CRC Handbook of Nutritional Supplements

Volume I
Human Use

Editor

Miloslav Rechcigl, Jr.
Nutrition Adviser and Chief
Research and Methodology Division
Agency for International Development
U.S. International Development Cooperation Agency
Washington, D.C.

CRC Series in Nutrition and Food

Editor-in-Chief
Miloslav Rechcigl, Jr.

CRC Press, Inc.
Boca Raton, Florida

(NASA-TM-108074) AQUATIC VASCULAR PLANT FOODS (NASA) 11 p
N93-70468
Unclas
Z9/52 0130464

NASA-TM-108074

#65

NASA
7N-52-TM
130464 P.11

AQUATIC VASCULAR PLANT FOODS

B. C. Wolverton and Rebecca C. McDonald

INTRODUCTION

Research efforts on the nutritional quality of vascular aquatic plants under controlled environmental conditions has been very limited to date. Most of the data in this area have been determined on plants that were collected from natural lakes and ponds. The climate and nutrient content of these aquatic systems were highly variable. In general, the nutritional quality of the plants is a reflection of the conditions under which they were grown. Current research on utilizing vascular aquatic plants to remove nutrients from domestic sewage lagoons has revealed that the crude protein, phosphorus, and other essential elements content of the plants can be improved and consistently maintained at a high level.

In the data following, the nutritional quality of some common vascular aquatic plants has been compiled. A small part on the nutritional value of leaf protein extracts has also been included. All of the information was collected on plants grown on lakes and ponds, unless otherwise noted.

Crude protein was calculated as Kjeldahl nitrogen × 6.25. Carbohydrate was calculated as the difference between 100% and the sum of the percentages of protein, fat, and ash.

PRECEDING PAGE BLANK NOT FILMED

NUTRITIONAL COMPOSITION OF VASCULAR AQUATIC MACROPHYTES

Table 1
PROXIMATE COMPOSITION

Species	Dry weight (%)									
	Water	Crude protein	Fat	Ash	Carbohydrates	Crude fiber	Cellulose	Tannin	Caloric content (kcal/g)	Ref.
Alternanthera philoxerides	85.5	15.6	2.68	13.9	67.82	—	21.3	1.2	3.46	2
	—	19.0	—	18.39	—	—	—	—	—	3
	—	17.94	—	14.72	—	—	—	—	—	8
Aphanizomenon flos-aquae	—	53.56	—	7.21	—	—	—	—	—	3
Brasenia schreberi	89.6	12.5	4.71	8.8	73.99	—	23.7	11.8	3.79	2
Cabomba caroliniana	93.0	13.1	5.42	9.6	71.88	—	26.8	15.6	3.78	2
Ceratophyllum demersum	94.8	21.7	5.97	20.6	51.73	—	27.9	1.9	3.71	2
Chara sp.	—	15.38	—	43.41	—	—	—	—	—	3
Eichhornia crassipes	94.0	22.85	2.12	17.75	57.28	18.3	—	—	—	16
	—	16.31	—	15.93	—	—	—	—	—	3
	91.1	9.6	—	—	—	—	—	—	—	14
	—	16.50	—	18.11	—	—	—	—	—	8
	—	14.94	—	—	—	—	—	—	—	9
E. crassipes (leaves)	84.2	10.7	2.7	14.7	71.9	17.0	—	—	—	14
E. crassipes (leaves)[a]	—	32.88	2.30	11.75	53.07	13.7	—	—	—	16
E. crassipes (stalks)[a]	—	18.88	1.79	17.85	61.48	22.4	—	—	—	16
E. crassipes (roots)[a]	—	22.94	1.39	19.15	56.52	17.8	—	—	—	16
Eleocharis acicularis	88.9	12.5	3.59	9.9	74.01	—	27.9	2.0	3.91	2
Elodea canadensis	—	26.81	—	21.87	—	—	—	—	—	3
Elodea densa	90.2	20.5	3.27	22.1	54.13	—	29.2	0.8	3.35	2
Hydrilla sp.	92.0	18.0	3.80	28.0	50.20	—	32.0	—	3.40	6
Hydrochloa carolinensis	80.6	10.4	2.78	6.1	80.72	—	22.0	0.8	4.10	2
Hydrocotyle ranunculoides	95.8	22.4	2.19	17.4	46.21	11.8	—	—	—	16
Hydrodictyon reticulatum	—	24.19	—	17.94	—	—	—	—	—	3
Hydrolea quadrivalvis	89.0	11.1	3.85	9.3	75.75	—	22.8	2.9	4.00	2
Hydrotrida caroliniana	93.6	9.7	3.85	22.7	63.75	—	29.5	2.5	3.32	2

