Pressing Characteristics Of Waterhyacinth [1,2]

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ABSTRACT

Waterhyacinth [*Eichhornia crassipes* (Mart.) Solms] at 95% moisture content was pressed in cylinders with perforated liners. Parameters affecting radial flow of expressed juices were examined. Particle size reduction, particularly by shearing, and cake rotation within the press increased expression efficiency. Fluid expression decreased as cylinder radius increased and available drainage area decreased. Optimum compression time is about 40 seconds. Cake density is related to material pressure.

INTRODUCTION

Waterhyacinth may be mechanically harvested as an alternative to chemical or biological control, but removal and disposal costs are high. Harvesting would be more desirable if the high costs were offset by sale of a product. The plant is approximately 95% water, which is difficult and costly to handle and remove. A processing system should include components to quickly and efficiently remove a large fraction of this water.

Expression, compression of a solid-liquid system so that the solid is retained and the liquid escapes, has been successfully applied to a wide variety of agricultural materials. A variety of press configurations are possible, but when product tissue destruction is tolerable, continuous screw presses are often used. A continuous screw press is a heavy screw conveyor, with a perforated or slotted housing, in which pressure is increased during passage by an outwardly tapered shaft, decreasing pitch, periodic flow restriction and/or discharge restriction. Dunning and Converse (7) and Dozier and Van Derveer (6) reported applications of screw presses in the paper industry to remove water and liquid chemicals from fiber; Casselman *et al.*, (3) and Pirie (11) used screw presses to remove a high-protein liquor from forage crops; Bruhn *et al.*, (2) and Bagnall *et al.*,[3] (1) dewatered aquatic plants with screw presses. Many of these applications were made with existing equipment and little understanding of the product characteristics or product-machine interactions. Ginaven and Adams (8), McDonald[4] and Nolan[5] developed and applied theory to screw press design, based on paper industry material characteristics. Nakamura (10) determined the Kraft pulp characteristics used in Nolan's development. His procedures, slightly modified, can be applied to a variety of materials, including waterhyacinth.

Density increases, or specific volume decreases, with increasing pressure. Deerr (5) proposed, from his work with sugar cane and bagasse, the empirical relation:

$$V = \frac{C}{p^n}$$

where V = cake specific volume (fiber plus unexpressed juice)
p = material pressure
C = constant
n = constant

Gurnham and Mason (9) developed, at equilibrium conditions, (when no further flow takes place) an equation:

$$p = a\,e^{b/V}$$

where a and b are constants. The pressure-volume relationship indicates the most efficient press geometry.

In order to develop a systematic procedure for design of waterhyacinth presses, particularly screw presses, the objectives of this investigation were to relate pressure, specific volume and moisture removal, to determine effects of press geometry and pressing procedures and to establish expression energy.

METHODS AND MATERIALS

About 4.5 kg of waterhyacinth was chopped, thoroughly mixed and dried at 103 C for 24 hr with forced convection. Random 1.5 g samples were introduced into previously weighed volumetric flasks. The flasks were again weighed and sufficient distilled water was added to cover the samples. The flasks were then evacuated to 1.33 kPa (0.0131 atm) absolute for 30 min to remove air trapped within the

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[1] Florida Agricultural Experiment Station Journal Series No. 5803.

[2] Support for the research reported herein was received from the Florida Water Resources Research Center, the Florida Department of Natural Resources and the Southwest Florida Water Management District.

[3] Bagnall, L. O., T. W. Casselman, J. W. Kesterson, J. F. Easly, and R. E. Hellwig. 1971. Aquatic forage processing in Florida. ASAE paper 71-536. 23 p.

[4] McDonald, M. C. 1944. Apparatus for the treatment and removal of chemicals from cooked or digested fiber pulp. U.S. Pat. 2,335,091.

[5] Nolan, W. J. 1971. Apparatus for the removal of liquids from fibrous materials. U.S. Pat. 3,585,924.

waterhyacinth. Distilled water was then added to bring the meniscus to the volumetric mark. The flasks were placed in 20 C bath for 2 hours. The menisci were checked and, if necessary, adjusted and the flasks weighed.

