al., 2020). The fermentation process carried out on agricultural waste and food waste is expected to improve the quality of feed ingredients by reducing crude fiber content and increasing crude protein content and increasing feed digestibility (Putra et al, 2020; Andriani et al., 2021). The fermentation process hoped that will be an increase in the utilization of the waste as feed ingredients, thereby reducing the level of dependence on imported feed ingredients.

In this article, a review will be conducted on the characteristics and content of various organic wastes, the fermentation process to improve the quality of various organic wastes, and the uses as fish feed ingredients that can improve fish growth performance.

Methods

The method used in this article is a systematic review article. The Literature Search was conducted in October-November 2021, using the Google Scholar database. The keywords used in the literature search include Organic Waste, Agricultural Waste, Food Waste, Fish Feed, and Fermentation. The inclusion and exclusion criteria in this review article can be seen in Table 1.

Table 1. Criteria of article.

Criteria	Inclusion	Exclusion
Study design	Research results	Books, review articles, conferences, abstract
Topic discuss	Organic waste fermentation process as fish feed ingredients	Outside the discussion topic the
Language	Indonesian and English	Outside of Indonesian and English
Subject Areas of	Agriculture, Fisheries and Feed Nutrition	Outside the Three Subjects

Characteristic and Nutritional of Organic Waste

Organic waste, whether sourced from agricultural products or food waste, is one of the problems in several regions of Indonesia (Prawirodigdo & Utomo, 2011) because the organic waste is still not utilized properly and only ends up in incineration or landfills. In fact, the burning and decomposition of organic waste can have a negative impact on climate and air pollution. Decomposition that occurs in the organic waste can produce methane gas ($CH4$) (Rajeh et al., 2020), methane gas can have an impact on global warming 30 times worse compared to carbon dioxide (Safitri et al, 2018). Favoino & Hogg (2008) explain that 41% of emissions released from agriculture are $CH4$. The emission factor of $CH4$ produced by organic waste in Indonesia is 0.07-0.11 kg $CH4$/kg dry weight and 0.42-0.47 kg $CH4$/kg wet weight organic waste (Kustiasih et al., 2014).

Various bad impacts can be caused by agricultural organic waste and food waste. Thus, a solution is needed to overcome and mitigate organic waste, the utilization of organic waste for fish feed becomes the best solution. However, agricultural organic waste and food waste have the characteristics of perishability, easy contamination, high water content, high crude fiber and low protein content, insufficient nutrient content for fish growth, and the nutritional content does not remain dependent on the composition of the waste (Table 2) (Sugiura et al., 2009; Chen et al., 2015; Cahya et al., 2020; Anasih et al., 2021; Andriani et al., 2021).

As one of the food ingredients and industrial raw materials, cassava peel has reached 15-20% per kilogram of cassava (Mulyasari et al, 2013), this is a problem if the waste is not utilized. Cassava peel has a fairly good nutritional content (Table 2). However, the high crude fiber content and cyanide acid (HCN) content in cassava peel can cause low digestibility and can be fatal if used as fish feed ingredients (Mulyasari et al, 2013). Crude fiber contains cellulose with saccharide bonds which are very difficult to digest, this is because fish do not have cellulase enzymes in the digestive tract (Dinsa, 2017; Nurhayati, 2018). Cyanide acid (HCN) is a toxic compound consisting of linamarin (93%) and lotaustralin (7%) (Andriani et al, 2016). The content of cyanide acid in cassava peel reaches 44.6 mg/kg dry weight (Oboh, 2006).

Corn is one of the food substitutes for rice in several regions of Indonesia. The corn milling industry in Indonesia has a fairly large capacity, even reaching 3,000 tons/month, so it will produce a large amount of side waste (Tangendjaja & Wina, 2007). Corn cobs waste generated from corn milling is 20%, so it requires more utilization so that it does not become a problem for the environment. Currently, corn cobs are mostly used in ruminant feed, this is due to the characteristics of corn cobs which have crude fiber content, high water content, and low palatability (Tangendjaja & Wina, 2007; Umiyasih & Wina, 2008; Zaenuri et al, 2014).

Table 2. Nutritional of organic waste.

