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Systematic Literature Review (SLR): Potential of Several Plants Species as Candidates for Vegetable Protein Sources of Artificial Feed for Sustainable Fish Farming

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Abstract – — Feed is an important factor that plays a key role in the development of fish farming activities, but there are obstacles, namely quality, and cost. Vegetable protein sources derived from plants can be used in feed formulations due to their relatively low prices and sustainable availability. This study aims to summarize the results of the Systematic Literature Review (SLR) from the analysis of several studies related to the latest findings regarding the use of local plants as candidates for sources of vegetable protein in artificial feed for sustainable fish farming. This type of research is qualitative by using the Systematic Literature Review (SLR) method. These 25 plant species have promising potential as sources of vegetable protein for fish feed and have been proven to improve feed quality and fish growth. Protein is one of the nutrients that affect fish growth. Protein derived from plants is the most suitable alternative to reduce feed production costs but can improve the nutritional quality of feed.

Keywords – feed, cultivation, protein, Systematic Literature Review, plant species

I. INTRODUCTION

Aquaculture is one option for increasing and maintaining human food security and poses very important economic challenges [1,2]. In 2016, aquaculture provided around 47% of fish in the world market with Asia accounting for around 89% of global aquaculture production over the past 20 years [3]. Optimum utilization of high-quality feed ingredients rich in protein content is one of the efforts in developing aquaculture [4]. Aquaculture which is carried out intensively requires continuous availability of quality and quantity of feed [5].

Aquaculture activities supply high-quality protein feed at an affordable cost [6]. Feed is an important factor that plays a key role in the development of fish farming activities, but there are obstacles, namely quality, and cost [7]. About 60-70% of the total expenditure in commercial aquaculture activities comes from feed [8]. Fish require high-quality, nutrient-rich feed to support adequate growth in a short period of time [9]. Therefore, the progress of aquaculture development is determined by the production and use of low-cost feed ingredients that are balanced and have high nutritional content [10]. The main nutrient that must be considered in selecting ingredients for feed formulation and production is protein [11].

In aquaculture feed, protein is one of the main macronutrients to support fish growth. In addition, protein is needed by fish to form new tissue and replace damaged tissue [12,13]. One source of protein that can be utilized in feed is vegetable raw materials. Fish feeds that use all or part of vegetable raw materials have been reported to be effective and inexpensive. However, most researchers recommend using part of vegetable protein to be more effective [14,15].

Vegetable raw materials are used as a source of vegetable protein in feed formulations due to their relatively low prices and sustainable availability [16]. Alternative vegetable protein sources that can be used in fish feed formulations are derived from local plants that have not been utilized optimally. Therefore, to achieve fish feed production that is economically sustainable, and environmentally friendly, it is necessary to have the latest innovations in utilizing local plants as raw materials for fish feed. This study aims to summarize the results of the Systematic Literature Review (SLR) from the analysis of several studies related to the latest findings regarding the use of local plants as candidates for sources of vegetable protein in artificial feed for sustainable fish farming.

II. Research Methods

This study uses a type of qualitative research. The method used is a Systematic Literature Review (SLR). SLR is a method that aims to identify, review, evaluate and interpret data in journals systematically according to the steps specified [17]. In searching for and collecting data related to the topic raised regarding the study of the use of local plants as a candidate source of vegetable protein in artificial feed for sustainable fish farming by collecting all articles, using Google Scholar, Web of Science, and Publish or Perish. Data were analyzed descriptively and tabulated into tables to summarize all the data obtained. For the year, the country of each publication and the top 10 plant genera are presented in graphical form.

III. Results And Discussion

40 studies have been conducted in various countries to obtain sources of vegetable protein from several plant species. As many as 25 species from 14 plant families have the potential as sources of vegetable protein in feed formulations for various types of fish. The list of plant species used as a source of vegetable protein in artificial feed for various types of fish is shown in Table 1.

All recent studies on the potential of plants as vegetable protein feed indicate a great opportunity to develop fish farming activities, especially for the production of feed at an affordable cost. The research that has been carried out uses the Completely Randomized Design (CRD) method by conducting data analysis using SPSS software predominantly. This shows that utilizing plants in fish feed can affect the growth of various types of fish. Figure 1. shows the published data reviewed and the latest research results from 2013 – 2022. Most research on the use of plants as raw material for fish feed was carried out in 2020, while the least was done in 2014.