The specific volume of the dry waterhyacinth was calculated using

$$V_f = \frac{V_t - \dfrac{m - m_s}{d_w}}{m_s}$$

where V_f = specific volume of dry waterhyacinth. cm^3/g,
V_t = total volume (water and dry waterhyacinth), cm^3,
m = total mass (water and waterhyacinth),
m_s = mass of oven-dry waterhyacinth, g,
d_w = density of water at observed temperature, g/cm^3, (20 C = 0.99823).

Assuming that the specific volume of the waterhyacinth at any consistency (dry matter content) can be calculated from the specific volume of the dry material, the following relation can then be used:

$$V_x = V_w + (V_f - V_w)x$$

where V_x = specific volume of waterhyacinth at consistency x, cm^3/g,
V_w = specific volume of water, cm^3/g,
V_f = specific volume of dry waterhyacinth, cm^3/g,
x = consistency = $m_f/(m_w + m_f)$
m_w = mass of water, g,
m_f = mass of dry waterhyacinth, g.

Pressing tests were performed in three specially built cylinders and a standard Carver pressing cage. Each cylinder had five sections, as shown in Figure 1: (a) 178 mm long longitudinally grooved cylinder wall, with drainage holes at the base; (b) a double crimped square mesh wire cloth (4.2 mm centers, 1.6 mm wire) that fit snugly against the cylinder wall; (c) a stainless steel inner-liner with 0.96 mm diameter perforations arranged in different patterns giving open areas of 22, 26, and 46%, which fit snugly against the surface of the wire cloth; (d) a close fitting piston for each cylinder with diameters of 67.9, 92.2 and 142.8 mm; and (e) a base plug for each cylinder of the same diameter as the piston to prevent the cake from escaping when pressure was applied. The Carver cage consisted of a cylinder 90 mm in diameter and 190 mm deep with narrow vertical milled slots. Open area was approximately 5%. A vernier scale was attached to the press to measure the height of the cake after pressure was applied. All cylinders and cages were loaded in a standard hand-operated Carver laboratory press.

Whole waterhyacinth, grown on secondary-treated sewage effluent, was used in all steps of this investigation. Moisture contents of 500 g samples of waterhyacinth used in these tests were found by oven drying ten randomly selected samples on different days at 103 C for 24 hours. The 95% confidence interval on the mean moisture content was 94.96 ± 0.38%. This mean value was used in all our calculations.

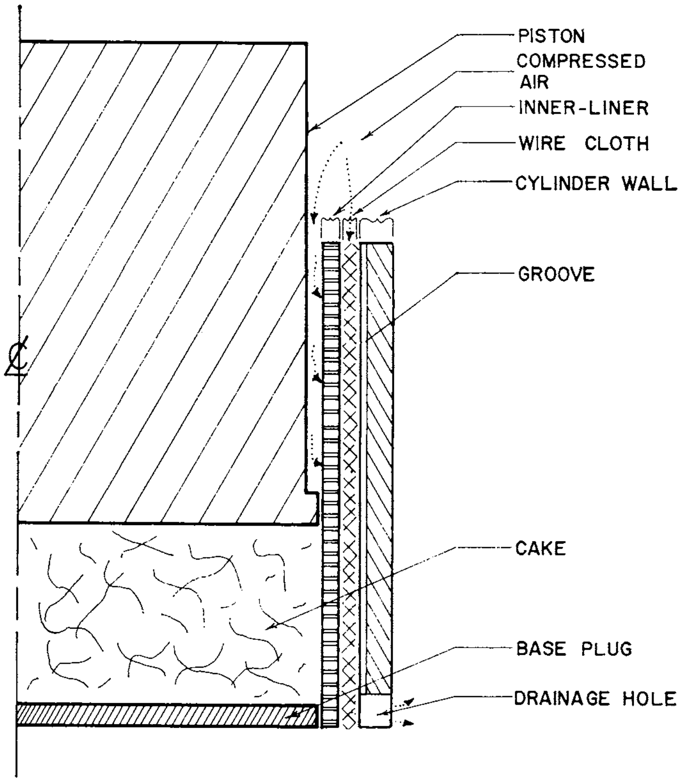

Figure 1. Waterhyacinth pressing cylinder cross-section.