Type of Wastes	Parameters (%)			
	Protein	Fat	Crude Fiber	Ash
Cassava Peel[(1)]	8.20	3.10	12.50	6.40
Cassava Peel [(2)]	7.71	1.14	15.07	3.35
Cassava Peel [(3)]	9.79	1.73	8.04	7.22
Corncob[(4)]	3.96	2.08	40.29	1.17
Corncob[(5)]	2.61	1.57	36.18	-
Corncob[(6)]	3.00	0.50	36.00	2.00
Corncob[(7)]	2.92	1.03	51.30	2.27
Banana Peel[(8)]	7.21	-	20.60	-
Banana Peel[(4)]	9.54	4.23	17.48	11.81
Noodle Industrial Waste[(9)]	8.57	8.73	1.37	-
Restaurant Waste[(10)]	15.58	7.77	4.88	6.54
Restaurant Waste[(11)]	10.89	9.70	9.13	-

Information : [(1)]Oboh, 2006; [(2)]Suprayudi et al., 2012; [(3)]Mulyasari et al., 2013; [(4)]Andriani et al., 2016; [(5)]Koes et al., 2020; [(6)]Umiyasih & Wina, 2008; [(7)]Kamaruddin et al., 2014; [(8)]Agustono et al., 2011; [(9)]Sukarma, 2011; [(10)]Andriani et al., 2021; [(11)]Achadri et al., 2018; - no data available.

Table 3. Nutrient content of organic waste after fermentation.

Type of Waste	Microorganisms used	Results	Source of
Cassava Peel	Saccharomyces cerevisae, Lactobacillus delbruckii, Lactobacillus coryneformis.	Fermentation carried out on cassava peel waste provides an improvement in the nutritional content, and reduced the anti-nutritional content. Protein content increased up to 162%, reduced fat content by 32%, and decreased crude fiber by 6%, and anti-nutrients such as cyanide and phytic acid in fermented waste only amounted to 6.2 mg/kg and 789.7 mg/100 g, while in non-fermented of 44.6 mg/kg and 1043.6 mg/100 g.	Oboh et al., 2006
Cassava peel	Treatment 1: Trichoderma viride, Phanerochaete chrysosporium Treatment 2: Bacillus megaterium	Crude protein and fat content in the ingredients increased by 113% and 42%, while crude fiber decreased by only 1% with treatment 1. Meanwhile, fermentation with treatment 2 was able to increase crude protein by 22% and reduce crude fiber and fat by 37% and 24%, respectively.	Mulyasari et al, 2013
Cassava peel	Saccharomyces cerevisae	There was an increase in fat and crude protein content by 12.75% and 17.80%, while crude fiber decreased by 2.45%. This study also stated that fermentation also increased the digestibility of feed.	Suprayudi et al, 2012
Corn Cob	Saccharomyces cerevisae	Fermentation on corn cobs gave a very large increase in crude protein content by 374%, fat content increased by 16%, and crude fiber decreased to 7% by utilizing *Saccharomyces cerevisae* for 3 days (72 hours)	Koes et al, 2020
Corn Cobs	Treatment 1: Aspergillus niger Treatment 2: Rhizopus oryzae Treatment 3: Trichoderma viride	The fermentation process during for 4-5 days. The best increase in crude protein content was 13% (T1), fat increased by 54% (T2) and crude fiber decreased by 20% (T3). Overall, the fermented treatment had better nutritional content (higher protein and fat content and lower crude fiber) than without the fermentation process.	Kamaruddin et al, 2014

Type of Waste	Microorganisms used	Results	Source of
Banana Peel	Trichoderma viride, Bacillus subtilis	Fermentation process on banana peels gave significant differences in protein and crude fiber content. The increase in crude protein in the material was 21% and the decrease in crude fiber reached 45%.	Yusuf et al, 2012
Banana Peel	Trichoderma viride	Treatment of *Trichoderma viride* 7% in the fermentation process gave an increase in protein content of up to 96% and 5% treatment of *Trichoderma viride* gave a decrease in the crude fiber content of the material up to 10%.	Agustono et al, 2011
Restaurant Waste	Saccharomyces cereviceae., Lactobacillus sp., Bacillus sp. (BIOM-S Probiotics)	Fermentation on restaurant waste for 7 days using BIOM-S probiotics which contains 3 types of microorganisms. The crude fiber content decreased by 30.74%, fat decreased by 7.72%, and crude protein increase up to 50.83%.	Andriani et al., 2021
Vegetable waste	Cow rumen fluid	Fermentation with a dose of 15 ml of cow rumen fluid during 5 days. As a result, there was an increase in protein content increased by 4%, fat decreased by 33%, and crude fiber decreased by 48%.	Pure et al, 2017

Bananas are fruit plants originating from Southeast Asia which contain high levels of vitamins, minerals, and carbohydrates (Andriani et al., 2016). Bananas easily found in Indonesia, based on data obtained from Badan Pusat Statistik (the Central Statistics Agency of Indonesia) and Direktorat Jenderal Hortikultura (the Directorate General of Horticulture from the Ministry of Agriculture of Indonesia), it is known that banana production in Indonesia in 2019 reached 7,280,658 tons with a production increase 0.22% from 2018. However, there has not been much utilization of banana peel. The high content of crude fiber (Yusuf et al., 2012) and tannins (Andriani et al., 2016) in banana peels makes it difficult for fish to digest banana peel-based feed. This reason is the cause of the lack of use as fish feed ingredients.

