Genus *Lemna* - applications for industry and agriculture

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Abstract. Our article is a minireview of the genus *Lemna*, a species with past use and potential for future use. Currently 14 species of *Lemna* are known, but some have a taxonomy still unclear. The genus is included in the Araceae family. The rapid growth of these plants finds applications in the bioremediation of polluted waters and as test organisms for environmental studies. It is also used as a gene expression system for the industrial production of biopharmaceuticals and other biomedical studies. The dry biomass of *Lemna* species is a good feed for cattle. It contains 25-45% protein (the percentage varies according to growing conditions, species composition), 4.4% fat and 8-10% fiber, calculated when the plant is dry. Species of this genus have been proposed for biofuel production due to the rapid accumulation of starch in their organism. In Chinese and Russian folk medicine, a tincture of *L. minor* is used in hives, vitiligo, asthma, influenza and as a general tonic. There are many applications of duckweed culture in the Recirculating Aquacultural Systems (RAS) and waste water treatment. According to Ardiansyah (2018) and references cited therein, *L. minor* has a good Total Nitrogen removal efficiency when used for wastewater treatment or Recirculating Aquacultural System improvement.
Key Words: aquaculture, biofuel, duckweed, feed, *Lemna minor*, RAS, wastewater treatment.

Introduction. *Lemna* is a genus of floating aquatic plants that grow and multiply rapidly (Figure 1). These plants have use as a model system in studies in synecology, basic botany, ecotoxicology, and biopharmaceutical production, as well as a source of animal feed in agriculture and aquaculture (www.ro.wikipedia.org). Our article is a minireview of the genus *Lemna*, a species with past use and potential for future use.

Figure 1. The common duckweed, *Lemna minor* (source: www.ro.wikipedia.org).

Taxonomy. Currently 14 species of *Lemna* are known (www.theplantlist.org), but some have a taxonomy still unclear (Bremer et al 2003). The genus is included in the Araceae family.

Species (www.theplantlist.org) which are better known:

Lemna aequinoctialis Welw. – tropical and subtropical areas.
Lemna perpusilla Torr. – eastern United States of America, Quebec.
Lemna gibba L. – widespread.
Lemna minor L. – common duckweed - in different countries.
Lemna trisulca L. – trisulcate lentil - in different countries.
Lemna minuta Kunth – dwarf lentil - North and South America.
Lemna valdiviana Phil. – Valdivian lentil - North America and South America.
Lemna japonica Landolt - Japan, China, Korea, Russian Far East.
Lemna obscura (Austin) Daubs - United States, Mexico, Chile, Colombia, Ecuador.
Lemna tenera Kurz - Indochina, Sumatra, Northern Territory of Australia.
Lemna turionifera Landolt - temperate zones of Europe, Asia, North America.
Lemna yungensis Landolt – Bolivia.

Biology. The genus *Lemna* is one of the smallest flowering plants (Wang et al 2021) and produces the smallest flowers in the world. They are formed in some microscopic bags and are devoid of petals. Species of the genus *Lemna* grow as simple floating thallus above or just below the surface of the water. Most are small, no more than 5 mm in length, except for the species *L. trisulca*, which is elongated and has a branched structure (www.ro.wikipedia.org). Plants in the genus *Lemna* have a single root, which distinguishes this genus from the related genera *Spirodela* and *Landoltia* (www.ro.wikipedia.org).

Plants spread over the surface of the water mainly by vegetative reproduction: two daughter plants detach from the adult plant. This form of growth allows very rapid colonization of the waters. Genus *Lemna* contains flowering plants and almost all its species are known to reproduce sexually (Chmilar & Laird 2019), flowering and producing seeds under appropriate conditions. Certain *Lemna* species (such as *L. gibba*) are long-day plants, while others (such as *L. minor*) are short-day plants (www.ro.wikipedia.org).

When water lentil invades a navigable body of water, it can be mechanically removed by collection, by populating with Asian cyprinids, or treated with herbicide (www.ro.wikipedia.org).

Uses. The rapid growth of these plants (Stewart et al 2021) finds applications in the bioremediation of polluted waters (Garcia-Rodríguez et al 2014; Coughlan et al 2022) and as test organisms for environmental studies (Pop et al 2021; Loll et al 2021; Singh et al 2022). It is also used as a gene expression system for the industrial production of biopharmaceuticals and other biomedical studies (Wahman et al 2022).

The dry biomass of *Lemna* species is a good feed for cattle. It contains 25-45% protein (the percentage varies according to growing conditions, species composition etc. (Iatrou et al 2019), 4.4% fat and 8-10% fiber, calculated when the plant is dry (www.ro.wikipedia.org).

