Water hyacinth (Eichhornia crassipes)

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Common names

Water hyacinth, common water hyacinth, "million dollar weed" [English]; camalote, flor de bora, jacinto de agua común [Spanish]; aguapé, jacinto-de-água, aguapé de flor roxa, jacinto-aquático, orquídea d'agua, rainha dos lagos [Portuguese]; mururê [Portuguese/Brazil]; jacinthe d'eau, camalote [French]; waterhyacint [Dutch]; Dickstielige Wasserhyazinthe [German]; eceng gondok, enceng gondok [Indonesian]; giacinto d'acqua [Italian]; lục bình, bèo lục lình, bèo tây, bèo nhật bản, phù bình [Vietnamese]; 凤眼蓝 [Chinese]; [Hindi]; ホテイアオイ [Japanese]; 부레옥잠 [Korean]; [Malayalam]; سنبل آبی [Persian]; водяно́й гиаци́нт [Russian]; ผักตบชวา [Thai]

Species

Eichhornia crassipes (Mart.) Solms [Pontederiaceae]

Synonyms

Eichhornia speciosa Kunth, *Pontederia crassipes* Mart.

Feed categories

- Aquatic plants
- Other forage plants
- Forage plants

Related feed(s)

Description

The water hyacinth (*Eichhornia crassipes* (Mart.) Solms) is a free floating perennial herb of fresh water ecosystems. It is found at the surface of rivers, lakes, canals and ponds and may root in the mud of shallow waters. It is generally 10-20 cm high but can reach 1 m high when established in dense mats (Ecoport, 2011; Pieterse, 1997). Water hyacinth is a rhizomatous and stoloniferous plant with long, pendant and adventitious roots. The leaves arise from the rhizome nodes and stand above the water. They are dark green, ovate and cordate at the base, borne on swollen bladder-like petioles (Pieterse, 1997). The plant has considerable buoyancy and the leaves act as sails in the wind (Hasan et al., 2009a). The inflorescence bears 8-10 pale violet or blue lily-like flowers. The fruit is a dehiscent capsule containing up to 200 small seeds (Ecoport, 2011; Pieterse, 1997).

Water hyacinth is one of the most noxious weeds in tropical and subtropical regions, and many attempts have been made to eliminate or control it (see **Environmental impact** below). Harnessing its considerable productivity is considered as a sustainable and possibly less expensive method of control. Water hyacinth can be used as a vegetable, fodder, green manure, compost and mulch for soil improvement. Much research has been devoted to its use as a feed material for many classes of livestock. In South-East Asia, integrated fish-pig-water hyacinth farming systems have been developed in order to increase global animal production: water hyacinths grown in fish ponds have higher nutritive value (higher protein content) and can be fed to fish and pigs in different forms. Fish and pig manures fertilize fish ponds and provide nutrients to water hyacinth (Yang Huazhu et al., 2001). Animals are usually fed the aerial part (leaves and stems without the roots) or only the leaves, but sometimes the whole plant (root included) is used. Water haycinth can be fed fresh, ensiled or dried but many other processes are used or have been tried, including cooking and fermentation (see **Processes** below).

Other products and services derived from water hyacinth have been investigated, including as a source of pigments for poulty nutrition (Lareo et al., 1982), and leaf protein concentrates for food and feed (Abo Bakr et al., 1984; Wu Wenbiao et al., 2011). Water hyacinth is used for making textiles, paper and for camouflaging fish traps (Ecoport, 2011; Pieterse, 1997). It ferments rapidly due to its high water content and can supply biomass for biogas production. Water hyacinth is used as a water-clearing agent, as a substrate for mushroom production and as an ornamental species (Pieterse, 1997).

***Note**: the term "whole plant" used in the scientific literature is sometimes confusing. For an aquatic plant, it can designate either the whole plant including the roots or the whole aerial part.*

Distribution

Water hyacinth originated from Amazonia and spread naturally throughout South America. It was introduced as an ornamental species into the USA, South East Asia and South Africa in the late 19th century and is now naturalized in most tropical and subtropical areas. It can be found between 38°N and 38°S and is referred to as a noxious weed in more than 50 countries on five continents (GISD, 2011).

Water hyacinth thrives in a wide range of fresh water habitats (shallow ponds, marshes, small streams, lakes and rivers) provided they are not saline or do not become saline during drought. The most favourable conditions are average temperatures ranging from 14 to 29°C, water pH about 7, low salinity, N, P, K-rich water, full sunlight and absence of physical disturbance or pests. Under such conditions, water hyacinth readily establishes and forms dense mats due to its efficient vegetative reproduction. The plant cover can double within 6-15 days (Ecocrop, 2011; Hasan et al., 2009a). The growth of water hyacinth is hampered by low temperatures (below 13°C), nutrient scarcity, frost and salinity. It has a low tolerance of flooding, as the physical disturbance caused by the waves breaks the mat and leaves of the plant stranded on the land. Drought and frost also quickly kill the stand (Hasan et al., 2009b).

Processes

Water hyacinth can be used fresh, ensiled, dried, whole, chopped or ground. Roots are usually discarded.

Fresh forage

Water hyacinth is usually chopped and fed directly to animals. However, it is not very palatable due to the presence of oxalate crystals in the leaves that cause mouth irritation in livestock (see **Potential constraints** on the "Nutritional aspects" tab).

Dried and meal form

The physical structure of the plant makes it unsuitable for the normal methods of making hay and silage. The plants dry rather quickly in the sun, but the neck between the petiole and the lamina is very brittle. The lamina shrinks and breaks off with handling, leaving only the petiole which remains round and full of air. The hay is therefore very bulky. Water hyacinth foliage is often sun-dried, typically for between 2 and 5 days but up to 10 days depending on environmental conditions (Hasan et al., 2009a; Dada, 2002; Biobaku et al., 1991). The process may involve numerous manipulations (Biobaku et al., 1991). The nutritive value per unit of dry matter is too low to warrant the cost of artificial drying (Göhl, 1982). Dried water hyacinth can be ground in a hammermill and turned into a meal, for instance for pigs (Domínguez et al., 1996).