Food waste consisting of noodle industry waste, restaurant waste, and agricultural waste has considerable potential to be used as fish feed ingredients. This is because these wastes have high production, especially in urban areas. Restaurant waste and vegetable waste have high crude fiber content and low protein content, other than that other characteristics of this restaurant waste are perishable, easily contaminated and the nutritional content is not fixed because it depends on the composition of the waste (Sugiura et al., 2009; Sandra et al., 2019; Salam et al., 2019; Anasih et al., 2021; Andriani et al., 2021).

Based on the description of the characteristics and nutritional content of organic waste, it can be seen that organic waste has almost the same characteristics, nutrient content that does not support fish growth, and anti-nutrient content in several types of waste. Thus, to utilize organic waste in fish feed ingredients, it is necessary to improve the nutritional content and detoxify anti-nutrients through the fermentation process.

Fermentation of organic waste

Fermentation is a process of changing the complex structures of chemical compounds into simpler structures, the fermentation process utilizes the enzymes produced from microbial secondary metabolites (Pamungkas, 2011; Andriani et al, 2016). The fermentation process is a method that has been widely used to improve the quality of feed ingredients (Table 3) because it has many advantages including being able to reduce the crude fiber content and increase the crude protein content in the ingredients, increase feed digestibility, eliminate anti-nutritional content and can create a taste and aroma (Sitohang et al., 2012; Andriani et al., 2016; Sandra et al., 2021). As previously explained, the fermentation of organic waste can provide various advantages. Fermentation is able to improve the nutritional content of organic waste, this is due to the activity of microorganisms that produce enzymes (Andriani et al, 2016). *Bacillus* sp. is a bacterium that has the ability to degrade many compounds, including recalcitrants and xenobiotics (Hatmanti, 2000). *Bacillus* sp. is also able to increase the crude protein content in the material because it can produce protease enzymes, this enzyme is able to break the protein into amino acids and will be used by microorganisms to increase the number of colonies, increasing the number of colonies will increase the crude protein content because *Bacillus* sp. is a source of single-cell protein (protein derived from microorganisms) (Naidu & Devi, 2005; Putri et al, 2012). *Trichoderma* sp. is a fungus that is generally produced from soil isolation, *Trichoderma* sp is able to break the complex bonds of cellulose by producing cellulase enzymes, the degradation that occurs in cellulose will reduce the crude fiber content of the material (Brotman *et al.,* 2010; Putri et al, 2012). *Saccharomyces cerevisiae* is species of yeast that has been widely used (Ahmad, 2005), this yeast is able to reduce the crude fiber content in the material because it can hydrolyze various types of starch into simpler compounds such as maltose and glucose (Ngili, 2009). *Lactobacillus* sp. is lactic acid bacteria that are resistant to anaerobic conditions and have the ability to break complex bonds (Hammes & Vogel, 1995). According to Suryani et al. (2017), the decrease in crude fiber fermented with *Lactobacillus* sp. because these bacteria degrade, the cellulose content in the material by utilizing the cellulase enzyme. *Aspergillus niger* is a microorganism that plays a very important role in biotechnology, this microorganism is used as a producer of exoenzymes and citric acid which is useful in industry (Schuster *et al.,* 2002). *Aspergillus niger* is a yeast that has the ability to produce various enzymes including proteolytic, amylolytic, and lipolytic enzymes that can improve the nutritional quality of feed ingredients for the better (Indariyanti & Rakhmawati, 2013). *Rhizopus oryzae* is a fungus that has the potential to produce lactic acid, this fungus has the ability to reduce crude fiber content in organic waste because it is able to utilize polysaccharides as a carbon source to produce lactic acid (Manfaati, 2010). *Rhizopus oryzae* is also a fungus capable of producing protease and cellulase enzymes, thereby increasing protein and crude fiber content in feed ingredients (Nuryana et al, 2016).

The fermentation process is also able to improve the physical quality of the waste meal produced. According to Andriani *et al.* (2020), fermentation of restaurant waste is able to reduce the diameter and distance between particles. The decrease in particle size in fermented restaurant waste meals makes it easier to apply as fish feed ingredients, easy to digest and improves feed quality. Increasing the distance between particles in the material will make it easier for water particles to enter the gaps formed so that the feed made will break down faster in the water and will have an impact on the FCR. In addition, according to Andriani *et al.* (2019), the fermentation of *Lemna* sp. does not affect the structure of organic chain bonds, so the functional structure will remain the same but the quality of the resulting material will be better than without the fermentation process.

