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Bulk Mechanical Properties of Hydrilla[1]

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ABSTRACT

Bulk samples (0.16 m^3) of fresh intact hydrilla (*Hydrilla verticilata* Royle) were compressed to determine physical and mechanical properties. Mean initial density was 63 kg/m^3. Pressure increased gradually to 14 kPa as density was increased to 400 kg/m^3, then rose abruptly to 92 kPa as density was increased to 800 kg/m^3. Compression to 400 kg/m^3 required 5.2 W•h/Mg and compression to 800 kg/m^3 required 18 W•h/Mg.

INTRODUCTION

Capacities of mechanical management systems for aquatic plants are usually limited by the volume of the plant material that must be handled, transported and stored. Chopping and compacting have been proposed as means of reducing volume or increasing density. Stewart (5) found that chopping increased the density of waterhyacinth (*Eichhornia crassipes* [Mart.] Solms) by up to 300% and required as little as 380 W•h/Mg. Bagnall[2] reported that chopping increased the densities of water hyacinth and hydrilla 190% and 130%, respectively. Bulk density and compression characteristics of hydrilla are needed for determination of feasibility of compaction as a means of volume reduction and for rational design of compaction, handling, transportation and storage systems.

Koegel, *et. al.* (4) reported physical-mechanical properties of Eurasian watermilfoil (*Myriophyllum spicatum* L.) and Cifuentes and Bagnall (1, 2)[3,4] determined properties of waterhyacinth. They worked on small, intensively-treated samples at high pressures, but the techniques and analysis procedures are adaptable to low pressures. Bagnall[5] deter-

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[1] Florida Agricultural Experiment Station Journal Series Number 1948.

[2] Bagnall, L. O. 1978. Composting characteristics of waterhyacinth and hydrilla. Paper to Aquatic Plant Management Society, Jacksonville.

[3] Bagnall, L. O. 1974. Mechanical properties of mature waterhyacinth stems. Paper to Southern Association of Agricultural Scientists—Southeast Region ASAE.

[4] Bagnall, L. O. and F. J. Corral. 1974. Static pressure fractionation characteristics of waterhyacinth. ASAE paper 74-5008. American Society of Agricultural Engineers. 20 p.

[5] Bagnall, L. O. 1978. Bulk mechanical properties of waterhyacinth. Paper to Aquatic Plant Management Society, Jacksonville.

mined bulk properties of waterhyacinth and the techniques developed in those tests have been adopted for the bulk tests on hydrilla.

The objective of the work reported here was to determine the pressure and energy required to compress bulk intact hydrilla. Secondary objectives were to determine the bulk density of the intact plants and losses incurred during low pressure compression.

METHODS AND MATERIALS

A bulk press (Figure 1), consisting of 61 cm diameter by 61 cm deep cylinder with a platen, loading beam and perforated base, was built to apply loads up to 80 kN. Loads up to 2 kN were applied by a calibrated deadweight-lever system. Higher loads were applied by a hydraulic cylinder and measured by a pressure gauge. Displacements during light loading were measured with a meter stick at four locations on the platen pheriphery. When the hydraulic system was used, displacement was measured on the calibrated piston rod.

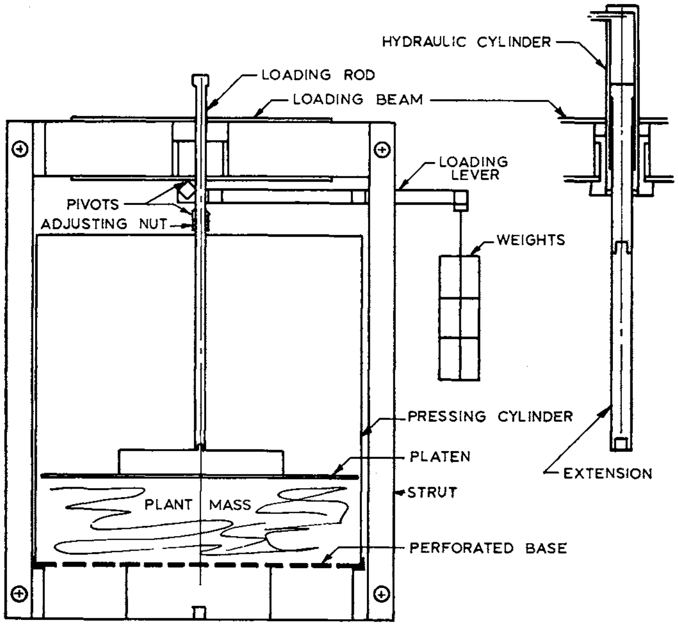

Figure 1. Bulk pressing apparatus, shown with deadweight-lever system in place. Auxiliary drawing shows hydraulic system.