Jussiaea decurrens	88.2	19.1	3.93	11.7	65.27	—	29.5	4.1	3.88	2
J. diffusa	86.9	10.7	3.76	11.1	74.44	—	24.2	12.6	3.68	2
J. peruviana	81.5	9.4	7.10	7.8	75.70	—	27.5	15.6	3.89	2
Justicia americana	85.0	22.9	3.40	17.4	56.30	—	25.9	1.8	3.98	2
Lemna minor	—	12.63	—	16.07	—	—	—	—	—	8
Lemna sp.[a]	—	15.94	—	18.71	—	—	—	—	—	3
Microcystis aeruginosa	90.0	17.0	3.0	17.6	62.40	10.2	—	—	—	12
Mougeotia sp.	—	50.50	—	6.20	—	—	—	—	—	3
Myriophyllum brasiliense	—	11.06	—	14.54	—	—	—	—	—	3
M. heterophyllum	86.3	14.1	3.78	11.2	70.92	—	20.6	11.9	3.69	2
M. spicatum	90.0	8.5	2.67	15.5	73.33	—	32.7	3.2	3.35	2
Najas flexilis	87.2	9.8	1.81	40.6	47.79	—	18.8	3.2	2.47	2
N. guadalupensis	—	11.63	—	19.16	—	—	—	—	—	3
Nelumbo lutea	92.7	22.8	3.75	18.7	54.75	—	35.6	1.4	3.55	2
Nuphar advena	83.2	13.7	5.25	10.3	70.75	—	23.6	9.2	3.74	2
Nymphaea odorata	88.0	20.6	6.25	6.5	66.65	—	23.9	6.5	4.30	2
Nymphoides aquaticum	86.3	16.6	5.38	9.2	68.82	—	20.7	15.0	3.95	2
Orontium aquaticum	89.7	9.3	3.29	7.6	79.81	—	37.4	2.9	3.95	2
Paspalum fluitans	86.8	19.8	7.85	14.1	85.90	—	23.9	3.3	3.74	2
Phragmites communis	—	11.94	—	12.71	—	—	—	—	—	3
Pistia stratiotes	—	11.44	—	5.90	—	—	—	—	—	3
Pithophora sp.	94.1	16.50	3.75	21.0	58.75	—	12.0	—	3.50	5
Polygonum hydropiperoxides	—	16.06	—	27.77	—	—	—	—	—	3
P. pensylvanicum	80.8	11.9	2.39	7.8	77.91	—	26.9	6.8	4.06	2
P. sagittatum	76.1	10.3	2.77	7.4	79.53	—	23.1	6.8	3.90	2
Potamogeton crispus	85.0	11.0	2.99	8.0	78.01	—	31.2	5.9	4.01	2
P. diversifolius	88.2	10.9	2.85	16.0	70.25	—	37.2	7.2	3.61	2
P. illinoensis	90.2	17.3	2.87	22.7	57.13	—	30.9	2.0	3.40	2
P. nodosus	—	21.44	—	26.49	—	—	—	—	—	3
Rhizoclonium sp.	84.2	11.2	3.62	10.9	74.28	—	21.7	3.4	3.77	2
Ricciocarpus nutans	—	19.75	—	17.16	—		—	—	—	3
Sagittaria latifolia	91.0	10.6	1.1	20.6	67.7	10.6	—	—	—	12
Saururus cernuus	85.0	17.1	6.71	10.3	65.89	—	27.6	2.5	4.12	
Sparganium americanum	78.1	12.1	6.85	11.3	69.75	—	25.3	70	4.28	2
Spirodela oligorrhiza[a]	89.1	23.7	8.11	11.4	56.79	—	20.5	3.7	4.17	2
S. oligorrhiza[d]	87.1	28.5	5.5	17.7	48.3	11.8	—	—	—	12
S. oligorrhiza	91.1	37.7	4.7	11.8	45.8	7.6	—	—	—	12
	—	31.7	5.2	11.4	51.7	8.2	—	—	—	15

