Hydrilla Silage Production, Composition And Acceptability[1,2]

LARRY O. BAGNALL, K. E. DIXON, and
J. F. HENTGES, JR.

Associate Professor of Agricultural Engineering, Graduate Assistant and Professor of Animal Science, Respectively, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611

ABSTRACT

Hydrilla (*Hydrilla verticillata* Royle) was pressed and ensiled in lots ranging from 0.4 to 2000 kg to determine characteristics and acceptability of silage to cattle. About 40% of the harvested dry matter was available for feeding after processing and storage. Adequate supplementary fermentable carbohydrate (dried citrus pulp (DCP), ground shelled corn (GSC)) and propionic acid enhanced product quality. Steers readily accepted hydrilla silage fermented with adequate levels of dried citrus pulp, ground shelled corn, and propionic acid. Steers consumed all of the hydrilla silage and 'Coastal' Bermudagrass (*Cynodon dactylon* L.) hay offered them, but only 67% of the hydrilla hay. It is technically possible to utilize hydrilla by ensiling and feeding to cattle.

INTRODUCTION

Hydrilla infests up to 300,000 ha of Florida's fresh waters[3] and is the most serious and rapidly growing aquatic weed problem, with its range of adaptation extending far to the North (9). Mechanical control of hydrilla appears to be economically comparable to chemical control (1). One potential use of the hydrilla harvested in mechanical control

[1]Florida Agricultural Experiment Station Journal Series No. 905.

[2]Use of brand names does not constitute endorsement by the Florida Agricultural Experiment Station.

[3]Burkhalter, A. P. 1977. Personal Communication.

operations is as cattle feed (6, 7). Efforts to feed dried hydrilla have had inconsistent results (10, 13), and recent energy cost increases may have made the cost of drying prohibitive.

Corn, sorghum, grass, and a variety of products are ensiled for storage and used as animal feeds. Ensiling consists of anaerobic storage of a biological material of appropriate moisture and carbohydrate content and sufficient lacto-bacilli inoculum (natural or introduced) to lead to rapid lactic acid-producing fermentation. The lactic acid suppresses further biological activity and produces a palatable product.

Aquatic plants have not ensiled consistently (3, 4, 12, 14). Ensiled northern lake weeds were not palatable (12, 14), but waterhyacinth (*Eichhornia crassipes* (Mart.) Solms.) has been successfully ensiled (3, 4, 8) and fed to beef cattle and sheep (5, 8, 11).

The objectives of this study were to ensile hydrilla, determine the acceptability and voluntary intake of ensiled hydrilla and sun-cured hydrilla by mature ruminating cattle, and determine the chemical composition of the processed plants.

METHODS AND MATERIALS

Hydrilla was harvested from Orange Lake, about 24 km south of Gainesville, in late August to early October of 1976, by hand for preliminary evaluation and by an Aquamarine harvester[4] for animal evaluation.

The hydrilla, initially at 7.5 ± 3.0% (95% confidence interval) dry matter content, was screw-pressed to reduce moisture content. Fifteen kilograms was pressed in a 10 cm press for preliminary trials, 480 kg was pressed in a 20 cm press for preliminary animal acceptability trials, and 15 700 kg was chopped by forage harvester and pressed in a 30 cm press for animal acceptability and consumption trials. Press performance is shown in Table 1.

The pressed hydrilla (PHV) was mixed with dried citrus pulp (DCP), ground shelled corn (GSC), and Chemstor III[5] (CS), as shown in Table 2, and packed into closed containers. Hydrilla was ensiled in 450 ml widemouth polyethylene bottles for preliminary evaluation, and in 208 l drums and 1.2 x 2.4 m culvert silos for animal evaluation. Mean density of the silage in the bottles was 868 kg/m³ and of that in the culverts was 808 kg/m³. During storage, the silage temperature, drainage loss, and pH were monitored by imbedded thermocouples, trapped collection, and electrical measurement of collected drainage, respectively. Bottle samples were stored 300 days, barrel silages were stored 113 days (119 days to feeding), and culvert silages were stored 133 days. After storage, the silos were opened and the contents were examined and prepared for feeding.

