ISSN No. 0125-169X

ORYZA Vol. II/No. 4, Januari 2004

ORYZA

majalah ilmiah universitas mataram

REDESAIN INKUBATOR BAYI DENGAN LOGIKA FUZZY BERBASIS MIKROKONTROLER AT89C51

PEMANFAATAN KOMPOS HASIL DEKOMPOSISI JAMUR *Trichoderma harzianum* UNTUK PENGENDALIAN PENYAKIT LAYU FUSARIUM PADA TANAMAN TOMAT(THE UTILIZATION OF COMPOST RESULTED BY DECOMPOSITION WITH *Trichoderma harzianum* PREPARED TO CONTROL FUSARIUM WILT DISEASE OF TOMATO)

EKSPERIMEN ALAT PEMANAS AIR TENAGA SURYA TANPA DAN DENGAN REFLEKTOR CERMIN KOMERSIAL

DUCKWEED AS A NEW FEED SOURCE FOR FARM ANIMALS - A REVIEW

PENGARUH PENAMBAHAN ABU SEKAM PADI TERHADAP PERMEABILITAS BETON

CONTRIBUTIONS OF THE MEDUSAE OF PHYLLORHIZA PUNCTATA IN THE PRODUCTION OF DISSOLVED ORGANIC CARBON (KONTRIBUSI MEDUSAE PHYLLORHIZA PUNCTATA DALAM PRODUKSI KARBON ORGANIK TERLARUT)

PENGARUH PROPORSI CAMPURAN DAN KETEBALAN BAHAN TERHADAP KETAHANAN BEBAN IMPACT PAVING BLOCK (THE INFLUENCE OF MIXTURE PROPORTION AND MATERIAL THICKNESS AGAINST THE IMPACT LOADING RESISTANCE OF PAVING BLOCK)

PENANGGULANGAN LIMBAH CAIR TERSUSPENSI PADA INDUSTRIRUMAH TANGGA TAHU DAN TEMPE DI KOTA MATARAMDENGAN PENYARINGAN BERTINGKAT

PENGGUNAAN METODE INCINERATION SEBAGAI ALTERNATIF PENGELOLAAN SAMPAH KOTA MATARAM

PENGARUH PERUBAHAN PENGGUNAAN LAHAN TERHADAP KARAKTERISTIK HIDROGRAF

PROMOSI PERPUSTAKAAN MELALUI KOMUNIKASI MASSA DI MASYARAKAT

ANALISA PERPINDAHAN PANAS PADA ALIRAN MENYILANG SILINDER TAK BUNDAR MENGGUNAKAN ANALOGI PERPINDAHAN MASSA (HEAT TRANSFER ANALYSIS FOR NONCIRCULAR CYLINDERSIN CROSS FLOW USING MASS TRANSFER ANALOGY)

PENGARUH KEPADATAN TANAH GRANULER TERHADAP KAPASITAS GESER ANYAMAN BAMBU SEBAGAI BAHAN PENGGANTI GEOSINTETIK (INFLUENCE OF DENSITY OF GROUND GRANULAR TO SHIFT CAPACITIES OF BAMBOO MATTING UPON WHICH GEOSYNTHETICS SUBSTITUTION)

TINJAUAN KALA ULANG DEBIT TERUKUR BERDASARKAN KALA ULANG HUJAN 10 TAHUN DI DPS DODOKAN NTB

ANALISIS BANGKITAN PERJALANAN DARI KAWASAN PERUMAHAN (STUDI KASUS PADA PERUMAHAN PAGUTAN MATARAM) (GENERATED TRIP ANALYSIS FROM RESIDENTIAL AREA (CASE STUDY AT PAGUTAN MATARAM RESIDENT)

DUCKWEED AS A NEW FEED SOURCE FOR FARM ANIMALS - A REVIEW

K.G. Wiryawan[1]dan A. Rai Somaning Asih[2]
Faculty of Animal Science The University of Mataram.
[1]Department of Animal Nutrition and Feed Science; [2]Department of Animal Production;

SUMMARY

Conventional feed sources of dietary protein such as soybean meal and fish meal for farm animals are increasing in cost. Therefore, alternative sources of plant protein will be required in future. Duckweeds are potential new- inherent protein source to farm animals in tropical developing countries. These plants have been thoroughly recognized as being equal or superior to traditional livestock crops with regards to the amino acids and proteins as well as fat, fiber, Ca, P, ash, xanthophyll and carotene contents. This paper concentrates on production and nutrient composition of duckweeds compared to the conventional protein sources. The possibility of its use as feed for poultry, pigs and ruminants is also discussed.