NUTRITIONAL COMPOSITION OF VASCULAR AQUATIC MACROPHYTES

Table 1 (continued)
PROXIMATE COMPOSITION

Species	Dry weight (%)									
	Water	Crude protein	Fat	Ash	Carbohydrates	Crude fiber	Cellulose	Tannin	Caloric content (kcal/g)	Ref.
S. polyrhiza[a]	—	39.53	3.40	12.5	44.57	15.6	—	—	—	16
S. polyrhiza[f]	—	24.88	3.05	12.0	60.07	11.8	—	—	—	16
Spirogyra sp.	—	16.88	—	13.33	—	—	—	—	—	3
Typha latifolia	77.1	10.3	3.91	6.9	78.89	—	33.2	2.1	3.69	2
	—	9.94	—	9.70	—	—	—	—	—	3
	—	8.56	—	6.75	—	—	—	—	—	8
Wolfia arrhiza	96.0	19.8	5.0	18.3	56.90	13.3	—	—	—	1
Wolfia sp.	—	21.5	5.5	14.5	58.50	10.6	—	—	—	12

[a] Average of the analyses of plants collected from two, heavily loaded, domestic sewage lagoons.
[b] Average.
[c] Grown in treated waste water effluent.
[d] Average of plant samples collected from anaerobic swine waste lagoon.
[e] Plants collected from one, heavily loaded, domestic sewage lagoon.
[f] Plants collected from natural aquatic system with low nutrient content.

