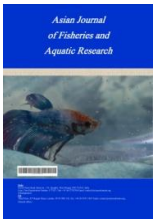

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Utilization of Water Hyacinth (*Eichhornia crassipes*) as Fish Feed Ingredient

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Authors' contributions

This work was carried out in collaboration between both authors. Author DYP writing draft article and finding materials. Author AA editing and proffreading article. Both authors read and approved the final manuscript.

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ABSTRACT

A freshwater plant, water hyacinth (*Eichhornia crassipes*) is commonly found in public waters in Indonesia. Water hyacinth often experiences blooming which causes negative impacts such as lowering oxygen levels, reducing the number of fish, increasing evapotranspiration, disrupting transportation, becoming habitat for disease vectors, and others. However, water hyacinth can be used as an alternative raw material because it still contains nutrients such as carbohydrates, proteins, fats, vitamins, and minerals. Water hyacinth also has potential as an antibacterial agent because it contains secondary metabolites (alkaloids, saponins, steroid compounds, flavonoids, phenolic compounds, glycosides, and cardiac glycosides). The utilization of water hyacinth as fish feed ingredient has been shown to give positive effect on the growth of African catfish (*Clarias gariepinus*), grass carp (*Ctenopharyngodon idella*), goldfish (*Cyprinus carpio*), and Tilapia (*Oreochromis niloticus*) seeds. The use of water hyacinth as an alternative fish feed ingredient can be a solution to reduce production costs and reduce the impact of water hyacinth blooms.

Keywords: Water hyacinth; proximate analysis; secondary metabolites, fish feed.

1. INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is an aquatic plant that can be found in rivers, lakes, or ponds. This plant can grow in a variety of aquatic environmental conditions. However, optimal environmental conditions for the growth of water

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hyacinth are shallow waters, cloudy waters, temperature ranges of 28-30ºC and pH ranges of 6-8 [1]. Water hyacinth does not tolerate salinity above 1.6% [1]. In an environment rich in nutrients, especially Nitrogen (N) and Phosphorus (P), water hyacinth can grow rapidly, causing water hyacinth blooms. The relative growth rate of water hyacinth (RGR) can reach 7.26%/day [2].

Some areas in Indonesia that experience water hyacinth blooms include Rawa Pening in Banyubiru Village, Semarang Regency [3], Limboto Lake, Limboto District, Gorontalo [4] and Cirata Reservoir, West Java [5]. In 2016, 47% of the area of Rawa Pening was covered by water hyacinth [6] and currently, the area of water hyacinth in Rawa Pening is 70% [2]. Water hyacinth in Lake Limboto grows widely with a distribution reaching about 30% of the lake area [7]. Likewise, the Cirata reservoir is about 40-50% covered by water hyacinth [4]. This plant has been identified as one of the 100 most aggressive invasive species by The International Union for Conservation of Nature (IUCN) [8].

Water hyacinth bloom causes many losses, including silting of water bodies [6], lack of dissolved oxygen, decreased productivity of phytoplankton [9], reduced biodiversity, reduced number of fish, increased evapotranspiration [2], obstruction of water flow, transportation, reduced aesthetics [4], and can become a microhabitat for vectors of various diseases and pests [10].

However, this plant still has a lot of potential that can be utilized by humans. One of the potentials of water hyacinth is as fish feed because it contains various nutrients such as proteins, lipids, carbohydrates, vitamins and secondary metabolites. Feed is an important component in the success of fish farming because the growth rate of fish is influenced by the nutritional content of the feed. In addition, about 60% of production costs are dependent on feed costs [11].

Certain feed ingredients have a high enough price to add to the total cost of aquaculture. The existence of alternative feed ingredients at lower prices is needed for the success of aquaculture. Fish feed that utilizes local raw materials can save aquaculture production costs by 25-35% [11]. Therefore, the use of water hyacinth as a fish feed ingredient is expected to be a solution to water hyacinth blooms in various regions and also a solution on the need for cheap feed ingredients.