INTRODUCTION

Conventional feed sources of dietary protein such as soybean meal and fish meal for farm animals, especially for monogastric animals are increasing in cost (FAO, 1995), and the feeding of animal protein meals, especially meals made from the same species are being increasingly banned (Anonym, 1998). Alternative sources of plant protein will therefore be required in future (D'Mello, 1995). Duckweed has been thoroughly recognized as being equal or superior to traditional livestock crops with regards to the amino acids and proteins as well as fat, fiber, Ca, P, ash, xanthophyll and carotene contents (Culley, 1973; Rusoff *et al.*, 1980; Skillicorn, 1993). Some species of duckweeds contained up to 44.7 % crude protein (Culley and Epps, 1973); less fibre content of about 5-15 % and a polyunsaturated fat content of about 5 % depending on the species involved (Leng, 1985). Therefore, these plants are potential new- inherent protein source to farm animals in tropical developing countries. As an animal feed particularly for ruminants, such weeds may be utilised in huge amount because ruminants can relatively utilise it more than poultry, fish, and other monogastric animals.

This paper concentrates on production and nutrient composition of duckweeds compared to the conventional protein sources. The possibility of its use as feed for poultry, pigs and ruminants is also discussed.

Production and Nutrient Composition of Duckweeds

Duckweed is a generic term for several species of free-floating macrophytes of the genus' *Lemna*, *Wolffia* and *Spirodella*. It is commonly available in developing countries especially in Indonesia growing on paddy field, which has to be removed by farmers regularly as a worthless waste. Although about forty species have been recognised, only several species have been investigated as animal feeds particularly in poultry and fish and only a few on ruminants as well as a feed to human in Burma and northern Thailand (Bhanthumnavin and MacGarry, 1971; Hillman and Culley, 1978; Gaigher, *et al.* 1984; Haustein *et al.* 1990; Haustein *et al.* 1992a; 1992b).

The habitat of duckweeds is very wide-range-environmental conditions (Leng *et al.* 1994). As a result, the chemical composition of duckweeds as reported in research varied, though in the same species, depend on the condition, environmental temperature and nutrient-aqueous environment of water area where they are growing (Culley and Epps, 1973; Rusoff *et al.* 1980). Duckweed grows slowly in clear, low nutrient waters and has a higher content of fibre, ash and carbohydrates, but contains relatively less protein (Muztar *et al.* 1976). In contrast duckweed grown on sewage lagoons grows rapidly and has higher protein content (Leng *et al.* 1995). This was confirmed by a study on effect of different organic fertilizers on production of *Lemna minor*. With the same input of nitrogen, plants nutrients derived from biodigester effluent supported higher concentrations of crude protein in duckweed, than nutrients from raw manure. Manure and effluent from pigs tended to support higher concentrations of crude protein in duckweed than when cows were the source of these inputs. The optimum level of nitrogen in the pond water was in the range of 20 to 30 mg/litre (Chau, 1998).

The stage of growth of this tiny plant also influents its chemical composition, particularly in its protein content. Under static-sewage-effluent conditions, duckweed harvested a week after being planted contained almost four times crude protein as compared to plants harvested at the 8-week growing period (Sutton and Ornes, 1975). Their nutritional values apparently increase when they are grown on nutrient-rich waters (Culley and Epps, 1973). Table 1 shows that different enriched conditions of growing-duckweed sites result in different nutritional composition of duckweeds. The nutrition of duckweeds is wide-range, namely 19.8 - 44.7 % crude protein; 1.5 - 6.6 % fat; 5 - 13.5% fibre and 7 - 20.3% ash.