Table 2
MINERAL COMPOSITION

Species	P (%)	K (%)	Na (%)	Ca (%)	S (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)	Ref.
	Dry weight basis											
Alternanthera philoxerides	0.17	4.56	0.37	1.43	0.14	0.31	720	440	—	—	—	3
	0.32	5.20	0.37	0.52	0.29	0.52	720	440	90	15	—	8
Aphanizomenon flos-aquae	1.17	0.68	0.19	0.73	1.18	0.21	833	—	—	—	—	3
Brasenia schreberi	0.14	0.99	0.66	1.79	0.11	0.26	500	265	267	32	—	7
Cabomba caroliniana	—	—	—	—	0.10	—	—	—	—	—	—	3
Ceratophyllum demersum	0.26	4.01	1.16	0.77	0.18	0.42	1,053	486	100	30	—	3
	—	—	—	—	0.30	—	—	—	—	—	—	7
Chara sp.	0.25	2.35	0.13	9.03	0.55	0.92	2,520	—	—	—	—	3
Eichhornia crassipes	0.87	3.12	1.75	0.65	0.49	0.26	1,920	189	37	26	—	16
	0.17	4.16	0.10	1.99	—	0.40	250	—	—	—	—	3
	0.43	4.25	0.34	1.00	0.33	1.05	250	3,940	50	11	—	8
	0.54	4.45	0.41	1.35	0.48	0.56	3,420	270	67	15	20	9
E. crassipes[a]	0.91	3.60	1.83	0.53	0.45	0.85	143	69	21	11	—	16
E. crassipes[b]	0.95	3.02	0.94	0.64	0.34	0.21	130	132	24	22	—	16
E. crassipes[c]	0.56	2.92	1.79	0.61	1.62	0.23	5,790	199	70	63	—	16
Eleocharis acicularis	0.24	2.86	0.54	0.53	0.18	0.33	2,920	192	68	42	—	3
	—	—	—	—	0.28	—	—	—	—	—	—	7
Eleocharis quadrangulata	0.10	1.81	0.12	0.20	0.15	0.10	560	120	45	20	—	7
Elodea canadensis	0.57	3.65	0.90	2.80	0.27	0.65	1,320	—	—	—	—	3
Hydrilla sp.	0.28	2.80	—	4.30	0.40	0.90	—	—	—	—	—	5
Hydrocotyle ranunculoides	0.42	3.33	1.34	0.77	0.31	0.21	7,490	357	59	12	—	16
Hydrodictyon reticulatum	0.23	4.21	0.38	0.69	1.41	0.17	1,313	—	—	—	—	3
Juncus effusus	0.27	0.89	0.40	0.38	0.26	0.11	—	—	—	—	—	7
Justicia americana	0.12	3.28	0.17	0.90	0.18	0.41	1,085	112	265	26	—	8
	—	—	—	—	0.13	—	—	—	—	—	12.1	3
Lemna minor	0.63	5.20	0.30	0.70	0.30	0.51	1,690	750	—	—	—	3
Lemna sp.	0.68	2.03	—	1.34	—	0.30	6,500	1,500	364	14	—	12
Microcystis aeruginosa	0.68	0.79	0.04	0.53	0.27	0.17	382	68	—	—	—	3
Mougeotia sp.	0.25	1.20	0.49	1.68	0.36	0.57	1,080	2,300	—	—	—	3
Myriophyllum brasiliense	—	—	—	—	0.14	—	—	—	—	—	23.5	3
M. heterophyllum	0.16	1.25	1.87	1.47	0.24	0.26	2,000	473	54	44	—	7
M. spicatum	0.42	1.87	0.75	2.77	0.43	0.74	660	5,130	30	—	—	3
Najas flexilis	0.30	1.82	0.78	6.11	0.48	0.97	—	—	—	—	—	3
N. guadalupensis	0.15	3.49	0.61	0.98	0.28	0.47	712	201	48	48	—	7
Nelumbo lutea	0.19	2.27	0.28	1.56	0.16	0.23	126	607	50	40	—	7
Nuphar advena	0.40	1.88	1.47	1.08	0.32	0.27	740	300	50	35	—	7
Nymphaea odorata	0.18	1.28	1.35	1.06	0.14	0.14	600	128	32	36	—	7
Panicum hemitonium	0.14	1.06	0.19	0.38	0.23	0.25	133	292	31	26	—	7
Paspalum fluitans	0.10	2.54	0.22	0.26	0.35	0.22	—	—	—	—	—	3
Phragmites communis	0.10	0.52	0.26	0.43	—	0.27	—	—	—	—	—	3
Pistia stratiotes	0.30	2.9	—	4.40	0.39	0.90	—	—	—	—	—	5
Pithophora sp.	0.30	3.06	0.07	3.82	1.42	0.20	2,836	929	—	—	—	3
Pontederia cordata	0.24	2.58	0.83	0.96	0.22	0.15	200	970	67	60	—	7
Pontamogeton diversifolius	0.27	3.08	0.44	1.14	0.50	0.19	1,240	160	60	36	—	7
Potamogeton illinoensis	0.12	2.66	0.19	2.76	0.20	0.84	—	—	—	—	—	3
Rhizoclonium sp.	0.34	2.37	0.08	0.60	0.27	0.19	—	—	—	—	—	3
Ricciocarpus natans	0.20	1.8	—	0.79	—	0.28	26,800	9,500	82	19	—	12
Scirpus americanus	0.27	0.89	0.40	0.38	0.26	0.11	—	—	—	—	—	7
Spirodela oligorrhiza[a]	1.0	1.57	—	1.3	—	0.29	3,400	700	420	34	—	12
Spirodela oligorrhiza[c]	1.71	1.82	—	0.73	—	0.25	4,700	1,500	119	13	—	12
Spirodela polyrhiza[a]	1.01	2.13	0.74	0.88	0.85	—	—	—	—	—	—	16
Spirodela polyrhiza[d]	0.36	1.22	5.54	1.34	0.45	—	—	—	—	—	—	16

