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The Restaurant Waste Fermentation as Feed Material: A Literature Review

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ABSTRACT

Waste is the excess of individual regular activities and, or natural processes in solid form. Waste is classified into two categories, namely organic and inorganic waste. Restaurant waste is known as organic waste because of its biodegradable character in nature. Waste is one of the main issues in Indonesia that got no resolution continuously. On average, Indonesian people produce around 2.5 liters of waste per day. Based on its composition, dominated by organic waste around 58%, and the remaining 42% is inorganic waste. One of the uses of waste, especially restaurant waste, is that it has utilization in the fields of agriculture, livestock, and fisheries. One of the uses of restaurant waste in fisheries is its application as a feed ingredient. However, giving restaurant waste directly as fish feed doesn't provide optimal fish growth due to its nutritional content as the low protein and high crude fiber. Fermentation is the process of breaking down organic compounds into simpler compounds by involving microorganisms. Fermentation can increase the nutritional value of restaurant waste and gives additional function as a fish feed component. The nutritional value of fermented restaurant waste is 29.72% protein, 4.81% crude fiber, and 16.09% fat. The use of restaurant waste is known in various studies such as feed ingredients for catfish (*Clarias* sp.), Tilapia (*Oreochromis niloticus*), Grass carp, Grey mullet (*Mugil cephalus*), livestock such as broiler chickens, and organic fertilizers.

***Keywords*:** Fermentation, Fish feed, Restaurant waste, Restaurant waste utilization

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1. INTRODUCTION

Waste is the excess of individual regular activities and, or natural processes in the solid form [1]. Waste is categorized into two, namely organic and inorganic waste. Organic waste is easy to weathering or rottenness, while inorganic waste is difficult to weathering [2]. Restaurant waste is known as organic waste because of its biodegradable character in nature [3]. The nutritional value of fermented restaurant waste is 10.89% protein, 9.70% fat, and 9.13% crude fiber [4]. Based on the nutritional content, restaurant waste can be managed and used as a source of fish feed ingredients [5]. However, giving restaurant waste directly as fish feed doesn't provide optimal fish growth due to its nutritional content as the low protein and high crude fiber [6].

Fermentation is the process of breaking down organic compounds into simpler compounds by involving microorganisms [7]. Fermentation can increase or improve the nutritional value of local feed raw materials and use them as raw materials for fish feed [7]. Moreover, there is an improvement in restaurant waste organic matter quality through the fermentation process [3]. Bacterial activity in the fermentation process can convert protein into amino acids, and then these amino acids can be used by bacteria to reproduce themselves to increase the protein content [8]. The fermentation process uses the activity of a particular microbe or a mixture of several microbial species to produce enzymes that can break down complex compounds into simpler compounds so that they can be digested easily by fish [9]

Feed material consists of two, namely vegetable protein sources and animal protein sources. Vegetable protein sources are vegetable waste and food scraps, while animal protein sources are waste derived from the remains of meat, chicken, fish, and bones [6]. Food waste availability is considered abundant and has not been widely used to support fish cultivation [6].

2. METHODS

This literature study was obtained from online journals such as Pubmed - NCBI, Elsevier, Research Gate, Springer, and Google Scholar. The keywords were "fermentation"; "restaurant waste"; "organic waste"; "fish feed"; "nutritional content of restaurant waste"; and "utilization of restaurant waste" used for the data search. Thus, the arranges of the theoretical framework will following the subject matter of the discussion.

3. CHARACTERISTICS OF RESTAURANT WASTE

The nutrition content of restaurant waste used for fish feed ingredients must suffice the standards for fish feed ingredients and fulfill the fish nutrition needs [10]. Several studies have been conducted to determine the nutritional content of restaurant waste (Table 1.), i.e.

Proteins are complex organic compounds that contain the elements carbon, hydrogen, nitrogen, oxygen, sulfur, and phosphorus [16]. The protein function in feed ingredients by NRC (1993) is to maintain the role of more vital body tissues [17]. Protein in fish is composed of about 70% of the dry weight of organic matter in fish body tissue, so that protein content is one of the most valuable nutritious compounds in fish [6].

Table 1. Nutrition Content of Restaurant Waste.