Silage

Ensiling is a good method of perservation for water hyacinth and enhances its palatability. Because of the high moisture content of water hyacinth, it should be wilted in the shade for 48 hours and lacerated or screw-pressed before ensiling (Göhl, 1982). The silage can be mixed with carbohydrate sources such as molasses (up to 20%), dried citrus pulp or maize grain (Nguyen Thanh Van et al., 2010; Bagnall et al., 1974; Aboud et al., 2005). Salt and urea are reported to increase the nutritive value and quality of the silage (Göhl, 1982). For instance, water hyacinth wilted and ensiled with 15% defatted rice bran (25% final DM) or rice bran (22% final DM) was well preserved (Lowilai et al., 1995). Water hyacinth leaves added at between 20 and 35% to a silage based on rice straw, urea, molasses and soybean meal gave a good quality product (Malek et al., 2008). Prior wilting is preferable but even pre-wilted silage may be unsuitable (Aboud et al., 2005). Adding acids gave satisfactory quality silage (Byron et al., 1975). A method for ensiling water hyacinth with by-products (rice straw, chopped sugarcane and molasses), enzymes and lactic acid bacteria has been patented (Simsa et al., 1994).

Cooking

In South-East Asia, the plants are often chopped and mixed with by-products such as banana stems, rice bran, copra meal or fish meal and then boiled to make a suitable feed for pigs, ducks or pond fish (Jafari, 2010). A "recipe" for water hyacinth-based pig diets has been described as follows: a mixture of water hyacinth and banana stems is boiled slowly for a few hours until the ingredients turn into a paste, to which oil cake, rice bran and sometimes maize and salt are added. The cooked mixture is good for only three days, after which it turns sour. A common formula is 40 kg of water hyacinth, 15 kg of rice bran, 2.5 kg of fish meal and 5 kg of coconut meal (Göhl, 1982).

Forage management

Water hyacinth can be exceptionally productive under favourable conditions. In China, ponds fertilized with sewage nutrients yielded up to 657 t fresh matter/ha/year (Hasan et al., 2009a). In Tanzania, yields of 322 t fresh matter/ha/year (30.5 t DM) have been recorded (Aboud et al., 2005). However, such extreme yields may not be sustainable on a large scale and a production of 200 t/ha/year is a more realistic goal in eutrophic waters in the tropics (Hasan et al., 2009a).

Environmental impact

Invasive species

Water hyacinth is a major environmental concern in many countries. It quickly invades large water areas, due to a high rate of vegetative propagation, and forms dense mats that obstruct waterways. It affects all water-based economic activities, including fishing, irrigation, traffic, water quality, hydraulic and hydroelectric infrastructures (Ecoport, 2011; Practical action, 2006; Hasan et al., 2009b). Water hyacinth was already causing concern in 1908 in Vietnam, Laos and Cambodia (Pieterse, 1997). In China, where it was introduced as fodder in the 1950s to solve feed shortage, water hyacinth became problematic in the 1980s and is now considered to be responsible for most of the economic damage caused by foreign invasive species (Ding JianQing et al., 2001; Chu JianJun et al., 2006).

Water hyacinth is detrimental to biodiversity, notably by smothering native aquatic plant species. Water hyacinth increases water evaporation and intercepts light: the subsequent reduction of water oxygen content and increase in water acidity can be lethal to fish. The plants provide a breeding habitat for undesirable vectors of human and animal diseases, such as mosquitoes and bilharzia-carrying snails (Ecoport, 2011).

Water hyacinth is difficult to eradicate. The seeds spread through animal faeces and can survive 15-20 years. The most widely used and effective control method is mechanical and consists in removing the plants from the water. Though expensive and slow, this method has several advantages: the excess nutrients are extracted with the plant, which can be used for fodder, green manure or other applications. Chemical control is usually done with the herbicides 2,4-D, glyphosate or Paraquat, which may cause environmental concerns and may not ensure long-term sustainability. The dead plants may also contaminate water when they decay (Chu JianJun et al., 2006). Biological control can be achieved with fungi or insects (*Neochetina eichhorniae* and *Neochetina bruchi*) but only in association with other control methods (Pieterse, 1997).

Phytoremediation

Water hyacinth can be useful for the remediation of water contaminated with heavy metals, as the roots trap and remove from water large amounts of minerals, including heavy metals and radio-active elements (Hasan et al., 2009a). It has been effective in removing cadmium and zinc from moderately contaminated water (Lu XiaoMei et al., 2004). However, there is still no

commercial or large-scale application (Ecoport, 2011; Pieterse, 1997). Combining both water-clearing capacity and biogas production might be profitable: studies have shown that about 1 million L/d/ha of domestic sewage can be treated with water hyacinths, reducing the biochemical and chemical oxygen demand by 89 and 71% respectively (Hasan et al., 2009a).

Datasheet citation

Heuzé V., Tran G., Hassoun P., Régnier C., Bastianelli D., Lebas F., 2015. *Water hyacinth (Eichhornia crassipes)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/160 *Last updated on October 13, 2015, 16:25*

English correction by Tim Smith (Animal Science consultant) and Hélène Thiollet (AFZ)

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Nutritional attributes

Fresh water hyacinth has a very low DM content, usually below 10, that makes the plant extremely bulky, resulting in low intakes of nutrients. The composition of the plant is very variable. The protein and the mineral content are extremely dependent on the composition of the water in which the plants are grown: for example the protein and phosphorus content in the plant is directly correlated to the nutrient loading rate of the water (Boyd, 1970; Mako et al., 2011; Le Thi Men et al., 2006; Gosset et al., 1971).

The mineral content of water hyacinth is very high in all parts of the plant: 12 to 25% DM for the aerial part, and up to 30% or more for the whole plant. Silica may account for 20-40% of mineral matter (Abdelhamid et al., 1991). The leaves of water hyacinth are particularly rich in protein when young (more than 20% DM, occasionally over 30%) but the protein content decreases with age (Boyd, 1970). However, the stems are poorer in protein and as a result the aerial parts (leaves and stems) or the whole plant (roots included) have a protein content in the 10-20% range. The lysine content in the protein of water hyacinth is quite high (4-6% of the protein). The fibre content is relatively high with crude fibre in the 15-30% DM range, and NDF in the 55-78% range for the aerial part.

Potential constraints

Toxicity and palatability issues

There have been numerous reports of toxicity in animals fed fresh water hyacinth as the sole feed. Weight loss, poor animal performance, hepatic failure, renal lesions, tetany and even death have been observed in sheep and goats. Fresh water hyacinth fed alone was also reported to be lethal in rabbits and geese (Abdelhamid et al., 1991). However, the reasons for this toxicity are unclear (Cheat Sophal, 2010). Potential causes include oxalates, anti-nutritional factors, contaminants and malnutrition caused by the low amount of nutrients available in the fresh plant (Babu et al., 1988).