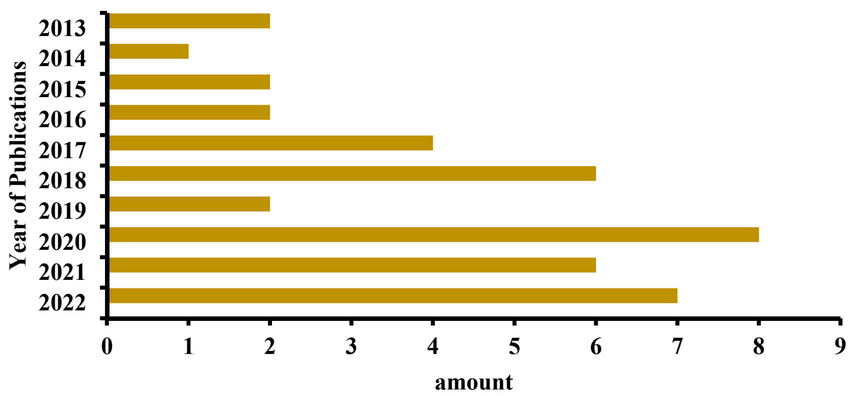

Figure 1. Number of publication data in each year

Figure 2. shows the amount of published data on the use of various plant species for each country. Most of the data is found in Indonesia, while the fewest are from Vietnam, Thailand, Italy, Iran, Egypt, Denmark, and Bangladesh. The large number of studies conducted in Indonesia is due to the large number of plant species that have the potential to be raw materials for fish feed. Indonesia is included in the Mega Biodiversity country because it is rich in biodiversity, both animals and plants that are found. As many as 25 plant species in the world have the potential as a source of vegetable protein in fish feed for sustainable fish farming.

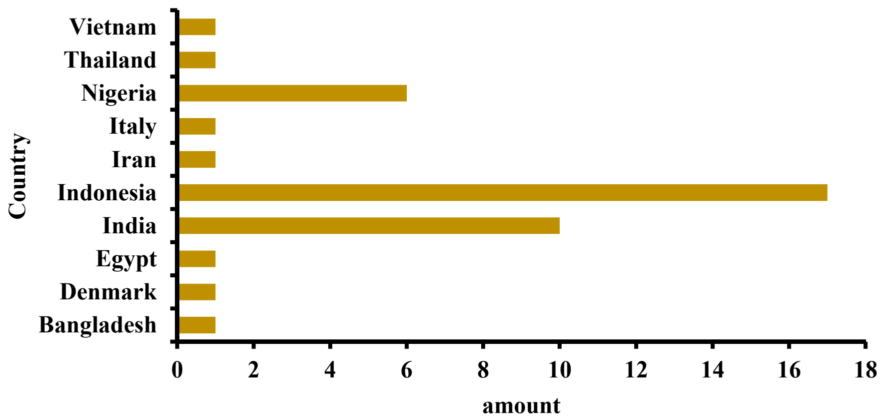

Figure 2. Number of publication data for each country

Feed is considered one of the factors to increase fish production. Therefore, the progress of the aquaculture industry and technology is determined by the manufacture and utilization of feed that is cheap and has balanced nutrition [18,19]. Feeds that contain protein, essential amino acids, fatty acids, vitamins, and minerals are generally able to increase the palatability of fish to consume the feed given [20].

Table 1. List of plant species as a source of vegetable protein feed for various types of fish