Table 2 (continued)
MINERAL COMPOSITION

Species	Dry weight basis											
	P (%)	K (%)	Na (%)	Ca (%)	S (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)	Ref.
Spirogyra sp.	0.21	0.95	1.42	0.70	0.25	0.38	1,552	—	—	—	—	3
Typha latifolia	0.21	2.38	0.38	0.89	0.13	0.16	120	412	30	37	—	8
Utricularia inflata	0.12	1.98	1.52	0.67	0.26	0.21	2,112	480	108	47	—	7
Wolfia sp.	0.97	3.76	—	0.77	—	—	—	—	—	—	—	12

- Average of the analyses of plants collected from two, heavily loaded, domestic sewage lagoons.
- Grown in treated waste water effluent.
- Average of plant samples collected from anaerobic swine waste lagoon.
- Plants collected from natural aquatic system with low nutrient content.

Table 3
AMINO ACID PROFILE

Essential Amino Acids

Species	Crude protein	Actual proteins[a]	Dry weight basis (g/100 g protein)								Ref.
			Ile	Leu	Lys	Met	Phe	Thr	Trp	Val	
FAO reference pattern	—	—	4.2	4.8	4.2	2.2	2.8	2.8	1.4	4.2	10
Eichhornia crassipes[b]	25.94	19.45	5.51	9.06	6.25	1.83	5.46	4.99	[c]	6.00	5
Eichhornia crassipes	4.7	—	5.6	8.7	7.6	2.3	5.2	5.0	[c]	11.4	13
E. crassipes (leaves)[d]	31.3	29.81	4.89	8.68	5.96	1.47	5.70	4.56	1.04	5.83	17
E. crassipes (stalks)[d]	18.9	16.13	3.35	5.27	3.35	0.87	3.66	3.35	1.04	3.60	16
Hydrocotyle ranunculoides	22.40	20.10	4.93	8.02	7.22	0.95	5.28	4.78	1.43	5.93	16
Justicia americana[e]	17.69	10.76	4.83	8.08	5.95	1.30	5.11	4.92	[c]	5.57	4
J. americana[f]	10.19	5.93	4.55	7.42	5.90	1.69	4.89	5.40	[c]	5.90	4
Pistia stratiotes	23.03	17.63	5.21	9.21	6.93	1.74	5.79	5.03	[c]	6.31	5
Spirodela polyriza[g,h]	39.53	27.79	4.64	8.89	6.44	2.16	5.69	4.61	2.10	5.83	16
S. polyriza[g,h]	24.88	17.74	4.51	8.35	5.53	1.86	5.13	4.46	2.36	5.47	16
Typha latifolia	8.00	—	5.0	9.2	4.6	1.5	5.6	5.3	[c]	6.2	6

Species	Ala	Asp	Arg	Cys	Glu	Gly	His	Pro	Ser	Tyr	Ref.
Eichhornia crassipes[b]	6.95	14.05	6.08	0.29	12.48	6.00	2.16	4.76	4.71	3.91	5
E. crassipes	7.1	10.2	5.2	0.7	9.8	6.4	2.3	4.8	4.8	3.4	13
	5.59	17.37	2.98	11.60	9.29	5.14	1.90	4.73	4.32	2.98	14
E. crassipes, (leaves)[d]	6.50	5.49	12.63	1.37	11.56	5.39	2.31	6.30	4.29	3.55	17
E. crassipes, (stalks)[d]	4.15	3.10	35.40	0.76	11.97	3.66	1.43	3.84	3.10	2.29	16
Hdrocotyle uncodes	5.88	12.40	5.18	1.54	17.28	5.18	2.34	4.43	4.58	2.74	16
Justicia americana[e]	6.13	16.44	5.76	0.09	14.03	5.95	2.69	4.74	5.02	3.44	4
J. americana[f]	5.90	15.34	6.07	0.17	12.98	5.90	2.87	5.40	5.90	4.05	4
Pistia stratiotes	7.06	11.86	4.60	0.37	13.40	6.21	2.19	4.95	5.03	4.17	5
Spirodela polyriza[g,h]	6.88	9.68	7.99	1.66	12.67	5.94	2.05	4.61	4.68	3.53	16
S. polyriza[g,h]	7.28	14.72	6.82	1.30	13.14	5.58	1.69	4.57	4.68	2.59	16
Typha latifolia	6.2	14.5	5.0	0.1	15.4	5.8	2.0	5.2	5.1	3.3	6