Experiments with cattle tested the acceptability of four treatments of silage from barrel (Experiment 1) and culvert (Experiment 2) silos. A group of four Hereford x Angus crossbred steers averaging 552 kg was offered cafeteria style access to each silage treatment; 9 kg/head/day for Experiment 1 and 34 kg/head/day for Experiment 2. Acceptability was measured by the percentage of each treatment consumed during the entire study because the order of preference for treatments did not change during each experiment. The duration of each experiment was determined by the available silage and was 5 days for Experiment 1 and 12 days for Experiment 2. Experiment 3 utilized the same

TABLE. 1 SCREW PRESS PERFORMANCE WHILE PREPARING HYDRILLA FOR ENSILING.

Press, cm	10	20	Vincent 12
Model	S4A	S8B	30
Pressure, kPa	—	90	150
Speed, rev/min	70	37	16
Feed Rate, kg/hr	150	430	2600
Mass Retention, %	28	65	47
Dry Matter Retention, %	76	88	79
Water Expression, %	73	37	55
Cake Dry Matter Content, %	14	10	11

[4]The authors are grateful to the U.S. Army Corps of Engineers and Dr. W. T. Haller for providing freshly harvested hydrilla and sun-cured hydrilla hay.

[5]Celanese Chemical Co.; 67% propionic acid, 10% formaldehyde, 23% inert ingredients.

TABLE 2. FORMULATION OF SILAGES STORED IN BOTTLES, BARRELS, AND CULVERT SILOS.[1]

Silo type		Mass (g)	PHV (g)	DCP (g)	CS (kg)	GSC (kg)	Dry Matter (g)	Dry Matter (%)
Bottle	1	411	411				59	14.4
	2	414	414				60	14.4
	3	400	385	15			69	17.3
	4	418	402	16			72	17.3
		(kg)	(kg)	(kg)			(kg)	
Barrel	1	102.4	100.0	2.0			11.8	11.5
	2	60.0	60.0[2]				5.2	8.6
	3	104.0	100.0	4.0			13.7	13.2
	4	100.0	100.0				10.1	10.1
Culvert	1	2010	1970	45			273	13.6
	2	1940	1910	23	7		237	12.2
	3	1970	1910			54	251	12.8
	4	1610	1580	25	3		192	12.0

[1] Abbreviations are PHV = Pressed hydrilla, DCP = Dried citrus pulp, CS = Chemstor III, GSC = Ground shelled corn.
[2] Whole hydrilla, not pressed.

steers in a 6-day study to compare the acceptability of hydrilla silage, hydrilla hay and Coastal Bermudagrass hay.

Hydrilla hay was prepared by hand-spreading hydrilla thinly on a pangolagrass (*Digitaria decumbens* Stent.) pasture. It did not dry uniformly, so over-dried parts suffered substantial leaf loss and under-dried parts mold and spoilage. The grass hay was from an average late summer cutting of fertilized, mature Coastal Bermudagrass grown on Hague loamy fine sand in Marion County, Florida.

Samples from two barrel silos, four culvert silos, hydrilla hay and grass hay were weighed, dried at 60 C, ground and stored at room temperature for laboratory analysis. Duplicate analyses for moisture, ash and crude protein were made according to standard methods (2).

RESULTS AND DISCUSSION

After 24 hours of storage in barrels, the temperature of the acid-treated and whole hydrilla was 29 C, that of the pressed hydrilla was 27 C, and that of the hydrilla with DCP was 26 C, 2 to 5 C above average ambient air temperature. After 53 hours of storage, all temperatures were identical and did not differ from each other by more than 1 C or from average ambient temperature by more than 2 C. The culvert silo with the high level of DCP and no CS had a temperature of 34-35 C, 8 C above average ambient, for 4 days after filling, while the other culvert silos were at ambient temperature. Generally, temperature rise caused by the biological activity in the silage was small and brief.