Culley and Epps (1973) reported that several genera of duckweeds grown on natural fresh-water sites (Table 2) had relatively much lower protein and fat content than those of grown on animal waste sites. The lowest were 7.4 % of crude protein and 1.1 % of fat. Their fibre and ash content, however, were higher than those of duckweeds grown on animal waste sites. *Wolffia arrhiza* cultivated in native method contains 43.6 % carbohydrate in dry weight (Bhanthumnavin and MacGarry, 1971). Duckweeds also have high mineral content such as Ca, P and K about 1 - 1.2 %; 1.1 - 1.8 %; and 1.8 - 4.2 % respectively. Therefore duckweeds are not only good source of protein to animals, but also potential sources of energy, minerals and vitamin A.

Efficiency of cultivating duckweeds

The utilization of duckweeds as animal feeds will give worthwhile commodity to farmers in developing countries. Nutritionally, particularly in production of protein, cultivating duckweeds are more beneficial than cultivating selected crops as showed in Table 3.

Compared to soybeans, duckweeds have ten times of total protein production per hectare per year. Similarly, compared with alfalfa hay, it was about 3 to 10 times. Even in northern Thailand, annual-protein yield of *Wolffia arrhiza* cultivated without fertilizer was more than 10 times compared to those of the traditional crops such as soybean, corn and rice (Bhanthumnavin and MacGarry, 1971). *Spirodela oligorhiza* and *Spirodela polyrhiza* cultivated on fertilized outdoor ponds in Louisiana became double every 3 days and produced about 500 kg of dry matter per ha per day during the growing season (Anonym, 1976). Furthermore, if these plants were harvested every day, their annually crude protein production per hectare would be the same as about 60 ha of soybean.

According to Oron (1990) the annual-DM yield of *Lemna gibba* cultivated in outdoor-shallow-effluent mini ponds and harvested two to three times a week was about 55 ton/ha, with protein content almost 30 %. It means that the crude protein yield was about 16.5 ton/ha. Farmers, therefore, will get more amount of protein per hectare area from duckweeds than those of soybeans, corn, rice and alfalfa. In Bangladesh, in the mirzapur experimental program, a farming system of duckweeds was developed (Skillicorn *et al.* 1993). The production can sustain dry-weight yields of 13 - 38 ton/ha/year, which is higher than single-crop soybean production six to tenfold.

Table 1. Approximate composition of duckweeds grown on various waste-treatment sites compared to soybean and cottonseed meal.

Treatment source	Species	Crude protein %	Fat %	Fibre %	Ash %	Ca %	K %	P %
Municipal waste lagoons*	*Spirodela oligorhiza*	32.7	6.3	13.5	20.3	1.5	1.8	1.1
Anaerobic swine waste lagoon*	*Spirodela oligirhiza*	44.7	4.6	8.3	13.4	1.0	2.8	1.8
Minicipal waste lagoon #	*Mixture oflemna minor and L. gibba*	39.0	-	-	-	-	-	-
Dairy cattle waste lagoon**	*Spirodela oligorhiza*	37.8	3.8	7.3	12.0	1.3	2.9	1.5
	Spirodela polyrhiza	40.9	6.7	8.7	12.9	2.1	2.1	1.4
	Lemna gibba (strain G3)	38.5	3.0	9.4	16.4	1.0	4.2	1.6
Natural lagoon ###	-	15-35	4.4	8-25	15	-	-	-
Grown on Armidale Sewage ###	–	40-43	5.4	5	13	–	–	–
Natural lagoon***	*Wolffia arrhiza*	19.8	5 43.6@	13.3	18.3	–	–	–
Cattle waste lagoon ####	*S.punctata*	28.7	5.5	9.2	13.7	–	–	–
	S. polyrhiza	29.1	4.5	8.8	15.2.	–	–	–
	Wolffia columbiana	36.5	6.6	11.0	17.1	–	–	–
	soybean meal&	45.0	3.9	3.6	6.3	0.26	1.99	0.64
	Cottonseed meal&	42.7	6.0	12	7.1	0.21	1.44	1.27

Table 2. Chemical composition of ducmkweeds grown on natural freshwater site (bottom land lakes and streams) in Louisiana and Arkansas.