- Sum of amino acids.
- Tryptophan analysis not obtained — where tryptophan omitted, author assumed tryptophan to not be present in large quantities and, therefore, the calculated compositional percentages to be reasonably accurate with this omission.
- Not analyzed.
- Plants grown in domestic sewage.
- Maximum protein.
- Minimum protein.
- Predominant species (small amounts of *Lemna* sp.).
- Plants gathered from aquatic system with low nutrient content.

Table 4
VITAMINS

Species	Thiamine HCl (B1) (mg)	Riboflavin (B2) (mg)	B_{12} (μg)	Niacin bound (mg)	C (mg)	A (IU)	Pantothenic acid (mg)	Pyroxidine HCl (B6) (mg)	E (IU)	Ref.
	Dry weight basis (constituents/100 g)									
U.S. RDA	1.5	1.7	6.0	20.0	60	5,000	10.0	2.0	30	11
Eichhornia crassipes										
Whole plant[a]	—	—	23.2	—	—	—	—	—	—	17
Leaves[a]	0.591	3.07	1.26	7.94	—	711	5.56	1.52	30	17
Stalks[a]	—	—	1.49	—	—	—	—	—	—	17
Roots[a]	—	—	68.2	—	—	—	—	—	—	17
Leaf protein extract	0.477	0.842	—	0.28	1.30	—	0.101	0.0613	14	16
Hydrocotyle ranunculoides	0.563	2.32	23.0	10.4	52.3	22,500	1.64	—	32.8	16
Spirodela polyrhiza[a,b]	1.38			13.0	49.0			0.882		16
S. polyrhiza[b,c]	0.664	1.88	26.0	0.687	27.8	31,700		0.876		16

[a] Plants grown in domestic sewage.
[b] Predominant species, small amounts of *Lemna* sp. present.
[c] Plants collected from natural aquatic system with low nutrient content.

NUTRITIONAL COMPOSITION OF LEAF PROTEIN EXTRACT

Table 5
PROXIMATE COMPOSITION OF LEAF PROTEIN EXTRACT

	Dry weight basis (%)						
Species	Crude protein	Fat	Ash	Total carbohydrate	Cellulose	Caloric content (kcal/g)	Ref.
Alternanthera philoxerides	31.4	7.68	12.47	48.5	5.9	4.58	2
Eichhornia crassipes	57.8	3.94	4.77	33.5	—	—	16
Justicia americana	45.73	9.37	8.19	36.7	1.6	5.22	2
Nymphaea odorata	40.0	8.57	4.24	47.2	8.3	4.94	2
Orontium aquaticum	49.	14.88	7.38	28.1	2.6	5.59	2
Sagittaria latifolia	42.8	16.62	4.23	36.4	—	5.42	2