Parameter	Nutrition Content of Restaurant Waste						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Protein (%)	10.89	15.58	10.89	15.58	22.33	15.29	12.69
Crude Fiber (%)	9.13	4.88	9.13	4.88	4.59	7.73	6.42
Fat (%)	9.70	7.77	9.70	7.77	13.38	8.97	7.45

Information:
1. Agricultural Research and Development Agency (2000) [4].
2. Sandra *et al.* (2019) [11].
3. Achadri *et al.* (2018) [6].
4. Andriani *et al.* (2021) [12].
5. Cahya *et al.* (2019) [13].
6. Setiawan (2006) [14].
7. Soewarno (2007) [15].

The optimum protein requirement for fish varies depending on the type of fish, life stage, water temperature, feed consumption, the daily feed amount, frequency of feeding, protein quality (amino acid composition), and non-protein energy quality [6]. The need for protein in feed between fish species is very different and generally ranges from 20% to 60% [18].

Crude fiber is a monosaccharide polymer [19]. Crude fiber is an indigestible part of carbohydrates, consisting of cellulose, hemicellulose, lignins, and polysaccharides [12]. When crude fiber is in a low value (> 10 percent) will follow in decreased digestibility, decreased absorption, increased metabolic waste, and decreased quality of culture water [20].

Fat is a source of energy. The ability of fat to produce energy is higher than carbohydrates and protein. However, because fish's ability to consume protein is fabulous, the performance of fat as an energy source occupies the second position after the proteins [17].

Restaurant waste used in the fields of fisheries, livestock, and agriculture in common. A slight explanation regarding the use of restaurant waste presented in Table 2, i.e.

Table 2. Utilization of Restaurant Waste.

No	Utilization of Restaurant Waste	Reference
1	Pig feed	[21]
2	Broiler feed	[4]
3	A mixture of rice bran and food waste as fish feed	[14]

4	Household waste as an alternative energy source	[22]
5	A mixture of market waste, oil palm meal, and fish waste on the nutritional content of maggot applied as carp feed	[23]
6	Restaurant waste as material for making African catfish pellets	[24]
7	Substitution of restaurant waste in tilapia (*Oreochromis niloticus*) feed	[25]
8	Food waste as animal feed	[26]
9	Restaurant waste as feed for trout (*Oncorhynchus mykiss*)	[27]
10	Household organic waste becomes liquid organic fertilizer	[28]
11	Restaurant waste as material for making compost	[29]
12	Restaurant waste becomes liquid organic fertilizer	[30]

4. FERMENTATION OF RESTAURANT WASTE

Fermentation is the process of substrate decomposing by microbial enzyme activity both aerobically and anaerobically [31]. Anaerobic fermentation is fermentation whose process does not require oxygen or air by the resulting products in the form of carbon dioxide and water, acetate, ethanol, volatile acids, alcohols, and esters [32]. Meanwhile, aerobic fermentation is a fermentation that occurs in an oxygenated environment [33]. Fermentation using microorganisms is one of those trials that can reduce the value of crude fiber in fish feed raw materials [34]. Fermentation can also improve protein quality and reduce crude fiber [35]. Besides being able to improve the nutritional quality of the substrate, fermentation can also increase digestibility, create an aroma and taste favored by livestock, including fish [36]. Furthermore, fermentation can change the structure and substrate particle size and result in a higher binding capacity [37]. Some research results regarding the nutritional content of fermented organic restaurant waste-based feed ingredients (Table 3), i.e

Table 3. Fermentation of Various Organic Restaurant Waste Based Feed Materials.