Application of fermented product as fish feed

Utilization of organic waste as fish feed (Table 4) is a solution to various problems, including reducing environmental pollution caused by the accumulation of organic waste, both agricultural and food waste, increasing income by reducing costs incurred for fulfilling feedstocks. (Kasapidou et al., 2015). According to Wong et al. (2016), food waste can be used as fish feed, especially for fish with low trophic levels such as herbivores and omnivores, because the need for protein and nutrients for these fish is lower than fish with high trophic levels (carnivores). In fact, to increase the growth rate and maintain fish health, food waste can be given a fermentation treatment.

Table 4. Utilization of fermented organic waste as fish feed.

Source of Material for	Application	Fermented	Source
Food Waste	Tilapia (*Oreochromis niloticus*)	The addition of fermented waste meal by 55% gives an FCR value of 1.15; Relative Growth Rate of 1,530%. The addition of fermented waste meal was 45%, giving an FCR value of 1.06; Relative Growth Rate of 1,230%.	Mo et al. 2019
	Fish Australian Jade Perch (*Scortum barcoo*)	Feeding with the addition of fermented waste meal does not affect the immune system of fish and this fermented waste meal is able to produce high-quality feed and reduce dependence on fish meal.	
Fermented Cassava Skin Waste	Tilapia (*Oreochromis niloticus*)	The addition of 16% fermented cassava peel waste meal gives an FCR value of 1.58; Specific Growth Rate of 1.68; Protein Retention of 41.04%. The smaller the protein retention value,	Azwar & Melati 2012

Source of Material for	Application	Fermented	Source
		the lower the growth value due to the limited availability of amino acids in the feed that can be absorbed by fish.	
Fermented Vegetable Waste Gouramy	Seed (*Osphronemus gourami*)	The addition of 45% of the fermented vegetable waste meal, gives 78% feed digestibility value and 83% protein digestibility value. The feed with the addition of fermented vegetable waste meal gave a feed efficiency value of 30.26%; protein retention of 26.38% and a specific growth rate of 2.31%.	Resti et al 2021
Fermented	Tilapia (*Oreochromis niloticus*)	The addition of 30% fermented restaurant waste meal can provide a daily growth rate of 1.57%; 0.53% FCR and 90% Survival Rate.	Andriani et al. 2021
Fermented Vegetable Waste	Vannamei Shrimp (*Litopenaeus vannamei*)	The addition of 10% vegetable waste fermented meal to shrimp feed is able to provide an absolute growth rate of 91.12%. Feed with the addition of fermented vegetable waste meal did not affect the water quality so the vannamei shrimp survival rate was 86.67%.	Salam et al 2019
Fermented	Tilapia (*Oreochromis niloticus*)	The addition of 20% fermented banana peel waste meal to the tilapia feed formulation provided an absolute growth rate of 2.93 grams and a feed efficiency value of 42.4%.	Jeharu et al. 2015
Tofu Waste	Catfish (*Clarias gariepinus*)	The addition of 1% fermented tofu gave an absolute growth rate of 10.15 grams; FCR of 2.81 and survival rate of 100%.	Yohanista 2018

Based on some of that studies, it can be seen that fermented organic waste has enormous potential to be used as fish feed ingredients. Fermentation of organic waste is proven to be able to improve the nutritional content and even reduce the levels of anti-nutrients. According to Andriani et al (2016), anti-nutrients such as cyanide acid and tannins found in cassava peel and banana peel waste are a problem because cyanide acid can interfere with growth and can even react with hemoglobin so that blood cannot transport oxygen. Meanwhile, tannins have functional bonds that can bind to protein in feed, making it difficult for fish to digest feed. The fermentation process of the organic waste can reduce or even eliminate the anti-nutrient content so as to help increase digestibility and increase the use of agricultural organic waste and food waste as fish feed ingredients.

Conclusion

Organic waste from the agricultural industry and food waste has enormous potential to be used as an alternative feed ingredient. Various problems such as insufficient nutrient content for fish growth and anti-nutritional content in the material can be anticipated by fermentation. Improving the quality of materials with the fermentation process can increase the use of organic waste as fish feed ingredients and can provide fish growth. Furthermore, the fermentation process is also able to ensure the safety of the ingredients and does not cause health problems for fish. The use of fermented organic waste as a feed ingredient is a solution that can be used to support the achievement of the blue economy and sustainable development goals.

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