Plant Species	Fish Species	Inclusion Level (%)	Recommended Level (%)	Key Findings	References
Azolla microphylla	*Osphronemus goramy*	0; 25; 50 75; 100	25	Increase specific growth rate, absolute weight, consumption i feed and protein efficiency ratio	[21]
Azolla pinnata	*Barbonymus goniototus*	0; 25; 50; 75; 100	25	in higher farming profits	[22]
Azolla pinnata	*Labeo calbasu*	0; 10; 20 ; 30; 40	30	There is no adverse effect on digestibility and improves the nutrition and utilization of fish feed	[23]
Azolla pinnata	*Labeo fimbriatus*	0; 10; 20 ; 30; 40	40	There is no adverse effect on the growth and survival of fish	[24]
Azolla pinnata	*Cirrhinus mrigala*	0; 10; 20; 30; 40	40	Increase fish weight and survival and economic performance	[25]
Colocasia esculenta	*Oreochromis niloticus*	0; 10; 15; 20; 25	20	Improve growth performance and feed efficiency	[26]
Colocasia esculenta	*Osphronemus goramy*	0; 5; 10; 15	10	Produces maximum fish growth	[27]
Curcuma xanthorrhiza	*Osphronemus goramy*	0; 14; 16; 18; 20	14	Increase absolute weight, absolute length, feed efficiency and fish survival	[28]
Delonix regia	*Clarias*	0; 20 ; 40;	40	There was no negative effect on	[13]

	gariepinus	60; 80; 100		growth response, feed utilization and survival and was able to reduce feed production costs	
Eichhornia crassipes	*Cyprinus carpio*	0; 10; 20; 30; 40	40	Produces an optimal specific growth rate, feed conversion ratio and fish survival	[29]
Eichhornia crassipes	*Oreochromis niloticus*	0; 25; 50; 75; 100	50	Increases enzyme activity, growth performance and fish digestibility	[30]
Eichhornia crassipes	*Labeo rohita*	0; 5; 10; 15 20	15	No adverse effects on growth and nutrient digestibility	[31]
Ficus carica	*Huso huso*	0; 0.1; 0.2; 0.4	0.2	Improve growth, feed efficiency, blood factor and fish immunity	[32]
Ficus racemosa	*Osphronemus goramy*	0; 10 ; 20; 30; 40	20	Improving the physical, organoleptic and chemical quality of feed	[33]
Gracilaria tenuistipitata	*Oreochromis niloticus*	100; 80; 60; 40; 20; 0	80	Increase growth, reduce feed costs and maintain water quality	[34]
Ipomoea aquatica	*Laboe rohita*	0; 30; 40; 50	40	Improve performance of specific growth rate, survival and feed utilization	[35]
Lemna gibba	*Clarias gariepinus*	0; 10; 20; 30	30	Resulting in increased fish weight and length, feed conversion ratio, protein efficiency ratio and better survival	[36]
Lemma minor	*Oncorhynchus mykiss*	0; 10; 20; 28	20	There is no negative effect on fish growth	[37]
Lemma minor	*Cyprinus carpio*	0; 5; 10; 15; 20	20	Increase the growth, survival and nutritional value of carp including EPA and DHA	[38]
Lemna sp.	*Oreochromis niloticus*	0; 25; 50; 75; 100	25	Increase the growth rate and immunity of fish	[39]
Leucaena glauca	*Oreochromis niloticus*	0; 5; 10; 15	10	Increase the growth rate of fish	[40]
Leucaena leucocephala	*Osphronemus goramy*	0; 10; 15; 20	15	Increase protein content and decrease crude fiber, resulting in optimal feed conversion ratio and fish survival	[41]
Leucaena leucocephala	*Osphronemus goramy*	0; 20; 40; 60; 80	40	Feed conversion ratio, protein efficiency ratio and survival showed better performance	[42]