Fresh water hyacinth contains sharp calcium oxalate crystals that cause irritation in the mouth and are responsible for the low palatability observed in several animal species (Franceschi et al., 1980; Bolenz et al., 1990). However, while oxalate needles may harm the digestive tract, the levels are too low (0.8-1.2% DM) to cause problems of calcium imbalance (Lareo et al., 1982; Bolenz et al., 1990). Trypsin inhibitors, saponins and alkaloids are almost non-existent, and tannins have only been found at relatively low levels (less than 1-2% DM) (Lareo et al., 1982; Mako et al., 2011).

A potential cause of toxicity is the ability of water hyacinth to absorb and concentrate all types of pollutants present in the water, and particularly heavy metals: contamination issues are, therefore, linked to the quality of water in which the plant was grown (Jafari, 2010). In one study, the plant contained 90-146 mg/kg DM of lead, a value just lower than the toxic dose (200 mg/kg). It also contained 0.4-0.5 mg/kg of mercury (Abdelhamid et al., 1991). Other studies have reported much lower levels of lead (4 mg/kg, Moreland et al., 1991; 15-20 mg/kg, Mako et al., 2011). High levels of arsenic were found in the liver and kidneys of rabbits fed dried water hyacinth (Gérard et al., 1980).

Herbicide residues

Most herbicides have grazing and feeding restrictions stated on the label that limit the use of the crop for livestock feed. These restrictions should be carefully taken into account when feeding chemically treated water hyacinth to livestock.

Ruminants

Water hyacinth can be fed to ruminants as fresh forage, hay or silage. The fresh leaves are sometimes eaten when other feeds are scarce (Göhl, 1982). It is generally recommended to give water hyacinth with supplements rich in energy and protein, particularly when animal performance is expected, as in the case of growing animals. Fresh water hyacinth has a low DM and high mineral content that tends to reduce DM intake: more than 25% fresh water hyacinth in the feed reduces intake (Aregheore et al., 2000; Göhl, 1982). When fed alone for a long period or with a small amount of concentrate, fresh water hyacinth cannot maintain body weight and cases of malnutrition, renal failure and death have been observed (Babu et al., 1988). Water hyacinth may be used as the sole forage without concentrate supplements for only short maintenance periods lasting no more than a few weeks (Ahmed et al., 1995). Dried water hyacinth is not palatable to cattle unless mixed with at least 20% molasses (Göhl, 1982).

Digestibility

The DM digestibility of fresh or dried water hyacinth is usually low, in the 47-58% range (Hira et al., 2002; El-Serafy et al., 1980; Abdelhamid et al., 1991). Silage is more digestible, with DM digestibility values of 67 and 64% obtained in water buffalo and sheep respectively (El-Serafy et al., 1980).

Examples of ruminant performance

The following summary and table present the DM intake and growth performance of cattle, sheep and goats fed water hyacinth.

- Fresh leaves gave better growth (Cheat Sophal et al., 2010) and DM intake (Bui Phan Thu Hang et al., 2011) than fresh leaves and stems.
- 0.75

When offered as sole forage to sheep, water hyacinth intake varied from 36 to 62 g/kg W (Abdelhamid et al., 1991; El-Serafy et al., 1980; Ahmed et al., 1995). These variations could be explained by the variability of ash content.

- Sheep fed sun-dried water hyacinth as the sole feed for a short duration (3 weeks) maintained their body weight (Abdelhamid et al., 1991; Ahmed et al., 1995). However, sun-dried water hyacinth fed alone for several months could not support growth or maintenance: animals suffered from weight loss, severe malnutrition and kidney problems, even when supplemented with 125 g/d of concentrate; 250 g/d were required for normal growth (Babu et al., 1988).
- Silage was not always well accepted by the animals even when it included palatable ingredients such as citrus pulp or molasses (Baldwin et al., 1975). Rice bran alone was more palatable than a water hyacinth-rice bran silage (Lowilai et al., 1995).

DM intake and growth performance of cattle, sheep and goats fed fresh, dried or ensiled water hyacinth (WH):

Country	Animal	Form	Diet	DM Intake	Growth	Reference
Cambodia	Yellow cattle, 100 kg	Fresh leaves	WH, cereal straw, dry cassava leaves		243 g/d	Cheat Sophal et al., 2010
Cambodia	Yellow cattle, 100 kg	Fresh leaves and stems	WH, cereal straw, dry cassava leaves		147 g/d	Cheat Sophal et al., 2010
India	Bulls	Fresh leaves and stems	WH, concentrate, rice straw		390 g/d	Biswas et al., 1988
Egypt	Water buffalo steers	Sun-dried	WH sole feed, *ad libitum*	52 g/kg $W^{0.75}$		El-Serafy et al., 1980
Japan	Heifers, 240-275 kg	Silage, leaves and stems	Wilted, ensiled with rice bran (15% DM)	36 g/kg $W^{0.75}$		Lowilai et al., 1995
Egypt	Buffalo	Silage	WH sole feed, *ad libitum*	41 g/kg $W^{0.75}$		El-Serafy et al., 1980
India	Sheep, 37 kg	Sun-dried	WH sole feed for 3 weeks	62 g/kg $W^{0.75}$	Maintained body weight	Ahmed et al., 1995
Egypt	Sheep, fat tail	Sun-dried	WH sole feed, *ad libitum*	34 g/kg $W^{0.75}$		El-Serafy et al., 1980
Egypt	Sheep, fat tail	Silage	WH sole feed, *ad libitum*	31 g/kg $W^{0.75}$		El-Serafy et al., 1980
Egypt	Sheep	Sun-dried leaves and stems	WH sole feed	36 g/kg $W^{0.75}$		Abdelhamid et al., 1991
India	Sheep	Sun-dried	WH sole feed for 4 months		Weight loss, malnutrition, renal problems	Babu et al., 1988
India	Sheep	Sun-dried	WH, 125 g/d concentrate for 4 months		Weight loss, malnutrition, renal problems	Babu et al., 1988
India	Sheep	Sun-dried	WH, 250 g/d concentrate for 4 months		Normal growth	Babu et al., 1988
USA, Florida	Sheep	Silage	WH, ensiled with dried citrus pulp (4% DM) and molasses (0.5% DM), *ad libitum*	Not well eaten		Baldwin et al., 1975
Vietnam	Goats, 3-4 months, 11 kg	Fresh leaves	WH, sesbania	435-500 g/d		Bui Phan Thu Hang et al., 2011
Vietnam	Goats, 3-4 months, 11 kg	Fresh leaves and stems	WH *ad libitum*, sesbania	300-380 g/d		Bui Phan Thu Hang et al., 2011
Vietnam	Goats, 3-4 months, 11 kg	Fresh leaves	WH, sesbania or water spinach or sweet potato vines		63 g/d	Bui Phan Thu Hang et al., 2011
Bangladesh	Goats, 10-12 kg	Fresh leaves	WH, 200 g/d concentrate		29 g/d	Hira et al., 2002
Nigeria	Goats, West African Dwarf, 5 months, 6-6.5 kg	Sun-dried leaves and stems	WH (30%), cowpea pods, groundnut stubble		8 g/d	Dada, 2002
Nigeria	Goats, West African Dwarf, 5 months, 6-6.5 kg	Sun-dried leaves and stems	WH (40%), cowpea pods, groundnut stubble		11 g/d	Dada, 2002