Hydrilla was harvested from Lake Lochloosa on July 21, August 9, and August 10, 1978 using an Aquamarine harvester. It was transported to Gainesville and pressed 1.4 to 7.0 hours after harvest. The hydrilla was placed in a 76 *l* garbage can, weighed on a platform scale and placed in the pressing cylinder. Two samples from the supply surplus were canned for oven drying. After levelling, the plants were loaded with the press platen, followed by the deadweight-lever system, then the hydraulic system. Depth of sample was observed at specified loadings. If the platen tipped excessively, it was removed, the charge redistributed and the platen replaced. All data were recorded orally on a continuously-running cassette recorded, which provided a time base for transcribing the data. Each pressing cycle required 12.3±1.8 minutes (95% confidence interval on mean). Juice samples were collected in beakers placed below the perforated base. After each test, the residue was weighed and sampled.

Cifuentes and Bagnall (2) regressed their aquatic plant compression data to an equation developed by Gurnham and Masson (3):

$$p = ae^{b/v}$$

where

p = pressure
v = specific volume
a,b = constants determined by regression

The regression followed the data quite well, but showed infinite volume at no pressure. The form,

$$\frac{V - V_e}{V_o - V_e} = ae^{bp}$$

where

V_e = equilibrium or asymptotic specific volume
V_o = initial specific volume

had inadequate curvature to follow the data. The data were finally regressed non-linearly to:

$$\frac{V - V_e}{V_o - V_e} = e^{bp^a}$$

which tracks the data almost precisely and locates the initial specific volume. Apparent specific volume, the ratio of volume to initial mass, was used in all analyses. It neglects the effect of mass loss during compression, but is more relevant to the design of the compression structure than true specific volume, which introduces uncertainties due to change of basis.

RESULTS AND DISCUSSION

Pressure required to compress intact hydrilla is shown in Figures 2 and 3. The plants compressed readily to 0.0035 m³/kg but lost little additional volume at pressures above 7 kPa.

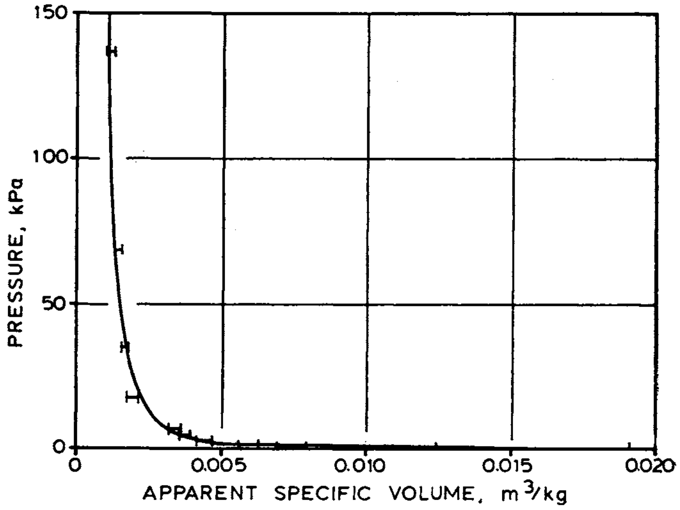

Figure 2. Full-range pressure-volume relationship for intact hydrilla. Short line segments with vertical ends show ranges of apparent specific volume at each observation pressure.

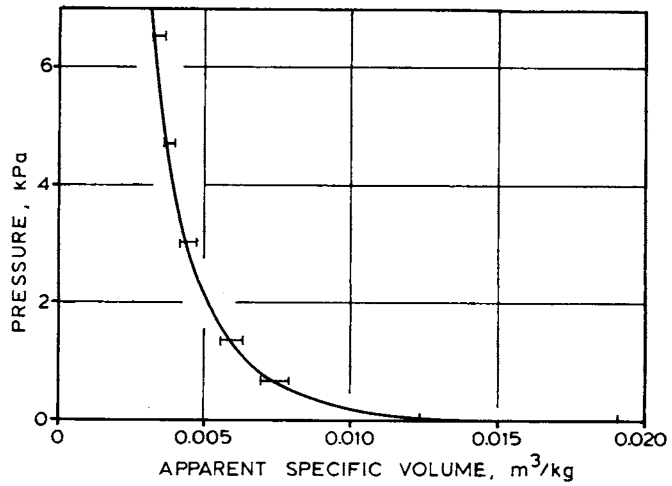

Figure 3. Low-range pressure-volume relationship for intact hydrilla. Short line segments with vertical ends show ranges of apparent specific volume at each observation pressure.