Dominant genera/species %	Crude protein %	Fat %	Fibre %	Ash %	Ca %	K %	P %	Water %
Ricciocarpus natan(100)	10.6	1.1	10.6	20.3	0.79	1.8	0.20	9.0
*Spirodela sp. (90)**	7.4	1.1	9.8	9.1	1.05	2.0	0.16	10.0
Lemna sp. (85)+	14.0	2.7	9.6	16.7	1.33	1.86	0.57	11.2
Lemna sp. (50)@	15.2	1.5	11.2	16.5	1.23	3.03	0.59	9.0
Lemna sp. (50) *Wolffia sp. (50)*	25.9	5.7	12.3	14.5	1.12	3.16	0.78	8.8
Lemna sp. (98)$	14.3	1.8	9.5	24.8	1.25	2.16	0.80	9.8
Lemna sp. (92)#	24.4	2.6	10.4	12.3	1.55	2.07	0.74	9.9
Spirodela sp. (97)&	23.3	2.2	9.5	15.5	1.23	2.41	0.67	9.4
Wolffia sp. (100)	21.5	5.5	10.6	14.5	0.77	3.76	0.97	-

Source : Culley and Epps, 1973.
*Remaining 10% consisted of species of Ricciocarpus natans.
+Remaining 10% consisted of species of Wolffia, Wolffiella and Spirodela.
@Remaining 15% consisted of species of Wolffia and Wolffiella.
$Remaining 2% consisted of species of Wolffia.
#Remaining 8% consisted of species of Wolffiella and Spirodela
&Remaining 3% consisted of species of Lemna.

Compared to soybeans, duckweeds have ten times of total protein production per hectare per year. Similarly, compared with alfalfa hay, it was about 3 to 10 times. Even in northern Thailand, annual-protein yield of *Wolffia arrhiza* cultivated without fertilizer was more than 10 times compared to those of the traditional crops such as soybean, corn and rice (Bhanthumnavin and MacGarry, 1971). *Spirodela oligorhiza* and *Spirodela polyrhiza* cultivated on fertilized outdoor ponds in Louisiana became double every 3 days and produced about 500 kg of dry matter per ha per day during the growing season (Anonym, 1976). Furthermore, if these plants were harvested every day, their annually crude protein production per hectare would be the same as about 60 ha of soybean.

According to Oron (1990) the annual-DM yield of *Lemna gibba* cultivated in outdoor-shallow-effluent mini ponds and harvested two to three times a week was about 55 ton/ha, with protein content almost 30 %. It means that the crude protein yield was about 16.5 ton/ha. Farmers, therefore, will get more amount of protein per hectare area from duckweeds than those of soybeans, corn, rice and alfalfa. In Bangladesh, in the mirzapur experimental program, a farming system of duckweeds was developed (Skillicorn *et al.* 1993). The production can sustain dry-weight yields of 13 - 38 ton/ha/year, which is higher than single-crop soybean production six to tenfold.

Other advantages of cultivating duckweeds.

Because of their ability to absorb nutrients through both the root and lower surface of the frond (Anonym, 1976), many species of duckweeds such as *Spirodela oligorrhiza; Spirodela polyrhiza; Lemna pinctata; Lemna gibba; Lemna minor; and lemna perpusilla* have been used to remove organic and inorganic material of polluted water (Leng *et al.* 1994; Sutton and Ornes, 1975; Staves and Knaus, 1985). About 97 % of orthophosphate phosphorus in the sewage effluent was removed by a mixed population of *Lemna gibba* and *Lemna minor* for 8-weeks planting (Sutton and Ornes, 1975). *Spirodela oligorhiza* was doubling its biomass about 3 to 7 days and calculations based on doubling time of 7 days showed that it will remove the nitrogen, phosphorus and potassium of 207-dairy cows' waste per day on 1 ha growing-spirodela-oligorhiza lagoon (Anonym. 1976). Oron (1990) emphasized that duckweeds have an extreme uptake preference for ammonia over nitrate and assimilate it into valuable nitrogen compounds, which are very useful for animal feed.

Staves and Knaus (1985) demonstrated that in removing Cr from industrial or residential wastewater at levels 10 p.p.m. and 20 p.p.m. Cr, *Spirodela punctata* was significantly more efficient than either *Spirodela polyrhiza* or *Lemna gibba*. At Cr levels less than 10 ppm., however, they were equally efficient. They recommended that using duckweeds as biological-treatment techniques was more economical than conventional wastewater treatments. Therefore, by utilizing duckweeds as animal feed it means we offer new high nutritional feed to animals as well as using these prolific aquatic plants extensively in wastewater management to remove heavy metals to keep the environment safe for our next generations.