Pigs

Water hyacinth foliage is commonly used as a supplement for pigs in smallholder farms in Asia. It is usually fed fresh or ensiled. Water hyacinth is also boiled with plant or animal by-products to make a complete pig diet, though this may not be very practical for pig farmers (Jafari, 2010).

Water hyacinth can be a protein source in pig diets and its amino-acid profile is well-balanced (Luu Huu Manh et al., 2002a; Le Thi Men et al., 2006; Le Thi Men, 2006). However, its utilization in pig feeding is limited by its bulkiness, high fibre content and low palatability, the latter due to the presence of oxalate crystals (Luu Huu Manh et al., 2002b; Lowilai et al., 1995; Göhl, 1982). The presence of hydrolysable and condensed tannins and the high fibre content (Mako et al., 2011) tend to decrease the activity of digestive enzymes in the pigs, and *in vitro* protein digestibility is only 40% (Ly et al., 2002; Domínguez et al., 1996). Ensiling and cooking improve the palatability of fresh water hyacinth foliage (Nguyen Nhut Xuan Dung et al., 2002; Luu Huu Manh et al., 2002b; Vo Van Son et al., 2002).

Including water hyacinth in pig diets is generally detrimental to the digestibility (protein, NDF, energy) of the whole diet (Domínguez et al., 1996). A maximum inclusion rate of 6-7% (diet DM) has been considered economically viable (Berto et al., 1988; Luu Huu Manh et al., 2002b; Le Thi Men et al., 2006). It is recommended to feed water hyacinth to finishing pigs or to local pigs that can utilize fibrous feeds more efficiently. Young leaves (without the stems and roots) are more suitable for pig feeding as they are more palatable and less fibrous than older leaves, stems and roots (Vo Van Son et al., 2002; Le Thi Men et al., 2006). For a 80 kg pig, the fresh matter intake of water hyacinth foliage is about 900 g/d (120 g/d DM) (Vo Van Son et al., 2002).

Poultry

Broilers and layers

Fresh water hyacinth is bulky and cannot be used in significant quantities by chickens. It has been suggested that dried and

ground water hyacinth could be used in poultry diets, but most studies reported poor performance (Santos, 1984; Ali et al., 1994). Water hyacinth could be a source of pigments for poultry (Lareo et al., 1982).

Ducks and Geese

Waterfowl are well adapted to bulk and wet feeding, and water hyacinth is more suitable for these species than for chickens. While experimental results are not consistent, water hyacinth has generally been found to be of relatively poor nutritive value (Ali et al., 1994). The replacement of 5 to 25% of a complete diet with water hyacinth in growing ducks led to decreased performance but was economically profitable due to the lower feed cost (Bui Xuan Men et al., 2005). As water hyacinth can be very valuable for wastewater purification, its utilization as a feed for waterfowl may have to be assessed in the context of integrated systems where both water hyacinth and waterfowl may play a part (Lu et al., 2008).

Geese and goslings have been recommended as a means to control infestation by water hyacinth in waterways and canals (Damron et al., 1983 cited by Hugo, 1995).

Rabbits

Water hyacinth should be considered mainly as a source of relatively digestible fibre for rabbits. The NDF digestibility is about 40% (Nguyen Van Thu et al., 2009) despite a significant lignin content of 8% (Grandi, 1981). However, due to a very high mineral content, the digestible energy content is moderate, around 6 MJ/kg DM.

Crude protein digestibility is 60% on average and typical for a forage with 10 to 15% of crude protein and a notable lignin content. The protein profile is characterized by a lysine content that is slightly above recommendations for rabbits. However, there is a significant lack of sulphur-containing amino acids and the protein of water hyacinth supplies only 70 to 80% of the requirements, according to different sources.

Fresh whole plant

Rabbit are very fond of fresh and whole water hyacinths (Lebas et al., 1986; Rakotozandriny et al., 1999). However, water hyacinth given as sole feed is unable to support maintenance requirements, due to an insufficient DM intake: 30 g DM/d for a 1 kg rabbit (Gérard et al., 1980). In Vietnam, the DM intake of fresh water hyacinth could be increased at up to 24 g/d when fed with limited amounts of concentrates to rabbits of 1.3 kg. The best growth performance was obtained with a 40:60 (DM basis) mixture of Para grass (*Brachiaria mutica*) and water hyacinth, distributed *ad libitum* in addition to a concentrate made of dry cassava roots and soybean waste. In this case water hyacinth represented 26% of the total daily DM intake (Nguyen Van Thu et al., 2009).

Dried whole plant

There was no significant difference in mean daily gain, feed intake/kg gain, mortality or slaughter indices in 4 groups of rabbits given diets with or without water hyacinth meal at 0, 4, 8 or 12% of the DM, from days 35 to 77. Contamination of tissues with chromium and lead was slight and there were no macroscopic or histological signs of damage associated with the utilization of dried whole water hyacinths cultivated on urban and industrial effluents in Italy (Grandi et al., 1983). In Nigeria, sun-dried water hyacinth was used safely at up to 30% of the diet and replaced most of the maize grain (Biobaku et al., 1991).

In Florida, the long term utilization of artificially dried water hyacinth from wastewater treatment facilities was studied for 2 generations of rabbits. Dried water hyacinth was included at 30% of the diet and completely replaced alfalfa without alteration of growth or reproduction rates. Survival of breeding stock, fertility, survival of offspring and teratogenicity were not affected. Trace element levels in muscle tissue from rabbits fed water hyacinth were below the levels reported as toxic (Moreland et al., 1991). In Mexico, significant levels of arsenic were observed in the kidneys, liver and meat (2.47, 1.41 and 0.69 mg/kg respectively) of rabbits fed a diet containing 50% dried water hyacinth collected from local ponds (arsenic content of the diet was 0.53 mg/kg). However, arsenic content was reduced by 75% in the liver and kidneys when 25% dried water hyacinth was used (Gérard et al., 1980).