Parameter	**Nutritional Content**					
	1	**2**	**3**	**4**	**5**	**6**
Protein (%)	17.39	22.40	24.18	23.50	26.16	29.72
Crude Fiber (%)	6.45	19.12	3.48	3.38	3.71	4.81
Fat (%)	22.54	5.96	11.87	7.17		16.09

Information:

1. Suari *et al.* (2019) [38].

2. Achadri *et al*. (2018) [6].
3. Andriani *et al*. (2020) [3].
4. Andriani *et al*. (2021) [12].
5. Andriani *et al*. (2020) [37].
6. Ruminant Nutrition and Feed Chemistry Laboratory, Faculty of Animal Husbandry, Padjadjaran University (2020)

The principle of fermentation is biological processing using microbial services, both naturally and through the addition of yeast/mold inoculums [39]. According to [40], the microorganisms used as fermenters in the fermentation process are bacteria and fungi. Furthermore, fermentation can be carried out using bacterial, fungal, and yeast microbes [41]. In addition, fermentation occurred by adding probiotics [42]. Probiotics present as a supplement for intact microbial cells or microbial cell components in the feed so that they can give benefit to the host [43]. Commercial probiotics sold in the market generally contain the bacteria *Lactobacillus* sp., *Bacillus*, and *Saccharomyces cerevisiae* [44]. These microbes types can produce enzymes such as protease, amylase, and lipase [40]. *Lactobacillus* sp. is a bacterium capable of producing the enzyme lipase. This enzyme can hydrolyze cellulose into simpler compounds. While *Bacillus licheniformis* can increase the production of chitinolytic protease enzymes that can break protein-protein-mineral covalent bonds so that protein content increases [44]. The increase in the nutritional value of restaurant waste is created by the enzyme appearance produced by bacteria during the fermentation process [45]. The usage of various types of microbes that fermentation organic restaurant waste (Table 4.), i.e

Table 4. Types of Microbes in The Fermentation of Restaurant Waste.

No	Microbes Variety	Substrat Variety	Result	Reference
1	Lactic acid bacteria (MAB Probiotics)	Restaurant organic waste	Fermentation can remove unpleasant odors from organic waste and can degrade the early stages of complex materials to be further processed into biogas	[46]
2	*Lactobacillus* sp., *Selubizing phosphate bacteria, molds* and *Azospirillum* sp. (M-Bio solution)	Restaurant organic waste	Fermentation lasts for 3 days, producing leachate which functions as liquid organic fertilizer	[47]
3	*Lactobacillus casei*, *Saccharomyces cerevisiae* and *Rhodopseudomon*	Restaurant organic waste (various types of vegetables,	Fermentation lasted for 17 days to produce the best liquid organic fertilizer with the addition of 15 mL of probiotic EM_4	[48]

	as palustris (EM_4 Probiotics)	fruit peels and others)		
4	*Lactobacillus casei*, *Saccharomyces cerevisiae* and *Rhodopseudomonas palustris* (EM_4 Probiotics), MOL and Probiotic mixture EM4+MOL	Restaurant organic waste (leftovers and vegetables)	The best compost is produced from fermentation that lasts 14-30 days in a mixture of EM_4 / MOL 0.6-1.2	[49]
5	*Lactobacillus casei*, *Saccharomyces cerevisiae* and *Rhodopseudomonas palustris* (EM_4 Probiotics)	Restaurant organic waste	The composting process of restaurant organic waste lasts for 30 days. The compost produced is by following per under the SNI seen from the color and NPK content. The compost produced can increase the fertility of tomato, chili and spinach plants	[50]
6	*Lactobacillus casei*, *Saccharomyces cerevisiae* and *Rhodopseudomonas palustris* (EM_4 Probiotics)	Restaurant organic waste (vegetables, fruits, rice, meat and eggs)	Fermented organic waste toward animal feed ingredients with a protein content of 22.40%. The pelleted fish feed produced is a sunk type feed that is suitable for cat-fish	[6]
7	*Lactobacillus casei*, *Saccharomyces cerevisiae* and *Rhodopseudomonas palustris* (EM_4 Probiotics)	Restaurant organic waste	Restaurant waste fermented using EM_4 produces liquid organic fertilizer that can be used to increase soil/plant fertility	[30]
8	*Lactobacillus* sp., *Bacillus licheniformis* and *Saccharomyces cerevisiae* (BIOM-S)	Sundanese restaurant waste	The addition of 8% probiotic concentration in the fermentation process gave the most influential in the nutritional quality of restaurant waste with an increase in feed protein by 50.83% and a reduction in crude fiber by 30.74%. The use of fermented restaurant waste meal as much as 30% in fish feed gave the highest daily growth rate of 1.57% and the best feed conversion	[12]