This review article aims to describe the nutritional content of water hyacinth, antibacterial potential and potential of water hyacinth as feed for several types of fish.

2. CHEMICAL COMPOSITION OF WATER HYACINTH (*Eichhornia crassipes*)

Water hyacinth contains various nutrients such as proteins, carbohydrates, lipids, minerals, vitamins and secondary metabolites [12]. The value of proximate analysis of water hyacinth can be seen in Table 1. The crude protein content in water hyacinth ranges from 3.3-56.38%. Its lipid content ranges from 0.65-10.21%. The fiber content ranges from 1.02 to 21.42% and the carbohydrate content ranges from 33.49 to 58.2%. The nutrient content is different for each part of the plant. The differences in nutrient content may also influence by habitat and season. Protein content can increase in winter and decrease in summer [13]. Proteins, lipids, and carbohydrates play an important role in obtaining energy for fish activity and growth. The protein and carbohydrate content in water hyacinth is high enough that it can be used as an alternative raw material to replace commercial fish feed raw materials. This plant also contains various kinds of amino acids (Table 2), fatty acids (Table 3), vitamins and minerals (Table 4).

3. ANTIBACTERIAL POTENTIAL OF WATER HYACINTH (*Eichhornia crassipes*)

Water hyacinth (*E. crassipes*) contains many secondary metabolites. Hossain et.al [24] reported that the ethanol extract of water hyacinth leaves and stems contained alkaloids, saponins, steroidal compounds, flavonoids, phenolic compounds, glycosides, and cardiac glycosides. In addition, Kiristos et.al [25] also found tannins and terpenoids in the ethanol extract and methanol extract of water hyacinth leaves. Phenolic compounds contained in water hyacinth include Quercetin, and Gallic acid [26], catechol, pyrogallol, vanillic, salicylic acids, syringic, resorcinol, and others [27]. Flavonoids contained in water hyacinth include apigenin, tricin, chrysoeiol, azaeleatin, gossypetin, luteolin, kaempferol, orientin, isovitexin, and others. Terpenoids contained include phytol, indole compounds and gibberellins, carotene [27]. Lata and Dubey [28] have identified 6 alkaloids in

water hyacinth, namely cytisine, nicotine, tomatine, codeine, thebaine, and quinine.

Several studies have proven that these metabolites can act as antibacterial. The mechanism of action for each metabolite as an antibacterial agnet is different. Alkaloids can act as antibacterial with various mechanisms, namely inhibiting bacterial cell division, respiratory inhibition and enzyme inhibition in bacteria, bacterial membrane disruption, affecting virulence genes [29]. The mechanism of action of flavonoids as antibacterial is thought to be by damaging the bacterial cell wall, because alkaloids can form complex compounds with extracellular and soluble proteins. Flavonoids are also thought to be able to damage the cell wall by creating pores in the cell wall [29]. Tannins can act as antibacterial allegedly through various ways, namely by inhibiting bacterial extracellular enzymes, inhibiting oxidative phosphorylation thereby inhibiting bacterial growth, and deprivation of the substrates required for microbial growth [30].The proposed mechanism of action for terpenoids, among others, is by inhibiting the synthesis of proteins, nucleic acids, components of bacterial cell walls, and inhibiting bacterial DNA replication and inhibiting metabolic pathways [31].

With various secondary metabolite contents, water hyacinth has the potential to be used as antimicrobials that fight various disease-causing pathogens in shrimp and other pathogenic bacteria. Ethyl acetate extract of water hyacinth leaves and stems has been shown to inhibit growth of *Staphylococcus aureus,* and *Salmonella typhi* [24]. Water hyacinth leaf extract can inhibit the growth of *Bacillus cereus* (mtcc 6840), *Streptococcus mutans* (mtcc 497), *Proteus vulgaris* (mtcc 7299), *Salmonella typhi* (mtcc 3917), *Bordetella bronchiseptica* (mtcc 6838) [32]. The ethanol extract of water hyacinth leaves can inhibit the growth of *Bacillus subtilis*, *Staphylococcus epidermidis* and *Escherichia coli* [33]. While the n-butyl alcohol extract of water hyacinth leaves has antibacterial activity against *Escherichia coli, Bacillus subtilis, Bacillus cereus, Lactobacillus casei* and *Pseudomonas aeruginosa* [34].