Drainage pH histories of the barrel and culvert silos are shown in Figures 1 and 2, respectively. Generally, the drainage pH, representative of the silage pH (11), of silages containing DCP, fell for 10 to 30 days, then remained stable at approximately 5.0. The final and only measured pH of drainage from silage with DCP and CS, in barrel 1, was 5.3. The pH of the whole hydrilla in barrel 2 rose to 7.0 after the initial fall, as shown in Figure 1. The pH of the hydrilla with corn in culvert 3 rose abruptly to 6.2 at 45 days, then gradually fell to 5.4, as shown in Figure 2. All pH levels were higher than is common for high quality silage (3.5-4.0) of common terrestrial crops, which would normally indicate low silage quality.

Drainage histories of the culvert silos are shown in Figure 3. The whole hydrilla drained profusely throughout the storage period. The pressed hydrilla drained about 2/3 as

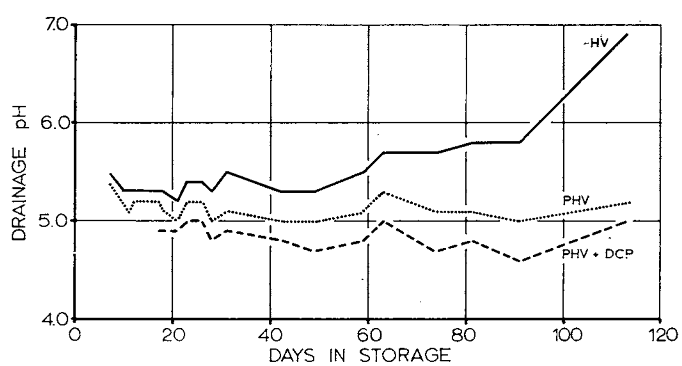

Figure 1. History of pH of fluid draining from hydrilla ensiled in barrels. Abbreviations: HV = whole unpressed hydrilla (Barrel 2), PHV = pressed hydrilla (Barrel 4), PHV + DCP = pressed hydrilla with dried citrus pulp (Barrel 3).

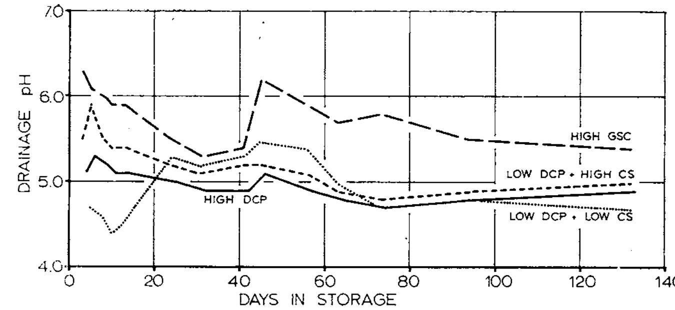

Figure 2. History of pH of fluid draining from pressed hydrilla ensiled in culverts. Abbreviations: GSC = ground shelled corn (Culvert 3), High DCP = 2.2% dried citrus pulp (Culvert 1), Low DCP = 1.4% dried citrus pulp, High CS = 0.4% Chemstor III (Culvert 2), Low CS = 0.2% Chemstor III (Culvert 4).

fast, which was still excessive. The pressed hydrilla with 4% DCP did not begin to drain until the 17th day of storage and only lost 12% of its initial water. The 113-day drainage from the three silages increased with initial dry basis moisture content:

$$D = -22.3 + 0.54\,M \qquad (r = 1.00)$$

where

D = 113-day drainage, % of initial water,
M = initial moisture content, %, dry basis, and
r = correlation coefficient

The acid-treated (CS) hydrilla did not begin to drain until the 91st day and drained substantially less than the other silages, even though its moisture content was higher than that of the 4% DCP silage. There was no drainage from the bottles. Leaking base joints on the culvert silos allowed dispersed leakage and prevented collection of all the drainage.