Leucaena leucocephala	*Clarias gariepinus*	0; 10; 20; 30; 40; 50	20	Increase the growth and protein content of fish	[43]
Leucaena leucocephala	*Tilapia zillii*	0; 2.5; 5; 7.5; 10	7,5	Improve performance-specific growth rate and feed conversion ratio	[44]
Leucaena leucocephala	*Clarias gariepinus*	0; 25; 50; 75; 100	0	Produce optimal fish growth performance and feed production costs	[45]
Manihot utilisima	*Osphronemus goramy*	0; 5; 10; 15; 20	20	Improve feed digestibility, feed efficiency, protein retention, survival and specific growth rate	[46]
Manihot utilisima	*Cyprinus carpio*	0; 10; 15; 20; 25	10	Improve absolute weight, daily weight and feed conversion ratio	[47]
Moringa oleifera	*Colossoma macropomum*	0; 10; 20; 30; 40	20	Provides influence on feed efficiency, protein retention and specific growth rate	[48]
Moringa oleifera	*Osphronemus goramy*	0; 2; 4; 6	4	Improve fish growth performance	[49[
Morus indica	*Labeo rohita*	0; 25 ; 50; 75	50	Increasing amylase enzyme activity, carbohydrate utilization and fish growth	[50]
Musaceaea sp.	*Pangasius hypophthalmus*	0; 5; 10; 15; 20	20	There is no negative effect on fish growth	[51]
Nelumbo nucifera	*Clarias gariepinus*	0; 0.1; 0.5; 1	0.1	Growth enhancement, gut morphology and feed utilization	[52]
Nymphaea sp.	*Cyprinus carpio*	0; 30; 40; 50	40	Increase weight, specific growth rate, feed conversion ratio, protein efficiency ratio and fish survival	[53]
Pistia sp.	*Labeo rohita*	0; 10; 20; 30	20	The highest weight, specific growth rate, feed conversion ratio and protein efficiency ratio	[54]
Pistia stratiotes	*Oreochromis sp.*	0; 10; 20; 30	0	Improve the nutritional quality of feed	[55]
Pistia stratiotes	*Clarias gariepinus*	0; 25; 50; 75; 100	50	Feed utilization efficiency, feed conversion ratio, protein efficiency ratio and survival are better	[56]
Pistia stratiotes	*Labeo rohita*	0; 10; 20; 30; 40; 50	30	Highest absolute weight and specific growth rate and lowest feed conversion ratio	[57]
Salvinia molesta	*Oreochromis*	0; 10; 20 ;	10	Increase growth, feed efficiency	[58]

	niloticus	30; 40		and survival of fish	
Zingiber officinale	*Osphronemus goramy*	0; 75; 50; 25	75	Improves weight and length growth, feed conversion ratio and feed efficiency	[59]

Various species of *Azolla* have been used as fish feed ingredients including *Azolla microphylla* . Giving *A. microphylla* fermented flour as much as 25% in the feed resulted in a feed conversion ratio value of 1.00, a protein efficiency ratio of 6.39% and a specific growth rate of *O. goramy fish* of 0.52% [21]. *A. microphylla* flour is used as a substitute raw material for fish meal which has a protein content of 19.54% - 31.25% [60,61].

In addition, *A. pinnata* has also been used as a source of vegetable protein for fish feed. Among them for *B. ganiototus* fish feed, using *A. pinnata* can reduce feed production costs [22]. The nutritional content of *L. calbasu* fish feed has increased and reduced feed costs [23]. The use of *A. pinnata was* able to influence the digestive enzyme activity of *L. fimbriatus* fish [24] and can be used as raw material to be considered for low-cost feed formulations for *C. mrigala* fish [25]. Different results were obtained from the research that had been done because the fish species used had different eating habits. Therefore, the *Azolla* plant can be used as a source of vegetable protein for fish feed because it contains protein, vitamins and minerals which are good for fish growth.

C. esculenta leaves as a substitute for soybean meal in feed formulations affects the growth and efficiency of *O. niloticus* fish [26] and *O.* goramy fish [27]. The value of the feed conversion ratio, protein efficiency ratio and energy retention increased significantly with the addition of *C.* esculenta leaves in the feed [26]. The addition of *C. xanthorriza* extract in artificial feed can increase weight, absolute length of feed efficiency and survival of *O. goramy* fish [28]. Substitution of groundnut meal with *D. regia* leaf meal as an alternative protein source showed a response to growth, feed utilization and survival of *C. gariepinus* fish. This leaf meal has considerable potential in reducing fish feed production costs so that it can produce maximum aquaculture benefits [13].

Eichhornia crassipes, is a vascular plant and is known as one of the vicious weeds because its biomass increases rapidly and can to consume large amounts of oxygen and nutrients [62,63]. The use of *E. crassipes* in feed has an influence on the growth rate of *C. carpio* fish [29], enzyme activity and digestibility of *O. niloticus* fish [30] and *L. rohita* fish [31]. *Ficus* is an Angiosperm plant and is a member of the Moraceae family and is widely distributed in tropical and subtropical regions [64]. Various species of *Ficus* have been widely used in fish feed formulations, including *F. carica* and *F. racemosa*. *F. carica* extract can improve hematological parameters and stimulate immune response as well as increase the growth performance of *H. huso* fish [32]. The use of *F. racemosa* fruit powder as a substitute for soybean meal can improve the physical, organoleptic and chemical quality of *O. goramy* fish feed [33].