Fresh or dried leaves

In Haiti, water hyacinth leaves, wilted for 4 hours in the sun thereby reducing the water content by 60%, were included with success as a standard feed in an experimental rabbit production unit (Kentor, 1990). Studies from Egypt suggest that the optimum inclusion level of dried water hyacinth leaves is 15 to 20%, depending on the feedstuff replaced with water hyacinth leaves (for example barley or alfalfa) in a complete diet (Zeweil et al., 1993; Eleraky et al., 1996).

Leaf protein concentrate

The isonitrogenous replacement of 50% of the soybean meal in the diet by a protein concentrate extracted from water hyacinth leaves increased rabbit growth and slaughter performances, but total replacement of soybean meal was not recommended (El-Adawy et al., 1999).

Fish

Water hyacinth is a potential ingredient in farm-mixed feeds for herbivorous or omnivorous freshwater fish in simple production systems and where it is available at low cost (Hasan et al., 2009a). Considerable research has been dedicated to investigate the use of water hyacinth in fish feeding, and a comprehensive review proposed by Hasan et al., 2009a is the basis for the present text. Water hyacinths are fed to fish either fresh, as a dried meal in pelleted diets, or composted as feed and fertilizer. Attempts are also made to feed water hyacinths to fish by processing them with other techniques. However, many of these studies were conducted under laboratory conditions and reports of on-farm utilization as fish feed are limited.

Inclusion rates, feed conversion and digestibility

Suitable inclusion levels are 25-50% when supplementing basic feed (rice bran, broken rice, chicken manure, etc.), or 5-10% when replacing protein sources in formulated feeds (fish meal, vegetable oil meals/cake) (Hertrampf et al., 2000). A feed conversion ratio of 3.0 is an acceptable level for fresh or processed water hyacinths. For all practical purposes, the protein digestibility of water hyacinth may safely be taken as 70-80% at 15-30% inclusion rates in the diet, while it may be around 50-60% at inclusion rates of 45% or above.

Fresh form

The use of fresh water hyacinth as fish feed has achieved limited success, principally because of its high moisture content and because of the presence of calcium oxalate crystals. Hyacinth leaves are generally cut into small pieces and fed to grass carp or other macrophytophagous fish. Generally, grass carp (*Ctenopharyngodon idella*) feed on this plant only when no other

macrophytes or feeds are available, though they have been found to readily accept roots and leaves (but not the swollen petioles). Grass carp grew well when fed exclusively with water hyacinth, though fish above 80-100 g were able to better utilize it (Riechert et al., 1977). In Vietnam, mixtures of fresh whole water hyacinth and rice bran (2:1), fermented or not, have replaced rice bran in nursery ponds of Nile tilapia (*Oreochromis niloticus*), common carp (*Cyprinus carpio*), grass carp and Java barb (*Barbonymus gonionotus*). Nile tilapia performed better than the other species, exhibiting a specific growth rate of 4.3-4.8%/day (Nguyen Anh Tuan et al., 1994).

Dried form

Fish were reluctant to accept water hyacinth leaf meal in pelleted diets (Hasan et al., 2009a). A major problem with the use of water hyacinth meal in fish diets is its relatively high fibre content, as fish do not appear to produce cellulase directly and, therefore, their ability to maintain a symbiotic gut flora capable of hydrolyzing cellulose is limited (Buddington, 1980). A number of growth studies have been conducted using dried water hyacinth in pelleted fish feeds, partially or completely replacing fishmeal or other conventional protein sources. Whole water hyacinth or its leaf meal was evaluated as a major ingredient in pelleted diets for Nile tilapia, Java tilapia (*Oreochromis mossambicus*), grass carp, common carp, rohu (*Labeo rohita*), stinging catfish (*Heteropneustes fossilis*), Java barb, sepat rawa (*Trichogaster* sp.), matrincha (*Brycon* sp.) and African catfish (*Clarias gariepinus*). The inclusion rate of water hyacinth meal used varied widely, ranging from as low as 2.5% to as high as 100%. Growth responses have been highly variable. Significant reductions in growth responses have been reported in rohu fry and fingerlings when 27-30% leaf meal was included to replace the fishmeal protein of the control diet (Hasan et al., 1990; Hasan et al., 1994). There was a similar response in Nile tilapia when fed a test diet containing 40% water hyacinth meal (Klinavee et al., 1990). Better or similar growth responses than those from the control diet have been observed in grass carp and common carp fed 50% water hyacinth (Murthy et al., 1990), Java tilapia fed only water hyacinth (Dey et al., 1982), and in matrincha (*Brycon* sp.) with an 18.5% inclusion rate (Saint-Paul et al., 1981). However, in some of these studies, the control diet consisted only of a rice bran-oil cake mixture, which itself may not have generated good growth. The specific growth rate was only slightly reduced (10-15%) in tilapia fed a diet replaced at 75 or 100% by water hyacinth meal, but the fish may also have obtained extra nutrients from plankton (Edwards et al., 1985), an indirect benefit that may also have been present in other studies (Dey et al., 1982; Murthy et al., 1990).

Composting, fermentation and other processes

Composting is one of the most widely used processing techniques to prepare water hyacinth for use as a fertilizer or fish feed. A large quantity of inorganic nitrogen and phosphorus accumulates in the roots, which makes it suitable as a compost or inorganic fertilizer. Composting increases the nutritive value and acceptability of water hyacinth: composted water hyacinth was found to have a protein content similar to that of the corresponding meal, half the crude fibre and fat content and twice the amount of ash (Edwards et al., 1985). However, in China, when fresh whole water hyacinth was applied to ponds as feed and fertilizer, the fish were reluctant to accept it and it took a long time to decompose, eventually resulting in inefficient utilization (Hasan et al., 2009a).