			ratio of 0.57 with a survival rate of around 75-90%	
9	*Lactobacillus* sp., *Bacillus licheniformis* and *Saccharomyces cerevisiae* (BIOM-S)	Domestic food waste	The addition of 8% probiotic concentration in the fermentation process gave the biggest change in the nutritional quality of domestic food waste with protein content being 26.16% and crude fiber content being 3.71%. The average particle size and distance between particles of fermented domestic food waste were 147.723 цm and 1708.802 цm, respectively	[37]
10	*Lactobacillus casei*, *Saccharomyces cerevisiae* and *Rhodopseudomonas palustris* (EM_4 Probiotics)	Restaurant waste (vegetables, fruit, rice, fish bones and chicken)	Fermentation arranged for three weeks – 1 month to produce compost with a soil-like color and odorless. The provision of household waste compost as much as 250 g/polybag gave the highest yield on the parameters of height and wet weight of mustard plants	[51]
11	*Saccharomyces*, *Lactobacillus* sp., *Acetobacter* and *Bacillus*	Restaurant organic waste (mixture of rice, vegetables, leftover chicken etc.)	Fermentation of restaurant organic waste carried out anaerobically with a microbial dose of 25 ml and a concentration of 106, resulting in the best increase in growth of chili plants in a 5 kg polybag	[52]
12	*Aspergillus oryzae* and *S. cerevisiae*	Restaurant organic waste (rice, noodles, eggs, coconut pulp, chicken bones, tomatoes, cucumber, cabbage, mustard greens, carrots, tofu, crackers, celery and potatoes)	Fermentation of restaurant waste into bioethanol was carried out for fou days under anaerobic conditions at room temperature. The use of inoculum form of Aspergillus oryzae fungus used in the fermentation process is the solid inoculum form with a sporulation period of 7 days and a growth rate of 29×106 CFU/ml. The treatment with the concentration of primary ingredients with a ratio of water (1:1) had the highest yield, which was to obtain a distillate volume of 18.8 ml with an ethanol content of 7%	[53]

The microorganisms that play a role in increasing protein are *Bacillus* sp. which belongs to the *Saccharolytic* bacteria. These bacteria can break down disaccharides or polysaccharides into more simplistic molecular groups [54]. *Bacillus licheniformis* can also increase the production of chitinolytic protease enzymes, which can break chitin-protein-mineral covalent bonds to enhance protein content [44]. In addition, the bacteria *Bacillus* sp. can break down protein into amino acids [55]. Furthermore [8] state in their research that the bacteria *Bacillus* sp. are proteolytic bacteria that can convert protein into amino acids. Amino acids produced then used by bacteria to reproduce themselves so that they can increase protein. Furthermore [12] stated that *Bacillus* sp. is included in the saccharolytic bacteria that can break down disaccharides or polysaccharides into more simplistic molecular groups. *Bacillus* sp. bacteria activity can increase the protein content in feed ingredients by multiplying themselves. When the bacteria die, it will become nitrogen which in turn will cause an increase in protein content because most of the body's cells are composed of protein. Not only by *Bacillus* sp. bacteria but the protein increasing also caused by *Lactobacillus* sp. which are proteolytic bacteria. These bacteria can produce protease enzymes and can break down proteins into polypeptides. The polypeptide will become a more simplistic material in an amino acid form, and the microbes will use it to multiply [56].

The crude fiber content in feed ingredients will decrease due to the production of cellulase enzymes by *Lactobacillus* sp. [37]. Cellulase enzymes are a group of fibrosis enzymes that can hydrolyze fiber into glucose [57]. In addition, crude fiber can also decrease due to the mycelium produced by the fungus *S. cereviceae*. The content of mycelium, which can degrade cellulose and hemicellulose influenced by the time and dose of fermentation [37].

The restaurant waste fermentation process was carried out by [12] which 500 grams of restaurant waste were collected, dried, and analyzed proximately to determine the nutritional content. Furthermore, as much as 5 kg of restaurant waste was chopped, then fermented using probiotics with concentrations of 0, 6, 8, and 10% of the total weight of the test sample and added molasses with a concentration of 10% probiotics. Then the samples were incubated for seven days, followed by proximate analysis. The best proximate analysis results were selected based on the indicators of the highest increase in protein, the highest decrease in crude fiber, and application to the mass fermentation process.