Using *G. tenuistipitata* in feed formulations as much as 80% can help maintain better water quality and reduce feed costs without affecting the growth of *O. niloticus* fish [34]. Ipomoea aquatica is a plant belonging to the Convolvulaceae family which grows vines [65]. Fermented *I. aquatica* leaf meal in feed has the potential to increase the growth of *L. rohita* fish [35]. *Lemna* plants can be used as a source of vegetable protein in feed because they are rich in essential amino acids [66]. *L. gibba* formulated in feed can produce better weight and length gain, feed conversion ratio, protein efficiency ratio and better *C. gariepinus* survival [36]. *L. minor* as much as 20% can increase the growth of *O. mykiss* fish [37] and the survival and nutritional value of fish *C. carpio* [38]. Administration of *Lemna sp.* Fresh as much as 20% in the feed resulted in an absolute weight growth rate of 11.2 g, feed efficiency of 21.33% and water quality was still in the safe range for the maintenance of *O. niloticus* fish [39].

Leucaena is a plant that is commonly found in various regions, especially Indonesia and has many benefits [67]. Fermentation of 15%. *L. leucocephala* leaves can increase protein content and decrease crude fiber content and produce better daily growth rates, feed conversion ratios and survival of *O. goramy* [41]. The addition of fermented *L. glauca* leaf meal in artificial feed by as much as 10% increased growth, feed utilization efficiency, protein efficiency ratio and better survival of *O. niloticus* fish. The protein content found in *L. glauca* leaf flour is 31.82% and 34.14 % crude fiber [40]. The use of L. leucocephala leaf meal in feed showed better performance of specific growth rate, weight gain and feed conversion ratio of *T. zillii* fish. The protein content of fresh leaves is 29.20% and 19.20% crude fiber [44]. Utilization of *L. leucocephala* flour showed increased growth and nutritional value of *C. gariepinus* fish [43]. The addition of 40% *L. leucocephala* seed fermentation showed better growth and protein content of *O. goramy* fish. The average protein content of gouramy ranges from 17.27% - 18.81% [42] . *Leucaena* is the most common genus obtained from the results of review articles, namely 6 studies. Figure 3 shows the 10 most common plant genera that are used as a source of vegetable protein in feed for various types of fish.

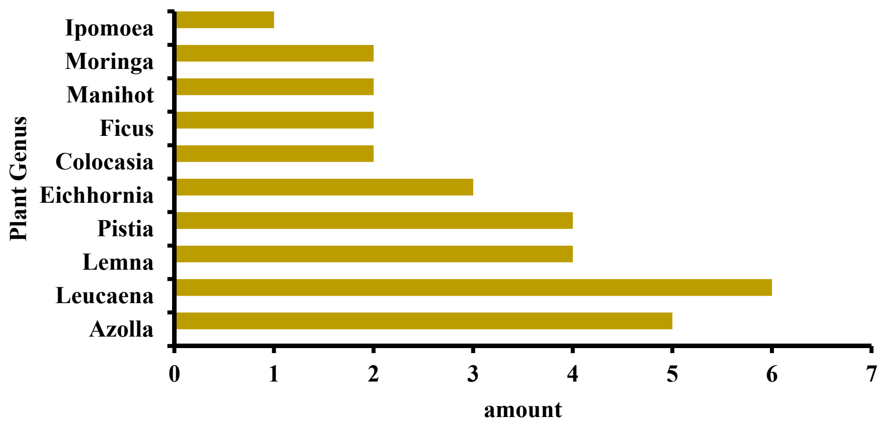

Figure 3. The 10 most common plant genera used in fish feed

Manihot utilisima is a local plant that is abundantly available in tropical environments and has been used as raw material for fish feed. The leaves contain 23.42% protein, 15.80% crude fiber, 6.31% fat, calcium, phosphorus and iron [68]. The use of fermented *M. utilisima* leaf meal in feed as much as 20% gave the best results on feed digestibility, feed efficiency, protein retention, specific growth rate and survival of *O. goramy* fish [46]. Then *M. utilisima* leaf meal can increase growth, feed conversion ratio and survival of *C. carpio* fish [47].