Other processes have been reported. In China, fresh water hyacinth is mashed into a liquid form with a high-speed beater and added to ponds containing carp fingerlings. The paste can also be mixed with rice bran and fermented before adding to the pond. Leaf extracts have also been tried. In one experiment, leaves were crushed with water and the resulting solution was sieved to remove the fibrous material. Rohu spawn that received the extract (100 ml/d for 120 spawn in 40 L tanks for 30 days) had a growth rate of 8.59 *vs.* 9.04 g/d for the control diet (phytoplankton) (Kumar et al., 1991). A dried protein concentrate made from pressed leaves of water hyacinth increased growth and reduced mortality in channel catfish fingerlings (*Ictalurus punctatus*) when included at up to 10% of the diet. The water hyacinth meal could be used as a replacement for alfalfa meal (Liang et al., 1971). In a series of experiments in Thailand, water hyacinths were added in three forms to a series of earthen ponds stocked with Nile tilapia: fresh whole plants that decomposed beneath the water *in situ*; freshly chopped water hyacinth spread on the surface; and composted water hyacinth. Extrapolated yields of 5 to 6 t/ha/year of fish were obtained with all three treatments at the same dry matter loading rate of 200 kg/ha/day (Edwards, 1987).

Datasheet citation

Heuzé V., Tran G., Hassoun P., Régnier C., Bastianelli D., Lebas F., 2015. *Water hyacinth (Eichhornia crassipes)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/160 *Last updated on October 13, 2015, 16:25*

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catégories Feed
Tous les aliments
Plantes fourragères
- Les céréales et les graminées fourragères
- légumineuses fourragères
- Les arbres fourragers
- Plantes aquatiques
- Autres plantes fourragères

Les produits végétaux / sous-produits
- Grains de céréales et sous-produits
- Graines de légumineuses et sous-produits
- Plantes oléagineuses et sous-produits
- Fruits et sous-produits
- Racines, tubercules et sous-produits
- Transformation du sucre sous-produits
- huiles et graisses végétales
- Autres sous-produits végétaux

Aliments d'origine animale
- Sous-produits animaux
- Produits laitiers / sous-produits
- graisses et huiles animales
- Insectes

D'autres aliments
- Minéraux
- Autres produits

noms latins
familles végétales et animales
Les espèces végétales et animales

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Water hyacinth (Eichhornia crassipes)

Description | Nutritional aspects | Nutritional tables | References

Tables of chemical composition and nutritional value

- Water hyacinth (Eichhornia crassipes), whole plant with roots, fresh
- Water hyacinth (Eichhornia crassipes), whole plant with roots, dried
- Water hyacinth (Eichhornia crassipes), aerial part, fresh
- Water hyacinth (Eichhornia crassipes), aerial part, silage (with molasses)
- Water hyacinth (Eichhornia crassipes), leaves, fresh
- Water hyacinth (Eichhornia crassipes), stems, fresh

Avg: average or predicted value; SD: standard deviation; Min: minimum value; Max: maximum value; Nb: number of values (samples) used

Water hyacinth (Eichhornia crassipes), whole plant with roots, fresh

Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	5.8	1.1	4.9	7.6	5
Crude protein	% DM	18.3	5.8	9.8	26.2	11
Crude fibre	% DM	22.6	6.4	17.1	31.8	7
NDF	% DM	57.3				1
ADF	% DM	33.4				1
Ether extract	% DM	2.0	0.5	1.1	2.5	8
Ash	% DM	21.1	8.0	11.1	34.1	9
Gross energy	MJ/kg DM	15.8				*

Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	9.5	5.2	5.6	17.2	4
Phosphorus	g/kg DM	6.3	2.9	3.1	8.9	4
Potassium	g/kg DM	26.3	7.5	16.4	34.5	4
Sodium	g/kg DM	17.9	1.8	16.3	20.2	4
Magnesium	g/kg DM	2.6	0.8	1.7	3.5	4
Manganese	mg/kg DM	164	89	86	291	4
Zinc	mg/kg DM	41	22	21	68	4
Copper	mg/kg DM	32	20	10	55	4
Iron	mg/kg DM	3028	2102	1581	6150	4

Amino acids	Unit	Avg	SD	Min	Max	Nb
Alanine	% protein	5.2		5.2	5.2	2
Arginine	% protein	4.5		4.4	4.7	2
Aspartic acid	% protein	10.5		10.1	11.0	2
Cystine	% protein	0.2		0.2	0.2	2
Glutamic acid	% protein	9.3		9.3	9.4	2
Glycine	% protein	4.5		4.4	4.6	2
Histidine	% protein	1.6		1.6	1.6	2
Isoleucine	% protein	3.9		3.8	3.9	2
Leucine	% protein	6.8		6.8	6.8	2
Lysine	% protein	4.7		4.4	5.0	2
Methionine	% protein	1.4		1.3	1.4	2
Phenylalanine	% protein	4.1		3.8	4.4	2
Proline	% protein	3.6		3.4	3.7	2
Serine	% protein	3.5		3.4	3.6	2
Threonine	% protein	3.7		3.7	3.7	2
Tyrosine	% protein	2.9		2.9	2.9	2
Valine	% protein	4.5		4.3	4.7	2

Pig nutritive values	Unit	Avg	SD	Min	Max	Nb

Energy digestibility, growing pig	%	54.6				*
DE growing pig	MJ/kg DM	8.6				*

The asterisk * indicates that the average value was obtained by an equation.

References

Boyd, 1969; Gérard et al., 1980; Jantrarotai, 1993; Klinavee et al., 1990; Nguyen Anh Tuan et al., 1994; Nguyen Van Thu et al., 2009; Wolverton et al., 1978

Last updated on 24/10/2012 00:45:19

Water hyacinth (Eichhornia crassipes), whole plant with roots, dried

Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	88.8	5.9	81.4	95.7	4
Crude protein	% DM	13.7	2.8	10.7	17.8	6
Crude fibre	% DM	24.0	5.1	17.1	28.6	5
NDF	% DM	58.0				1
ADF	% DM	32.3				1
Lignin	% DM	8.6				1
Ether extract	% DM	2.3	1.7	0.9	4.8	5
Ash	% DM	18.1	5.2	14.5	27.2	5
Gross energy	MJ/kg DM	16.4				*

Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	12.9	9.1	2.5	18.8	3
Phosphorus	g/kg DM	2.3	1.5	0.5	3.2	3
Potassium	g/kg DM	8.7	5.5	2.7	13.5	3
Sodium	g/kg DM	3.6	4.3	0.3	8.4	3
Magnesium	g/kg DM	2.8	1.4	1.6	4.3	3
Manganese	mg/kg DM	269	211	70	490	3
Zinc	mg/kg DM	151		101	200	2
Copper	mg/kg DM	18		9	26	2
Iron	mg/kg DM	1221		112	2330	2

Amino acids	Unit	Avg	SD	Min	Max	Nb
Alanine	% protein	4.0				1
Arginine	% protein	1.3				1
Aspartic acid	% protein	10.1				1
Glutamic acid	% protein	9.1				1
Glycine	% protein	3.8				1
Histidine	% protein	1.2				1
Isoleucine	% protein	3.0				1
Leucine	% protein	5.5				1
Lysine	% protein	6.4				1
Phenylalanine	% protein	3.9				1
Proline	% protein	2.4				1
Serine	% protein	1.4				1
Threonine	% protein	1.9				1
Tyrosine	% protein	0.6				1
Valine	% protein	5.1				1

Rabbit nutritive values	Unit	Avg	SD	Min	Max	Nb
Energy digestibility, rabbit	%	40.6				*
DE rabbit	MJ/kg DM	6.7		6.5	6.8	2
MEn rabbit	MJ/kg DM	6.3				*
Nitrogen digestibility, rabbit	%	55.0		38.9	71.1	2

The asterisk * indicates that the average value was obtained by an equation.