The bottled hydrilla without DCP was putrid and that in bottle 2 had decomposed to the extent that there was free fluid in the bottle. The final decomposition had taken place in the last few months of storage. The bottled hydrilla with DCP had acceptable odor, color and texture, but had some mold in the top few centimetres of silage, from a poor lid seal or from repeated opening.

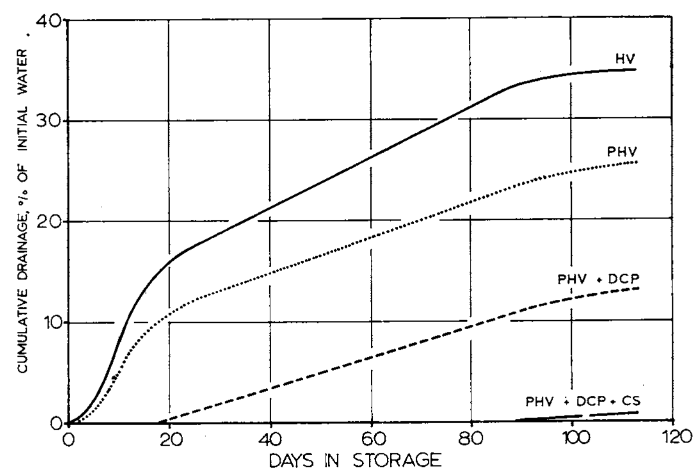

Figure 3. Cumulative drainage from hydrilla ensiled in barrels. Abbreviations: HV = whole unpressed hydrilla (Barrel 2), PHV = pressed hydrilla (Barrel 4), PHV + DCP = pressed hydrilla with dried citrus pulp (Barrel 3), PHV + DCP + CS = pressed hydrilla with dried citrus pulp and Chemstor III (Barrel 1).

The whole hydrilla in barrel 2 was completely spoiled, ranging from rank putrefaction on the top to bland and earthy through most of the mass. Spoilage on the other silages in barrels ranged from 22 to 30% and had a bland, earthy odor, similar to the best of the whole hydrilla. The odor of the usable acid-treated hydrilla was bland and very good, that of the 4% DCP silage was moderately strong and good, and that of the untreated pressed hydrilla was moderately intense and fair.

Spoilage in the culvert silos ranged from 17 to 25% and had the strong putrid odor typical of spoiled silage. Odor of the usable silages was typical of good silage. There was extensive spoilage around the doors in the sides of the culverts and around the base leaks, which should not be typical of production silos. Spoilage is primarily a surface effect and, as a percentage of the total mass, decreased with increasing silo size. It should be much smaller in properly filled commercial silos.

Retention of hydrilla during the ensiling process is shown in Table 3. Almost all of the mass in the bottles was retained, but there was a 20 to 48% loss of dry matter, converted to a 1.5 to 4.3% gain in water, by biological and chemical activity. The barrels lost 7 to 33% of their mass, much of it attributable to drainage; dry matter losses from the barrels ranged from 24 to 37%. The culverts lost 33 to 42% of their mass and 38 to 48% of their dry matter; part of this loss could have been due to poor fill accounting.

All of the silages with acceptable odor, flavor, appearance and texture had lower dry matter content at the end of storage than at the beginning, with a reduction of 2.6 $\pm$ 1.2% (95% confidence interval) during storage. Metabolic activity and drainage account for most of the dry matter loss.

Ensiling in barrels preserved 72% of the end product, 50% of the initial dry matter, or 44% of the harvested dry matter in condition suitable for feeding. Ensiling in culverts preserved 81% of the end product, 44% of the initial dry matter, or 35% of the harvested dry matter in condition suitable for feeding. Hydrilla in the culverts shrank 35 $\pm$ 12% (95% confidence interval), similar to that of some of the waterhyacinth silages (3). Final density was 774 $\pm$ 77 kg/m^3, 4% lower than initial density.