Table 3. Comparison of annual protein productivity and nutrient composition of duckweed and other crops.

Materials	Annual tons/ha	crude protein (%)	fat (%)	Fiber (%)	ash (%)	Protein prod.ton/ ha/year	Relative protein prod./ ha/year
Duckweed (dry)	17.60	37.0	5.0	7.5	11.0	6.512	100.0
Soybeans(dry seed)	1.59	41.7	19.2	5.8	5.4	0.663	10.2
Cottonseed (dry)	0.76	29.4	24.7	18.2	3.8	0.223	3.4
Peanut with skin and hulls (dry)	1.60-3.12	23.6	37.9	21.1	3.2	0.38-0.74	5.8-11.3
Alfalfa hay (sun cured)	4.37-15.69	15.9-17.0	1.9	30.6	9.9	0.74-2.67	11.3-41

Source : Hillman and Culley (1978)

Table 4. Essential amino acids in duckweed protein concentrate compared to FAO reference Pattern and other grains (g/ 100 g protein)

Amino acid	Duckweed[@]	FAO	Corn	Rice	Soybean[#]
Lysine	4.0	4.2	2.3	3.2	6.8
Isoleucine	3.6	4.2	6.2	5.2	5.6
Leucine	6.7	4.8	15.0	8.2	8.2
Methionine	0.9	2.2	3.1	3.4	1.4
Phenylalanine	4.2	2.8	5.1	5.0	4.9
Threonine	3.13	2.8	3.7	3.8	4.0
Valine	4.4	4.2	5.3	6.2	5.2
Tryptophan	-	1.4	0.6	1.3	1.4

Source : Rusoff *et al.* (1980)
@ Mean of four species (L. gibba; S. polyrhiza; S. punctata and Wolffia columbiana). # Ravindran and Blair (1992).

Duckweeds as animal feed

There is a wide variety of protein-rich plants in the tropics which could replace soya bean meal in poultry feeds in Asia (Ravindran and Blair 1992). Duckweed is one of the most promising. Results with duckweed in poultry diets in Peru showed that it could replace all the soya bean meal and fish meal for layers and broilers (Haustein *et al* 1990, 1992a; 1992b) with only slight reduction in performance. Duckweeds have higher protein content and more complete amino acids (Table 4) than other vegetable proteins (Hillman and Culley, 1978). As well, its amino acid profile is very similar to that of soybean, fishmeal and cottonseed meal (Rusoff *et al*., 1980) and also they have a little indigestible matter (Leng, 1985).

These tiny-plants are also a good source of minerals, particularly P and Ca, (Culley and Epps, 1973; Hillman and Culley, 1978; and Leng, *et al*., 1994) needed by animals particularly lactating-ruminants where the requirements of that minerals is commonly higher than other physiological stages (NRC, 1981). In addition, those plants contain 30 - 50 mg/lb carotene, which indicates a good source of vitamin A (Culley and Epps, 1973; Hillman and Culley, 1978).

A great deal of duckweed research on fishes (carp species) was done. Duckweed is common feed of carp species in some developing countries in Asia (Skillicorn *et al*. 1993). The nutritional value of duckweeds as poultry feed has long been recognised Haustein *et al*. (1990) concluded that the duckweed (*Lemna gibba*) could substitute soybean and fish meal in layer diets, especially in countries where these commodities are imported. The result of his experiment showed that there were no significant difference between control diet and treatment diets containing up to 40 % *Lemna gibba* meal on egg production and mean egg weights, although all diet were isocaloric and isonitrogenous. Even from Leghorn hens fed 15 and 25 % *Lemna gibba* had higher protein content and significantly increased yolk pigmentation than control diet. Contrarily, on broiler as the level of *Lemna gibba* increased, feed consumption and weight gain decreased (Haustein *et al*., 1992a). A study in Cambodia comparing duckweed and soybean supplements showed that offering small amounts of fresh duckweed (30-40 g/day) to scavenging native chickens when they were confined at night-time improved heir growth rate when they also have access to broken rice (Samnang, 1999).