References

Biobaku et al., 1991; Edwards et al., 1985; Gérard et al., 1980; Grandi et al., 1983; Grandi, 1981; Moreland et al., 1991

Last updated on 24/10/2012 00:45:18

Water hyacinth (Eichhornia crassipes), aerial part, fresh

Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	8.1	3.0	3.8	14.6	16
Crude protein	% DM	13.5	3.9	8.5	20.0	18
Crude fibre	% DM	20.2	4.9	14.6	33.2	12
NDF	% DM	64.7	7.9	54.2	77.9	9
ADF	% DM	33.8	4.3	27.8	39.7	8
Lignin	% DM	9.3				1
Ether extract	% DM	2.8	1.4	1.3	4.8	16
Ash	% DM	18.7	3.8	12.0	25.7	17
Gross energy	MJ/kg DM	16.2		10.5	16.2	2 *

Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	11.3	7.0	5.8	25.0	9
Phosphorus	g/kg DM	3.0	2.1	1.8	7.7	9
Potassium	g/kg DM	25.3	25.9	3.8	70.3	8
Sodium	g/kg DM	2.0	0.2	1.8	2.2	4
Magnesium	g/kg DM	5.0	4.6	1.5	13.8	9
Manganese	mg/kg DM	679	3	676	682	4
Zinc	mg/kg DM	52	1	51	53	4
Copper	mg/kg DM	12	0	11	12	4
Iron	mg/kg DM	523	5	516	527	4

Amino acids	Unit	Avg	SD	Min	Max	Nb
Arginine	% protein	6.7	0.5	6.2	7.1	3
Glutamic acid	% protein	8.8		8.3	9.4	2
Glycine	% protein	5.2	0.8	4.6	6.2	3
Histidine	% protein	1.7	0.4	1.3	2.1	3
Isoleucine	% protein	5.1	0.2	4.8	5.3	3
Leucine	% protein	8.4	0.5	8.0	8.9	3
Lysine	% protein	4.3	1.1	3.1	5.1	3
Methionine	% protein	1.3	0.4	0.9	1.7	3
Phenylalanine	% protein	5.2	0.4	4.8	5.5	3
Threonine	% protein	3.9	1.0	3.1	5.0	3
Valine	% protein	5.6	0.1	5.5	5.7	3

Secondary metabolites	Unit	Avg	SD	Min	Max	Nb
Tannins (eq. tannic acid)	g/kg DM	0.1				1

Ruminant nutritive values	Unit	Avg	SD	Min	Max	Nb
OM digestibility, Ruminant	%	59.5				1
OM digestibility, ruminants (gas production)	%	49	5	45	58	5
Energy digestibility, ruminants	%	54.2				*
DE ruminants	MJ/kg DM	8.8				*
ME ruminants	MJ/kg DM	7.1				*
ME ruminants (gas production)	MJ/kg DM	5.5	0.5	5.0	6.3	5
Nitrogen digestibility, ruminants	%	66.1				1

Rabbit nutritive values	Unit	Avg	SD	Min	Max	Nb
Energy digestibility, rabbit	%	32.6				*
DE rabbit	MJ/kg DM	5.3				1
MEn rabbit	MJ/kg DM	5.0				*
Nitrogen digestibility, rabbit	%	42.9				1

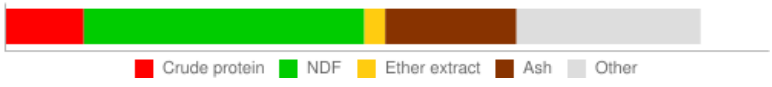
The asterisk * indicates that the average value was obtained by an equation.

References

Abdelhamid et al., 1991; Aboud et al., 2005; Aregheore et al., 2000; Baldwin et al., 1975; Bui Phan Thu Hang et al., 2011; Cheat Sophal et al., 2010; CIRAD, 1991; Gérard et al., 1980; Le Thi Men et al., 2006; Le Thi Men, 2006; Loosli et al., 1954; Ly et al., 2002; Mako et al., 2011

Last updated on 24/10/2012 00:45:18

Water hyacinth (Eichhornia crassipes), aerial part, silage (with molasses)



Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	11.3	3.6	6.3	14.8	4
Crude protein	% DM	11.2	2.6	8.5	13.5	4
Crude fibre	% DM	20.0	1.3	18.8	21.4	3
NDF	% DM	40.4				1
ADF	% DM	24.6				1
Ether extract	% DM	3.0	2.8	1.1	7.1	4
Ash	% DM	18.9	1.7	16.8	20.3	4
Gross energy	MJ/kg DM	16.1				*

Ruminant nutritive values	Unit	Avg	SD	Min	Max	Nb
OM digestibility, Ruminant	%	55.5	6.1	50.9	62.5	3
Energy digestibility, ruminants	%	49.5				*
DE ruminants	MJ/kg DM	8.0				*
ME ruminants	MJ/kg DM	6.5				*
Nitrogen digestibility, ruminants	%	43.0	24.1	25.4	70.5	3

The asterisk * indicates that the average value was obtained by an equation.