5. UTILIZATION OF FERMENTED RESTAURANT WASTE

Restaurant waste able to be implemented into fish or poultry feed (Table 5). The research results handled by [12] reported that fermented restaurant waste meal is reasonable as an artificial fish feed ingredient. Furthermore, the research results led by [6] state that the fermented organic waste from restaurants is potential as an alternative to cultivated fish feed. Restaurant organic waste is collected every day and then placed in one container by separating waste of toothpicks, plastic, and organic waste. Then the organic waste is treated by fermentation techniques by adding fermentation bacteria under aerobic conditions for 21 days. After a 21-day process, the fermented organic waste added with bran, salt, and starch, mixed homogeneously until a dough formed. The feed dough is then formed into pellets and then dried in the sun or the oven. The results showed that the nutritional value of fermented restaurant waste had increased. The nutritional value of fermented restaurant waste was 22.40% crude protein; crude fiber 19.12%; crude fat 5.96%; 8.94% ash, and 88.91% dry matter.

The research results conducted by [50] reported that household organic waste fermented using EM_4 that potential as organic fertilizer. The organic fertilizer produced can be a planting medium for the advancement of organic agriculture on a narrow land. Furthermore, the results of research conducted by [58] reported that restaurant organic waste fermented for two weeks can be used as a decomposer of bokashi fertilizer and applied bokashi fertilizer to chili plants in polybags. The research results directed by [49] also reported that restaurant organic waste fermented using EM_4 and MOL suitable as compost. Also, it can improve the quality of compost products so that they can be used as organic fertilizer and provide economic value for restaurant organic waste through the sale of the resulted compost. The research results by [46] reported that restaurant waste is accepted to produce biofuels (bioethanol and biogas) which can be used as renewable energy simultaneously through the engineering of reducing the size of the material and the combination of enzymes in the fermentation process. The final product is wastewater and solid waste. The wastewater produced is used for the biogas fermentation process using anaerobic bacteria to produce biogas that conceivable as fuel. Meantime, the waste probable as compost.

Table 5. Utilization of Fermentation Restaurant Waste for Animals.

No	Animals	Result	Reference
1	Catfish (*Clarias* sp.)	The addition of meals from fermented restaurant waste by 20% resulted in a feed conversion value of 1.95 with a daily growth rate of 1.63%.	[59]
2	Broiler Chicken	The addition of restaurant waste meal as much as 6.2% affects the weight growth of broiler chickens	[14]
3	Livestock	The addition of food waste to the ratio as much as 32% increased the concentration of NH_3, VPA, SPM, methane gas, dry matter digestibility, organic matter digestibility and reduced feed cost	[60]
4	Broiler Chicken	The use of 75% of restaurant waste meal from Warung Tegal around Jakarta city, mixed with feed can reduce production costs by up to 36% so that it has an impact on farmers' income	[61]
5	Tilapia (*Oreochromis niloticus*)	The addition of meal from fermented restaurant waste by 30% resulted in a growth rate of 1.57%; feed conversion ratio of 0.53 and survival rate of 90%	[62]
6	Tilapia (*Oreochromis niloticus*)	The addition of fermented household waste into fish feed as much as 60% resulted in a lifetime pass of 76% with a specific growth rate of 4.23	[63]
7	Grass carp, grey mullet and Tilapia	Appropriate portions of various types of leftovers can meet the basic nutritional needs of lower trophic level fish species such as carp and tilapia. The fermentation process can improve the quality of the feed, which leads to a higher growth rate, and enhances the immunity of the fish. Furthermore, fish-fed pelleted feed based on	[64]

		food waste is safer for consumption, when compared to those fed commercial feed pellets.	

6. CONCLUSIONS

The utilization of restaurant waste as fish feed ingredients needs to consider the nutritional content of restaurant waste that increased through the fermentation process. Fermentation using microorganisms produces an enzyme and can change complex compounds into simpler compounds. Thus, the feed given the addition of meal from fermented restaurant waste will be easily digested and increase the growth of fishes and livestock.

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