The ethanol and methanol extracts of water hyacinth leaves are also known to have antibacterial activity against *Vibrio harveyi* which causes vibrosis in shrimp [26]. Water and ethanol extracts of stolon and water hyacinth lamina also inhibit the growth of *Aeromonas hydrophila* which causes motile *Aeromonas septicemia* [35]. Table 5 shows the zones of inhibition of water hyacinth against various bacteria.

4. THE UTILIZATION OF WATER HYACINTH (*Eichhornia crassipes*) AS FISH FEED INGREDIENT

Several studies have been proven that water hyacinth can be added to fish feed and has a positive effect on growth. Provision of water hyacinth plant meal and water hyacinth leaf meal was also proven to increase the growth of African catfish (*Clarias gariepinus*) with a weight gain value of 14.79 g for fish fed of water hyacinth plant meal, and 19.13 g for fish fed made of water hyacinth leaf meal [19].

Table 1. Water Hyacinth Proximate Analysis (% dry weight)

Part of Plant	Crude Lipid	Carbohydrate	Crude Protein	Crude Fiber	Ash	Reference
Leaf	4.11	33.61	56.38	1.02	4.88	[12]
Leaf	2.20	49.98	8.20	21.42	18.20	[14]
Whole plant	2.5	58.2	12.52	4.5	15.37	[15]
Leaf	10..21	33.49	49.52	1.15	5.63	[16]
Root	-	-	9.60	19.08	20.95	[17]
Leaf	-	-	20.13	18.61	15.60	[17]
Leaf	1.93	-	21.97	-	13.10	[18]
Root	0.65	-	3.33	-	50.11	[18]
stem	0.98	-	7.70	-	21.20	[18]
Leaf	4.70	-	28.20	14.79	7.03	[19]
Whole plant	2.37	-	24.17	19.62	11.35	[19]
Leaf	1.56	-	15.27	15.23	16.79	[20]
Root	1.24	-	6.67	12.15	39.80	[20]
Whole plant	1.31	-	7.11	16.90	24.68	[20]

Table 2. Amino acid content in water hyacinth leaves (dry weight)

Amino acids	Concentration (mg/g)	Concentration (g/100g)	Concentration (% crude protein)
Aspartic acid	31.1	4.96	10.21
Asparagine	22.3	-	-
Glutamine	2.23	-	-
Glycine	2.5	3.00	6.51
Tyrosine	3.72	2.20	2.92
Leucine	11	5.01	9.56
Valine	110	2.81	7.46
Phenylalanine	5.93	3.67	6.01
Threonine	3.68	2.60	5.27
Proline	90.5	2.72	5.62
Glutamic acid	2.2	6.04	7.31
Cystine	1.63	0.72	0.38
Arginine	-	3.80	6.58
Histidine	-	1.10	2.22
Isoleucine	-	2.29	5.47
Lysine	-	3.72	5.06
Methionine	-	1.34	1.31
Tryptophan	-	-	1.42
Alanine	-	3.20	6.49
serine	-	2.52	10.21
Reference	**[15]**	**[12]**	**[21]**

Table 3. Fatty acid content in water hyacinth (dry weight)

Fatty acid	Concentration [17]
Suberic acid	0.30±0.02
Myristic acid	1.34±0.23
Palmitic acid	16.59±2.44
Margaric acid	3.24±0.18
Petroselinic acid	3.25 ± 0.21
Linoleic acid	5.28±0.35
Linolenic acid	7.34 ± 1.02

Table 4. Mineral content of water hyacinth (dry weight)