References

Loosli et al., 1954; Nguyen Nhut Xuan Dung et al., 2003

Last updated on 24/10/2012 00:45:19

Water hyacinth (Eichhornia crassipes), leaves, fresh

Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	11.3	4.0	5.5	18.3	12
Crude protein	% DM	21.7	5.8	13.1	34.9	17
Crude fibre	% DM	16.2	3.2	10.5	21.5	11
NDF	% DM	54.1	10.1	39.1	68.1	7
ADF	% DM	26.0	4.0	21.1	33.4	7
Lignin	% DM	7.2		6.1	8.4	2
Ether extract	% DM	3.1	1.8	1.3	6.6	13
Ash	% DM	14.6	3.9	10.5	25.6	16
Gross energy	MJ/kg DM	17.2				*

Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	12.9	6.3	2.9	21.6	7
Phosphorus	g/kg DM	6.0	2.8	3.0	9.2	7
Potassium	g/kg DM	35.7	0.5	35.2	36.0	3
Sodium	g/kg DM	12.4	10.1	0.7	18.3	3
Magnesium	g/kg DM	5.8	3.0	2.6	8.5	5
Manganese	mg/kg DM	169	174	69	370	3
Zinc	mg/kg DM	20	3	18	23	3
Copper	mg/kg DM	9	4	5	14	3
Iron	mg/kg DM	143		143	143	2

Amino acids	Unit	Avg	SD	Min	Max	Nb
Alanine	% protein	6.2				1
Arginine	% protein	5.2				1
Aspartic acid	% protein	12.0				1
Cystine	% protein	1.3				1
Glutamic acid	% protein	11.0				1
Glycine	% protein	5.1				1
Histidine	% protein	2.2				1
Isoleucine	% protein	4.7				1
Leucine	% protein	8.3				1
Lysine	% protein	5.7				1
Methionine	% protein	1.4				1
Phenylalanine	% protein	5.4				1
Proline	% protein	6.0				1
Serine	% protein	4.1				1
Threonine	% protein	4.3				1
Tryptophan	% protein	1.0				1

Tyrosine	% protein	3.4				1
Valine	% protein	5.6				1

Secondary metabolites	Unit	Avg	SD	Min	Max	Nb
Tannins (eq. tannic acid)	g/kg DM	1.2		1.2	1.3	2

Ruminant nutritive values	Unit	Avg	SD	Min	Max	Nb
OM digestibility, Ruminant	%	56.8				1
OM digestibility, ruminants (gas production)	%	53		50	57	2
Energy digestibility, ruminants	%	53.2				*
DE ruminants	MJ/kg DM	9.2				*
ME ruminants	MJ/kg DM	7.3				*
ME ruminants (gas production)	MJ/kg DM	5.6		5.2	5.9	2
Nitrogen digestibility, ruminants	%	65.4				1

The asterisk * indicates that the average value was obtained by an equation.

References

Abdelhamid et al., 1991; Abo Bakr et al., 1984; Aboud et al., 2005; Aregheore et al., 2000; Begum et al., 2000; Bui Phan Thu Hang et al., 2011; Cheat Sophal et al., 2010; Chhay Ty et al., 2007; CIRAD, 1991; Hira et al., 2002; Luu Huu Manh et al., 2002; Sen, 1938; Vo Van Son et al., 2002; Wolverton et al., 1978

Last updated on 24/10/2012 00:45:18

Water hyacinth (Eichhornia crassipes), stems, fresh

Main analysis	Unit	Avg	SD	Min	Max	Nb
Dry matter	% as fed	6.7	1.1	5.9	7.9	3
Crude protein	% DM	13.1	5.2	6.3	19.1	7
Crude fibre	% DM	21.8	5.3	15.2	30.9	7
NDF	% DM	55.1	2.1	52.7	56.5	3
ADF	% DM	34.3	4.6	29.7	38.9	3
Lignin	% DM	11.5		10.6	12.4	2
Ether extract	% DM	1.8	0.8	0.9	3.2	7
Ash	% DM	21.8	6.2	17.6	34.9	7
Gross energy	MJ/kg DM	15.3				*

Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	14.1	7.1	4.1	22.5	6
Phosphorus	g/kg DM	7.4	3.7	1.0	11.1	6
Potassium	g/kg DM	45.4	26.5	27.3	75.9	3
Sodium	g/kg DM	7.6	4.1	4.0	12.1	3
Magnesium	g/kg DM	58.0	118.6	1.5	270.0	5
Manganese	mg/kg DM	288	273	88	599	3
Zinc	mg/kg DM	22	9	15	32	3
Copper	mg/kg DM	15	23	1	42	3
Iron	mg/kg DM	130		82	178	2

Amino acids	Unit	Avg	SD	Min	Max	Nb
Alanine	% protein	3.5				1
Arginine	% protein	2.6				1
Aspartic acid	% protein	30.1				1
Cystine	% protein	0.6				1
Glutamic acid	% protein	10.2				1
Glycine	% protein	3.1				1
Histidine	% protein	1.2				1
Isoleucine	% protein	2.8				1
Leucine	% protein	4.5				1
Lysine	% protein	2.8				1
Methionine	% protein	0.7				1
Phenylalanine	% protein	3.1				1
Proline	% protein	3.3				1
Serine	% protein	2.6				1
Threonine	% protein	2.8				1
Tryptophan	% protein	0.9				1
Tyrosine	% protein	1.9				1

Valine	% protein	3.1				1

Secondary metabolites	Unit	Avg	SD	Min	Max	Nb
Tannins (eq. tannic acid)	g/kg DM	0.8		0.6	1.0	2

Ruminant nutritive values	Unit	Avg	SD	Min	Max	Nb
OM digestibility, ruminants (gas production)	%	58		56	60	2
ME ruminants (gas production)	MJ/kg DM	6.3		5.8	6.7	2

The asterisk * indicates that the average value was obtained by an equation.

References

Abdelhamid et al., 1991; Aregheore et al., 2000; CIRAD, 1991; Vo Van Son et al., 2002; Wolverton et al., 1978

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Datasheet citation

Heuzé V., Tran G., Hassoun P., Régnier C., Bastianelli D., Lebas F., 2015. *Water hyacinth (Eichhornia crassipes)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/160 *Last updated on October 13, 2015, 16:25*

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- Legume forages
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- Aquatic plants
- Other forage plants

Plant products/by-products
- Cereal grains and by-products
- Legume seeds and by-products
- Oil plants and by-products
- Fruits and by-products
- Roots, tubers and by-products
- Sugar processing by-products
- Plant oils and fats
- Other plant by-products

Feeds of animal origin
- Animal by-products
- Dairy products/by-products
- Animal fats and oils
- Insects

Other feeds
- Minerals
- Other products

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Water hyacinth (Eichhornia crassipes)

Description | Nutritional aspects | Nutritional tables | References

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Datasheet citation

Heuzé V., Tran G., Hassoun P., Régnier C., Bastianelli D., Lebas F., 2015. *Water hyacinth (Eichhornia crassipes)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/160 *Last updated on October 13, 2015, 16:25*

English correction by Tim Smith (Animal Science consultant) and Hélène Thiollet (AFZ)

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