The regression over the entire range of the data from all ten tests was:

$$\frac{V - 0.00082}{0.0160 - 0.00082} = e^{-1.115\,p^{0.257}} \qquad r = 0.997$$

where

V = apparent specific volume, m^3/kg
p = pressure, kPa
r = correlation coefficient on the transformed data.

The full range regression describes the data only moderately well in the low pressure range. The regression in the range up to 7 kPa was

$$\frac{V - 0.00212}{0.0160 - 0.00212} = e^{-1.143\,p^{0.412}} \qquad r = 0.999$$

Mean modulus of elasticity in the range up to 7 kPa, based on linear regression of the deadweight-lever loading data was 6.5 ± 0.4 kPa.

It follows from the pressure-volume relationships that as bulk intact hydrilla is stacked, the density near the bottom of the stack is greater than that near the top and that the average density of a deep stack is greater than that of a small stack. Numerical integration of the regressions leads to the depth-density relationships shown in Figure 4 and the mass-depth relationship in Figure 5.

Energy required to compress the hydrilla, based on numerical integration of the pressure-volume regressions, is shown in Figures 6 and 7. Energy consumption up to about 14 kPa was low, but increased rapidly after that point.

Mean initial density was 63 ± 6 kg/m^3. Mean initial dry matter content was 7.0 ± 1.2%. Mean mass loss during compression to 140 kPa was 7.4 ± 1.6%. The expressed fluid contained 69 ± 16 mg/l total Kjehldahl nitrogen, 10.3 ± 5.8 mg/l total PO_4 phosphorus, and 0.13 ± 0.09% total solids, 56 ± 11% of which was fixed solids. Little fluid was expressed by low pressure compression of bulk intact hydrilla and the quality of that fluid, though clearly

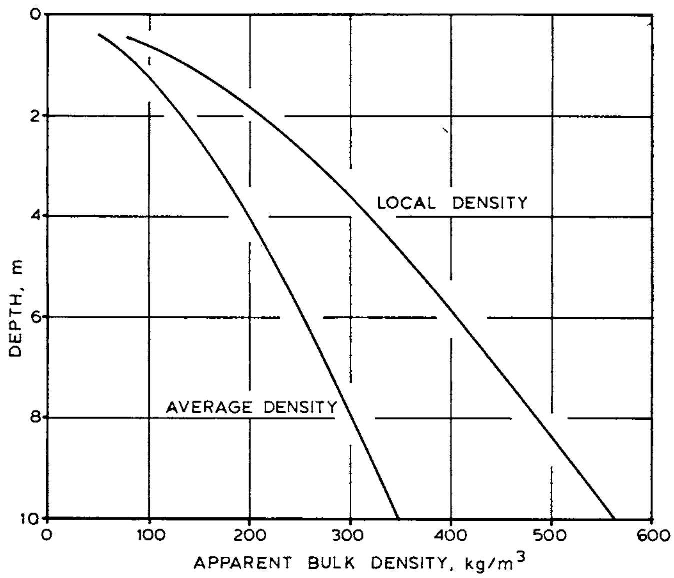

Figure 4. Apparent bulk density of intact hydrilla in columnar stacks. Local density is that occurring at the shown depth. Average density is that from the top of the stack to the shown depth.

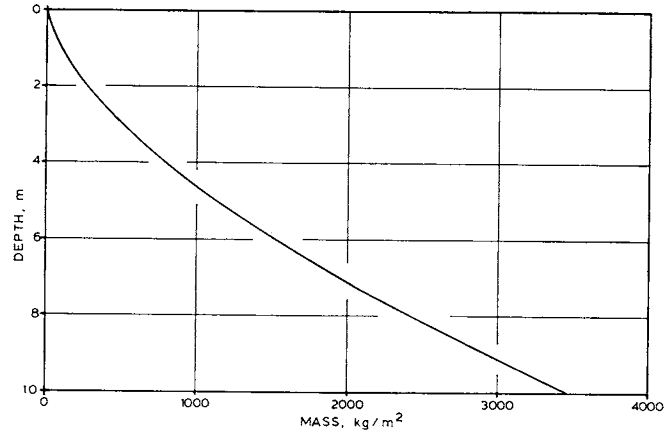

Figure 5. Mass of intact hydrilla in a columnar stack.