Mineral	Concentration mg/100g [14]	Concentration % [22]	Concentration % [23]
Ca	3.25	3.08	2.29
Mg	1.35	0.65	-
Na	2.69	-	-
K	0.47	4.13	2.44
P	0.98	0.28	0.53
Zn	1.56	-	-
FE	0.56	-	-

Provision of water hyacinth plant meal and water hyacinth leaf meal was also proven to increase the growth of grass carp (*Ctenopharyngodon idella*) fingerlings with a weight gain value of 6.871 g for fish fed water hyacinth plant meal, and 7.136 g for fish fed water hyacinth leaf meal. While the weight gain of fish that were not given water hyacinth was 5.806 g [36]. Mukti and Oktaviani (2020) [37] conducted another study by giving 25% water hyacinth to catfish. The absolute growth of catfish fed water hyacinth was 2.78 g while the control was 2.46 g. This shows that the administration of water hyacinth can increase the growth of various types of fish compared to control.

Table 5. Zone of inhibition of water hyacinth against various bacteria

Part of plant	Solvent	Bacteria	Inhibition zone (mm)	Reference
Leaf	Etil acetate	*Salmonella typhi*	8.00	[24]
stem	Etil acetate	*Salmonella typhi*	7.83	[24]
stem	Etil acetate	*Staphylococcus aureus*	7.67	[24]
Leaf	Aqueous	*Bacillus cereus* (mtcc 6840),	8	[32]
Leaf	Aqueous	*Streptococcus mutans* (mtcc 497	10	[32]
Leaf	Aqueous	*Proteus vulgaris* (mtcc 7299),	20	[32]
Leaf	Aqueous	*Salmonella typhi* (mtcc 3917)	22	[32]
Leaf	Aqueous	*Bordetella bronchiseptica* (mtcc 6838)	8	[32]
Leaf	Ethanol	*Bacillus subtilis*	11	[33]
Leaf	Ethanol	*Staphylococcus epidermidis,*	12	[33]
Leaf	Ethanol	*Escherichia coli*	15	[33]
Leaf	n-butyl alcohol	*Escherichia coli*	22.4	[34]
Leaf	n-butyl alcohol	*Bacillus subtilis*	23.8	[34]
Leaf	n-butyl alcohol	*Bacillus cereus*	17.7	[34]
Leaf	n-butyl alcohol	*Lactobacillus casei*	11.3	[34]
Leaf	n-butyl alcohol	*Pseudomonas aeruginosa*	15.3	[34]
Stolon and lamina	Aqueous	*Aeromonas hydrophila*	9.33	[35]
Stolon and lamina	ethanol	*Aeromonas hydrophila*	11.33	[35]

However, different results were obtained on the growth performance of Nile Tilapia on supplementation with different proportions of water hyacinth. The weight gain of tilapia fed water hyacinth was lower than the control although statistically not significantly different. The final weight values of 8.52±1.96 g for fish fed 15%, 8.45 ±1.94 g for fish fed 30%, 8.30 ±1.84 g for fish fed 45% water hyacinth and 8.68 ±1.85 g for fish fed control diet without water hyacinth [38].

Suplementation of water hyacinth to the feed of common carp fry (*Cyprinus carpio*) can also increase the growth of fish, but the value is slightly lower than the control. The weight gain of fish fed control diet was 3.76 g, while 3.57 g for fish fed an additional 10% water hyacinth, 3.55 g for fish fed 20% water hyacinth, 3.31 g for fish fed 30% water hyacinth and 3.08 g for fish fed 40% water hyacinth. However, the survival rate of fish given water hyacinth was better than the control [39]. However, water hyacinth can still be used as a feed additive to reduce the cost without affecting growth rate. With the use of water hyacinth as a feed ingredient, it is hoped that it will help to reduce the cost of fish farming production [19] and can reduce water hyacinth blooms.

5. CONCLUSION

Water hyacinth (*Eichhornia crassipes*) can be used as an alternative raw material for fish feed because it has a high protein content. Fish growth and survival rate have increased. Water hyacinth also has secondary metabolites as antibacterial.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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