Table 6
AMINO ACID PROFILE OF LEAF PROTEIN EXTRACT

Species	Dry weight (%)																			
	Crude protein	Ala	Asp	Arg	Cys	Glu	Gly	His	Ile	Leu	Lys	Met	Phe	Pro	Ser	Thr	Trp	Tyr	Val	Ref.
Alternanthera philoxerides	31.4	—	—	1.12	—	—	—	0.63	—	0.94	1.61	0.20	Tr[a]	—	—	0.96	—	—	1.37	2
Eichhornia crassipes	57.8	3.64	5.21	3.86	0.70	6.80	3.23	1.33	2.40	5.15	3.81	1.15	3.42	2.96	2.58	2.79	0.84	2.61	3.27	16
Justicia americana[b]	45.7	—	—	2.99	—	—	—	1.07	2.45	4.29	2.80	0.89	2.78	—	—	2.27			2.87	2
Nymphaea odorata	40.0	—	—	2.83	—	—	—	1.07	1.97	3.82	3.73	0.71	2.24	—	—	1.91	—	—	2.62	2
Orontium aquaticum	49.6	—	—	3.17	—	—	—	1.02	2.32	4.30	2.64	0.84	2.80	—	—	2.26	—	—	2.55	2
Sagittaria latifolia	42.8	—	—	2.14	—	—	—	1.14	1.46	1.87	1.52	0.56	Tr	—	—	1.57	—	—	1.80	2

[a] Tr = trace.
[b] Mean.

REFERENCES

1. Bhanthumnavia, K. and McGarry, M. G., *Wolffia arrhiza* as a possible source of inexpensive protein, *Nature (London)*, 232, 5311, 495, 1971.
2. Boyd, C. E., Fresh-water plants: a potential source of protein, *Econ. Bot.*, 22(4), 359-368, 1968a.
3. Boyd, C. E., Some Aspects of Aquatic Plant Ecology, in Reservoir Fishery Resources Symp., Athens, Ga., April 5-7, 1967, 114-129, 1968b.
4. Boyd, C. E., Production, mineral nutrient absorption, and biochemical assimilation by *Justica americana* and *Alternanthera philoxerides*, *Arch. Hydrobiol.*, 66(2), 139-160, 1969.
5. Boyd, C. E., The nutritive value of three species of water weeds, *Econ. Bot.*, 23(2), 123-127, 1969.
6. Boyd, C. E., Amino acid, protein, and caloric content of vascular aquatic macrophytes, *Ecology*, 51(5), 902-906, 1970.
7. Boyd, C. E., Chemical analyses of some vascular aquatic plants, *Arch. Hydrobiol.*, 67(1), 73-85, 1970.
8. Boyd, C. E., Vascular aquatic plants for mineral nutrient removal from polluted water, *Econ. Bot.*, 24, 95-103, 1970.
9. Boyd, C. E., Variation in the elemental content of *Eichhornia crassipes*, *Hydrobiologia*, 38(3-4), 409-414, 1971.
10. Burton, B. T., *Human Nutrition*, 3rd ed., McGraw-Hill, New York, 1976, 162.
11. Burton, B. T., *Human Nutrition*, 3rd ed., McGraw-Hill, New York, 1976, 158.
12. Culley, D. D. and Epps, E. A., Use of duckweed for waste treatment and animal feed, *J. Water Pollut. Control Fed.*, 45, 337-347, 1973.
13. Taylor, K. G., Bates, R. P., and Robbins, R. C., Extraction of protein from water hyacinth, *Hyacinth Control J.*, 9(1), 20-22, 1971.
14. Taylor, K. G. and Robbins, R. C., The amino acid composition of water hyacinth (Eichhornia crassipes) and its value as a protein supplement, *Hyacinth Control J.*, 8, 24-25, 1968.
15. Truax, T. E., Culley, D. D., Griffith, M., Johnson, W. A., and Wood, J. P., Duckweed for chick feed, *La. Agric.*, 16(1), 8-9, 1972.
16. Wolverton, B. C. and McDonald, R. C., National Aeronautics and Space Administrations, National Space Technology Laboratories, unpublished data.
17. Wolverton, B. C. and McDonald, R. C., Nutritional Composition of Water Hyacinths Grown on Domestic Sewage, ERL Rep. No. 173, National Aeronautics and Space Administration, NSTL Station, Mississippi, 1978.