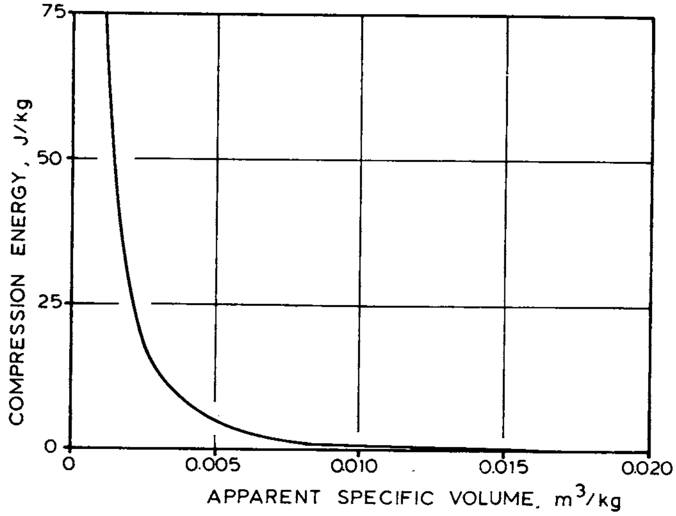

Figure 6. Energy required to compress intact hydrilla through the full range of pressures used.

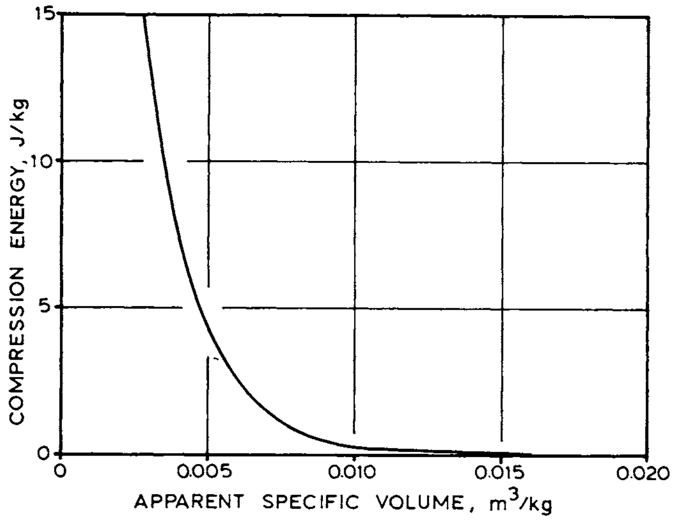

Figure 7. Energy required to compress intact hydrilla through the range of pressures up to 7 kPa.

not as pure as potable water, is not nearly as "polluted" as that from screw-pressing.

APPLICATION

A typical state-of-the-art harvester, capable of harvesting 0.4 ha/h and carrying 25 m^3 of harvested hydrilla, can carry 2500 kg. It must, therefore, be unloaded every 0.09 ha or 0.2 h. If the harvester were equipped with a lightweight compactor capable of applying 92 kPa to the hydrilla, carrying capacity would be increased to 20,000 kg and the harvester would need to be unloaded only every 0.7 ha or 1.9 h. Material transfer restricts system capacity. The sevenfold increase in hold capacity should substantially increase system capacity and/or reduce cost. The additional power required to operate the compactor would be 0.2 kW or 0.5 kW•h/ha. That energy should be recoverable many times over in reduction of transporation energy.

ACKNOWLEDGMENT

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Appendix

Conversions—SI metric to "English" units
length
1 m = 3.28 ft.
1 cm = 0.394 in.
volume
1 m^3 = 35.3 ft^3
1 l = 0.264 gal.
mass
1 kg = 2.20 lbm
1 Mg = 1.10 T
force
1 kN = 0.225 lbf
density—specific volume
1 kg/m^3 = 0.0624 lbm/ft^3
1 m^3/kg = 16.0 ft^3/lbm
pressure
1 kPa = 0.145 lbf/in^2
specific energy
1 W • h/Mg = 0.00122 hp • h/T
1 J/kg = 0.335 ft • lbf/lbm
1 J/kg = 0.000338 hp • h/T
1 kW•h/ha = 0.543 hp•h/A
power
1 kW = 1.34 hp
area
1 ha = 2.47 A

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