In the initial (Experiment 1) animal feeding trial, steers readily accepted the silages stored in barrels. Table 4 shows that they preferred silages with low DCP + CS, high DCP, and pressed with no additive, in that order. Composition of the two most favored treatments were similar to each other and the culvert-stored silages, as shown in Table 5.

TABLE 4. ACCEPTABILITY OF HYDRILLA SILAGES BY CATTLE IN CAFETERIA-STYLE ACCESS.

Silage Formulation	Percent Consumed[1]
EXPERIMENT 1 (offered 9 kg of each silage/head/day)	
Pressed, low pulp, acid (barrel 1)	100
Pressed, high pulp (barrel 3)	100
Pressed (barrel 4)	94
Whole (barrel 2)	0
EXPERIMENT 2 (offered 34 kg of each silage/head/day)	
Corn (culvert 3)	98.0
High pulp (culvert 1)	92.2
Low pulp, high acid (culvert 2)	87.3
Low pulp, low acid (culvert 4)	75.8

[1] Silage consumption as a percentage of that offered.

In the second (Experiment 2) feeding trial, culvert-stored silage treatments were accepted in the order of preference shown in Table 4. The rankings of the four silages were high GSC, high DCP, low DCP + high CS, and low DCP + low CS. The first three were readily eaten, but the last was not touched until all of the others were totally consumed. Silages preserved with high levels of GSC or DCP additives were the most preferred. In the two treatments which contained both CS and a low level of DCP, the steers preferred the higher quantity of CS.

The chemical composition shown in Table 5 reveals a wide variation in ash (coefficient of variation: 17%). The most preferred culvert-stored treatment also contained the

TABLE 5. CHEMICAL COMPOSITION OF HYDRILLA SILAGES AND HAY.[1] INITIAL FORMULATION IS SHOWN IN TABLE 2.

Product		Dry Matter (%)	Ash	Crude Protein
Hydrilla Silage	(Barrel)			
Low pulp, acid	1	13.5	15.1	26.0
High pulp	3	14.3	14.6	25.5
Hydrilla Silage	(Culvert)			
High pulp	1	12.9	12.0	23.8
Low pulp, high acid	2	14.9	17.8	25.6
Corn	3	13.3	15.9	26.6
Low pulp, low acid	4	12.2	17.2	23.1
Hydrilla Hay		83.8	12.9	25.6
Bermudagrass Hay		90.8	4.9	10.1

[1] Ash and protein expressed as percent of final dry matter.

TABLE 3. RETENTION AND LOSSES OF HYDRILLA SILAGE UNDER VARIOUS STORAGE CONDITIONS. REFER TO TABLE 2 FOR ADDITIVES AND FORMULATION OF SILAGE.

	Bottle				Barrel				Culvert			
	1	2	3	4	1	2	3	4	1	2	3	4
Final mass (% IM)[1]	98	95	98	98	93	67	81	67	60	64	58	67
Drainage (% IM)	0	0	0	0	0	32	11	23	—	—	—	—
Final dry matter (% IDM)	81	52	68	78	76	75	69	63	54	52	52	62
Final dry matter content (%)	12	8	12	14	10	10	11	10	12	10	11	11
Usable silage (% FM)	0	0	100	100	78	0	68	71	83	82	75	83
Final volume (% IV)	—	—	—	—	—	—	—	—	58	73	60	70
Final density (kg/m^3)	—	—	—	—	—	—	—	—	832	714	781	767

[1] Abbreviations of units are: % IM = percent of initial mass, % IDM = percent of initial dry mass, % FM = percent of final mass, % IV = percent of initial volume.

most protein but all four treatments were rich in protein (coefficient of variation: 6%). The lowest ranked culvert-stored silage was highest in moisture content, darkest in color and had a foul odor different from the other three treatments. In the literature, variation has been reported in the protein composition of hydrilla ranging from 17% to 46% (7). One explanation for the variation could be that the weeds were harvested from waters which varied in nutrient availability (7). In harvesting the hydrilla used in this study, it was observed that numerous fish were captured which may have increased the protein values.