Species of this genus have been proposed for biofuel production (Kuznetsova et al 2019; Kaur et al 2019) due to the rapid accumulation of starch in their organism (Iatrou et al 2019).

In Chinese and Russian folk medicine, a tincture of *L. minor* is used in hives, vitiligo, asthma, influenza and as a general tonic (Bolotova 2015).

There are many applications of duckweed culture in the Recirculating Aquacultural Systems (RAS) and waste water treatment. According to Ardiansyah (2018) and

references cited therein, the duckweed (*L. minor*) has a good TN (Total Nitrogen) removal efficiency (see Table 1).

Table 1

Summary of Total Nitrogen (TN) removal rates and efficiency of duckweed (*L. minor*) for waste water treatments according to a compilation by Ardiansyah (2018)

Parameters	*Removal efficiency (%)*	*Reference*
TN/TKN	17.59	Shah et al (2014)
	35	Gürtekin & Şekerdağ (2008)
	56-67	Erol-Nalbur et al (2003)
	73	Cedergen & Madsen (2002)
	70.35	Willett et al (2003)
	83-87	Ozengin & Elmaci (2007)
	34-99	Korner & Vermaat (1998)
	98	Mohedano et al (2012)
	50-95	Korner et al (1998)
	73-97	El-Kheir et al (2007)
Parameters	*Removal rate (g N $m^{-2}d^{-1}$)*	*Reference*
TN	0.54	Korner & Vermaat (1998)
	0.61	Lyerly (2004)
	0.77	Willett et al (2003)
	0.95	Cheng et al (2002b)
	1.2	Benjawan & Koottatep (2007)
	2.1	Cheng et al (2002a)
	3.4	Cheng et al (2002a)
	96	Selvarani et al (2015)

In his doctoral research, Ardiansyah (2018) evaluated the efficiency and sustainability of using duckweed (*L. minor*) as a biofilter medium for nutrient removal and its use as a feed source in barramundi (*Lates calcarifer*) RAS. He concluded the following: „Duckweed's integration into barramundi juvenile RAS can maintain optimum water quality for barramundi growth and survival due to its high bioremediation efficiency and assimilative capacity. Harvesting duckweed every four days resulted in higher TAN (Total Ammonia Nitrogen) removal efficiency from barramundi juvenile RAS. Duckweed biofilters are suitable substrates for the attachment, survival, and growth of PSB (Phosphate-Solubilising bacteria) and heterotrophic bacteria. Some bacteria may involve in both heterotrophic nitrification and phosphate solubilisation. A 4-day harvest frequency showed stronger correlations between duckweed SGR (Specific Growth Rate) and biomass harvest with the PSB and heterotrophic bacteria diversity in the biofilter tank. A 4-day harvest frequency maintained an optimum biomass of duckweed. The carrying capacity of barramundi IRAS (Integrated Recirculating Aquaculture Systems) may be affected by the capacity of duckweed compartment. Under normal aeration, the stocking density of up to 18.75 kg m^{-3} resulted in stressed fish, as indicated by the increase of plasma cortisol and total T4 (Triiodothyronine), and the decrease of total T3 (Thyroxine). A higher stocking density of 18.75 kg m^{-3} may be contributory factors in the increase of FCR (Feed Conversion Ratio) and the growth suppression of the target species. The stocking density of 21.63 kg m^{-3} affected the physiological stress responses in a differential manner according to fish size. However, no differences were resulted from different rearing systems, RAS and IRAS. Fish meal can be replaced with up to 35% fermented duckweed meal without compensating growth, survival and adverse physiological responses of the juvenile barramundi."

Conclusions. Currently 14 species of *Lemna* are known, but some have a taxonomy still unclear. The genus is included in the Araceae family. The rapid growth of these plants

finds applications in the bioremediation of polluted waters and as test organisms for environmental studies. It is also used as a gene expression system for the industrial production of biopharmaceuticals and other biomedical studies. The dry biomass of *Lemna* species is a good feed for cattle. It contains 25-45% protein (the percentage varies according to growing conditions, species composition), 4.4% fat and 8-10% fiber, calculated when the plant is dry. Species of this genus have been proposed for biofuel production due to the rapid accumulation of starch in their organism. In Chinese and Russian folk medicine, a tincture of *L. minor* is used in hives, vitiligo, asthma, influenza and as a general tonic. There are many applications of duckweed culture in the Recirculated Aquacultural System and waste water treatment. According to Ardiansyah (2018) and references cited therein, *L. minor* has a good Total Nitrogen removal efficiency when used for wastewater treatment or Recirculated Aquacultural System improvement.

Conflict of interest. The authors declare that there is no conflict of interest.

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