A similar trend was showed when duckweed was fed to growing pigs. Although weight gain was not significantly affected, feeding duckweed reduced digestibility of dry matter and crude protein (Gutierrez *et al*. 2001; Dung *et al*. 2002). These authors suggested that 20 to 35% duckweed could be included in pig diets.

Duckweeds also have a good prospect as a new protein supplement to ruminants in developing countries where the ruminants are commonly fed low quality forages. The combination of these feeds and duckweeds in fresh or meal will provide ruminants "a balance of nutrient capable of optimising rumen microbial fermentative capacity" (Leng, 1985). A digestibility study in cattle of Spirodela, Lemna and Wolffia, the most available species of duckweeds (Huque *at al.* 1996) showed that the rumen digestibilities of DM of the three species for 24 h were 410, 570 and 731 g /kg respectively and the digestibilities of CP were 528, 740 and 778 g/kg respectively. They also reported that mixed duckweeds as a component of a concentrate mixture were eaten by the cattle at the rate of 10% of their live weights. It may be concluded that the dry matter and crude protein of the available duckweeds were highly degradable in the rumen and may be fed to cattle mixed with concentrates. By feeding ruminants with duckweeds, it is promising a good prospect to recycle destroying-hopeless weeds in huge number to be important-rich-nutrient feed for big population in developing countries. Duckweeds, therefore, should be exploited as a source of high quality protein for domestic animal production especially in developing countries (Leng *et al.* 1994).

Limitations of duckweeds as an animal feed

Like other aquatic plants, duckweeds have high water and fiber contents and less palatable as an animal feed (Anonym, 1976). Culley and Epps (1973) reported that several species of duckweeds grown on natural freshwater sites in Louisiana and Arkansas had 88.8 - 91 % water content. This high water content of duckweeds raise main problem as an animal feed (Anonym, 1976) because it is rapidly mouldy and animals will not eat it as much as their requirement. These problems can be solved by processing them as ensilage or meal and combining with grains that commonly has low level of lysine and rich in methionine such as rice and corn. These diets can, therefore, be potentially as protein source to increase the nutritive value of the low quality forages for ruminants in developing countries. By feeding ruminants with duckweeds, it is promising a good prospect to recycle destroying-hopeless weeds to be important-rich-nutrient food for big population. As well, in the meantime these prolific aquatic plants are used extensively in wastewater management to remove heavy metals.

Conclusion

Duckweeds are good feed sources for farm animals with high protein, vitamin A and mineral contents and having similar nutrients composition to conventional protein sources such as soybean and cottonseed. However more intensive studies are needed to to provide information about their safe levels for monogastric and ruminant animals.

REFERENCES

Anonym, 1976. Making Aquatic Weeds Useful : Some Prospectives for Developing Countries. National Academy Sciences. Washington, D.C. pp : 91 - 97; 148 - 153.

Anonym, 1998. No more cannibals. *New Scientist* 2115: 5.

Bhanthumnavin, K. and MacGarry, M.G. 1971. Wolffia arrhiza as a possible source of inexpensive protein. *Nature*. Vol. 232: 495.

Chau, L.H. 1998. Biodigester effluent versus manure, from pigs or cattle, as fertilizer for duckweed (Lemnaceae). *Livestock Research for Rural Development* (http://www.cipav.org.co/lrrd/lrrd10/3/cont103.htm

Culley, D.D. and Epps, E.A. 1973. Use of duckweed for waste treatment and animal feed. *Journal of the Water Pollution Control Federation*. Vol. 45 (2) : 337-347.

D'Mello, J.P.F. 1995. Under-utilized legume grains in non-ruminant nutrition. In Tropical Legumes in Animal Nutrition, pp. 283-329 [J.P.F. D'Mello and C. Devendra, editors]. CAB International, Wallingford, UK.

Dung, N.N.X., Manh, L.H. and Uden, P. 2002. Tropical fibre sources for pigs: Digestibility, digesta retention and estimation of fibre digestibility in vitro. *Animal Feed Science and Technology* 102: 109-124.

Evans, M.1985. Nutrient Composition of Feedstuffs for Pigs and Poultry.Queensland Department of Primary Industries. Brisbane. p : 89 -95.