The third (Experiment 3) animal trial showed that the daily allotments of grass hay and hydrilla silage were entirely consumed, with the grass hay initially being preferred and consumed first. Near the end of the experiment, the steers showed no preference between hydrilla silage and grass hay. Hydrilla hay was consumed only when none of the other feeds remained, but this may have been a reflection of its low quality and mold content rather than its nutrient content.

TABLE 6. ACCEPTABILITY OF HYDRILLA SILAGE, HYDRILLA HAY AND COASTAL BERMUDAGRASS HAY BY STEERS FED AD LIBITUM (EXPERIMENT 3).

Feed	Percent Consumed
Grass Hay	100
Hydrilla Silage	100
Hydrilla Hay	66.8

CONCLUSIONS

Cattle readily accepted well-preserved hydrilla silage, but not low quality hydrilla hay. The vegetation must be dewatered and supplemented with fermentable carbohydrate to ensile satisfactorily.

LITERATURE CITED

1. Anon. 1976. U.S. Corps of Engineers Harvesting Hydrilla on Orange Lake in Florida. Aqua-Views 2(3):1. Aquamarine Corp.
2. A.O.A.C. 1970. Official Methods of Analysis. Association of Official Agriculture Chemists. Washington, D.C. pp. 16-393.
3. Bagnall, L. O., J. A. Baldwin, and J. F. Hentges, Jr. 1974. Processing and storage of waterhyacinth silage. Hyacinth Cont. J. 12: 73-79.
4. Baldwin, J. A., L. O. Bagnall, and J. F. Hentges, Jr. 1974. Preservation and cattle acceptability of waterhyacinth silage. Hyacinth Cont. J. 12:79-81.
5. Baldwin, J. A., J. F. Hentges, Jr., L. O. Bagnall, and R. L. Shirley. 1975. Comparison of pangolagrass and waterhyacinth silages as diets for sheep. Journal of An. Sci. 40(5):968-971.
6. Boyd, C. E. 1968. Evaluation of some aquatic weeds as possible feedstuffs. Hyacinth Cont. J. 7:26-27.
7. Boyd, C. E. 1969. The nutritive value of three species of water weeds. Econ. Bot. 23(2):123-127.
8. Byron, H. T., J. F. Hentges, Jr., J. D. O'Connell, and L. O. Bagnall. 1975. Organic acid preservation of waterhyacinth silage. Hyacinth Cont. J. 13:64-66.
9. Haller, W. T. 1976. Hydrilla: a new and rapidly spreading aquatic weed problem. Circular S-245, Agricultural Experiment Station, University of Florida. 13 pp.
10. Hentges, J. F., Jr. 1970. Processed aquatic weeds for cattle nutrition. Proc. of Aquatic Plant Res. Conf., Gainesville, 62-67.
11. Kiflewahid, B. 1975. Nutrient composition and digestibility of waterhyacinth (*Eichhornia crassipes*, Mart) by cattle. Ph.D. Dissertation, University of Florida. 114 pp.
12. Linn, J. G., R. D. Goodrich, and E. J. Staba. 1974. Aquatic plants from Minnesota. Part 5—Digestibility and fermentation of aquatic plants. Bulletin 70, Water Resources Research Center, University of Minnesota. 24 pp.
13. Salveson, R. E. 1971. Utilization of aquatic plants in steer diets: voluntary intake and digestibility. MSA Thesis, University of Florida. 45 pp.
14. Sy, S. H., R. G. Koegel, D. F. Livermore and H. D. Bruhn. 1973. Utilization of Eurasion watermilfoil. ASAE Paper 73-5510. Amer. Soc. Ag. Eng. 27 pp.