M. oleifera leaf meal has the potential to be a source of vegetable protein in *O. gourami* fish feed in increasing growth performance, feed conversion ratio and protein retention. The availability of *M. oleifera* leaves is quite abundant and available throughout the year, so that it can be considered for use as a raw material in relatively inexpensive fish feed formulations. The nutritional content contained in Moringa leaves is 21.49% protein, 6.29% fat, 9.88% crude fiber, 43.94% carbohydrates, 6.50% moisture content and 11.78% ash content [48]. Fermented *M. oelifera* leaf meal can reduce the use of soy flour in *C. macropomum* fish feed. The results of this study showed the best results for increasing the value of feed efficiency, protein retention, specific growth rate and fish survival [49].

Utilization of *M. indica* leaf meal in feed formulation can increase amylase enzyme activity, carbohydrate utilization and growth of *L. rohita* fish. *M. indica* leaf powder contains 26.25% protein, 1.50% crude fat and 7.32% crude fiber [50]. *Musaceae sp* . is one type of tropical plant which is very much produced in the world in general, Indonesia in particular. Banana peel can be used as raw material for feed because it contains 7.26% protein, 15.29% fat and 24.13% crude fiber [69]. Commercial feed substitution with the fermentation of *Musaceaea sp.* as much as 20% results in feed consumption rate, specific growth rate, feed efficiency, fat retention and energy retention of *P. Hypophthalmus* fish [51]. *N. nucifera* in artificial feed can increase growth, intestinal morphology and utilization of *C. gariepinus* fish feed. The use of *N. nucifera* has the potential as a natural feed additive in the aquaculture industry to enrich vegetable protein feed [52]. *Nymphaea sp.* leaf meal. as much as 40% can be used as a protein source in feed which can produce maximum specific growth rates, feed conversion ratios, protein efficiency ratios and fish survival [53].

Pistia, commonly known as watercress, is a highly productive aquatic invasive species. *Pistia* is rich in organic and mineral content, so it is considered as a potential alternative ingredient in fish feed [70]. *Pistia sp.* used in feed produced the highest weight, specific growth rate, feed conversion ratio and protein efficiency ratio in *L. rohita fish* [54]. Utilization of *P. stratiotes* leaves formulated in feed can improve the nutritional quality of feed and produce optimal growth, protein efficiency ratio, feed conversion ratio and survival of C. gariepinus fish [56]. Substitution of fish meal with *P. stratiotes* meal as much as 30% showed optimal growth in *L. rohita* fish and increased the nutritional quality of the feed [57]. Fermentation of *P. stratiotes* flour in feed produces good nutritional quality of feed for *Oreochromis sp.* [55]. Feed derived from weeds and invasive plants will be cheaper than conventional feed, because the abundant amounts in nature only require collection and processing costs.

Salvinia molesta is a plant that grows fast and is widely available in nature, and has quite good nutrition, namely 15.9% crude protein, 2.1% crude fat, 16.8% crude fiber, calcium and phosphorus. The use of fermented *S. molesta* flour can increase the growth, feed efficiency and survival of *O. niloticus* fish [58]. *Zingiber officinale* flour can increase growth, weight and length gain, feed conversion ratio and feed efficiency for *O. goramy* fish. This shows that feed with the addition of *Z. oficinale* can be used in fish hatcheries and aquaculture using the biofloc system [59]. The use of alternative plants as a source of vegetable protein in fish farming is quite promising and can increase sustainable aquaculture industry activities.

IV. Conclusion

Various studies on the use of 25 plant species as potential candidates for vegetable protein sources in artificial feeds have been carried out for the growth of several cultivated fish species. These 25 plant species have promising potential as sources of vegetable protein for fish feed and have been shown to improve feed quality as well as fish growth and survival . Protein is one of the nutrients that affect fish growth, especially vegetable protein for herbivorous and omnivorous fish. Protein derived from plants is the most suitable alternative to reduce feed production costs, but can improve the nutritional quality of feed. Feed is a very important factor in sustainable fish farming activities.

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