FAO. 1995. *Trade and Commerce Vol. 48*. Food and Agriculture Organisation of the United Nations, Rome.

Gaigher, I. G., Porath, D. and Granoth, G. 1984. Evaluation of duckweed (*Lemna Gibba*) as feed for tilapia (*Oreochromis niloticus* X *O. aureus*) in a recirculating unit. *Aqua Culture*. 41 (3) : 235 - 244.

Gutierrez, K., Sangines, L., Perez, F. and Martinez, L. 2001. Studies on the potential of the aquatic plant Lemna gibba for pig feeding. *Cuban Journal of Agricultural Science* 35: 343-348.

Haustein A. T., Gilman R. H., Skillicorn P. W., Hannan H., Diaz F., Guevara V., Vergara V., Gastanaduy A. and Gilman J. B. 1992a. Performance of broiler chickens fed diets containing duckweed (*Lemna gibba*). *Journal of Agricultural Science, Cambridge* (122) :285-289

Haustein A. T., Gilman R. H., Skillicorn P. W., Vergara V., Guevara V. and Gastanaduy, A. 1990. Duckweed. A useful strategy for feeding chickens: performance of layers fed with sewage-grown Lemnacea species. *Poultry Science*. (69):1835-1844

Haustein, A.T., R.H. Gillman, P.W. Skillcorn, , V. Guevara, F. Diaz,V. Vergara, A. Gastanaduy and J. B. Gillman. 1992b. Compensatory growth in Broiler chicks fed on Lemna gibba. *British Journal of nutrition* 68. 329 - 335.

Haustein, A.T., R.H. Gillman, P.W. Skillcorn, V. Vergara, V. Guevara, and A. Gastanaduy. 1990. Duckweed, a strategy for feeding chickens: Performance of layers fed with sewage-grown *Lemnaceae species. Poultry Science* 69: 1835-1844.

Hillman, W.S. and Culley, D.D. 1978. The use of duckweed. *American Sciencetist.* 66 (July/August): 442-451.

Huque, S.K., Chowdhury, A.S and Kibria, S.S. 1996. Study on the potentiality of duckweeds as a feed for cattle. *Asian Australasian Journal of Animal Sciences.* 9:133-137.

Leng, R.A. 1985. Determining The Nutritive Value of Forage. In Forages in Shouteast Asian and Shout Pacific Agriculture (G.J. Blair, D.A. Ivory, T.R. Evans, eds) pp. 111 - 123. *Proceeding of an international workshop held at Cisarua*, Indonesia. 19 -23 August.

Leng, R.A., Stambolie, J.H. and Bell, R.1994. Duckweed - a potential high-protein feed resource for domestic animal and fish. Symposium at AAAP Bali (July).

NRC. 1981. Nutrient Requirement of Goats : Angora, Dairy and Meat Goats in Temperate and Tropical Countries. National Academy Press. Washington, D.C. 10; 29; 47.

Oron, G. 1990. Economic Concidederations in Wastewater Treatment with Duckweed for effluent and Nitrogen Renovation. *Research Journal WPCF* 62 : 692 - 697.

Ravindran, V. and Blair, R. 1992. Feed resources for poultry production in Asia and the Pacific II. Plant protein sources. *World's Poultry Science Journal* 48: 205-231.

Rusoff, L.L., Blackeney, E. W. and Culley, D.D. 1980. Dckweeds (Lemnaceae Family): a potential source of protein and amino acids. *Journal of Agriculture and Food Chemistry* 28: 848-850.

Samnang, H. 1999. Duckweed versus ground soya beans as supplement for scavenging native chickens in an integrated farming system. *Livestock Research for Rural Development* (http://www.cipav.org.co/lrrd/lrrd11/1/cont111.htm).

Skillicorn, P., Spira, W. and Journey, W. 1993. Duckweed Aquaculture: a new aquatic farming system for developing countries. The International Bank for Recontruction. Washington, D.C., USA.

Staves, R.P. and Knaus, R. M. 1985. Chromium Removal from Water by Three Species of Duckweeds. *Aquatic Botany* 23 : 261 - 273.
Sutton, D.L. and Ornes, W.H. 1975. Phosphorus Removal from Static Sewage Effluent Using Duckweed. *Journal of Environmental quality* 3: 367 -370.