Samples were prepared for pressing in four different ways: (a) whole plants, cut only as much as needed to fit the cylinder; (b) chopped by hand to 25 mm lengths; (c) thoroughly blended into a slurry; and (d) minced with a meat grinder with a medium cutter. Samples of approximately 200 g were placed into the pressing cylinder or Carver cage. The pressure was increased so that in some predetermined time (10 to 80 sec) a selected maximum material pressure was obtained. As the pressure increased, fluid was expressed. A compressed air jet forcefully removed the filtrate from the cylinder surface, preventing fluid reabsorption after compression was released. Pressure was maintained for 80 sec after the maximum pressure was reached. The compressed cake was weighed and the amount of filtrate calculated from the difference between remaining cake and original sample. In some cases, pressing was repeated a second and third time under the same conditions with intermediate weighings and agitation.

RESULTS AND DISCUSSION

The mean "observed specific volume" of dry waterhyacinth, using water as the immersion medium, was 0.6036 ± 0.0204 cm^3/g. The predicted specific volume of waterhyacinth, as a function of consistency, is:

$$V_x = 1.0029 - 0.3993x.$$

Juice loss during pressing increased as plant particle size decreased, as indicated in Table 1. Waterhyacinth should be minced or otherwise very finely divided before or during pressing to maximize water removal. Such reduction destroys the fibrous structure of the plant, allowing

TABLE 1. EFFECT OF WATERHYACINTH PARTICLE SIZE ON FLUID EXPRESSION FROM 200 G SAMPLES IN CARVER PRESSING CAGE AT 1100 KPA.

Treatment	Samples	Fluid Expressed[a b] (%)
Whole Plants	4	17.5 ± 6.4 a[c]
Chopped 25 mm pieces	4	23.8 ± 5.1 b
Minced	4	52.7 ± 3.1 c
Thoroughly blended	2	57.5 ± 15.6 c

[a] (100 x filtrate mass)/(.9496 x initial mass)
[b] 95% confidence interval
[c] Letters indicate significant differences ($\alpha = .05$) by Duncan's New Multiple Range Test

the pressure to be applied to the fluid, and damages cells, exposing the fluid for random drainage. Filtrate opacity increased as particle size decreased, indicating higher loss of solids.

Juice expression increased rapidly with increasing pressure up to 600 kPa, but higher pressure did not remove much more juice (Figure 2). A production press need not be designed to achieve a higher continuous pressure. Cake agitation between additional pressings increased expression by 12 to 20%

Based on combined data from three sequential pressings, pressure and specific volume are related by regression to Gurnham's (9) equation as shown in Figure 3. For a maximum pressure of 600 kPa, the minimum specific volume of the material in the press would be 0.936 cm^3/g. Apparent specific volume, the ratio of volume to initial mass of waterhyacinth in the cylinder, is more appropriate for design than the true specific volume. It was much lower and decreased with water content.

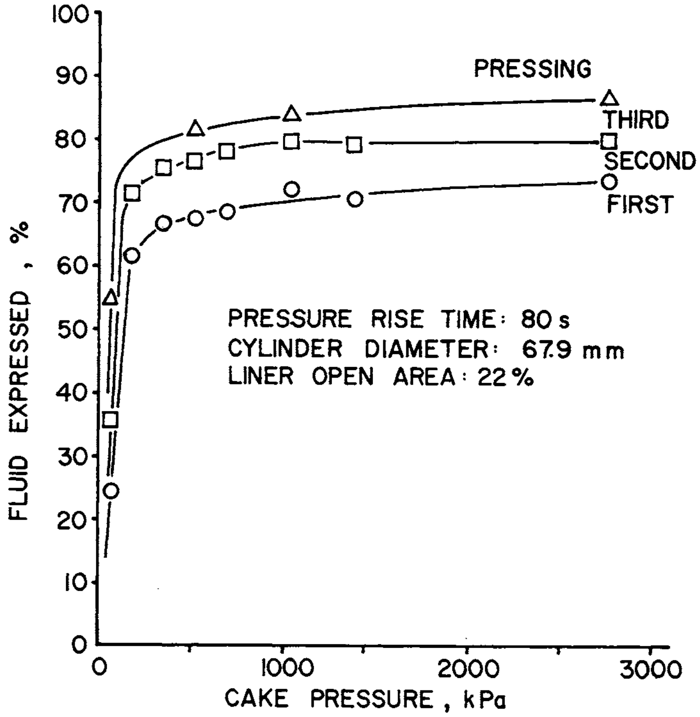

Figure 2. Effects of pressure and multiple pressings on fluid expression from minced waterhyacinth.

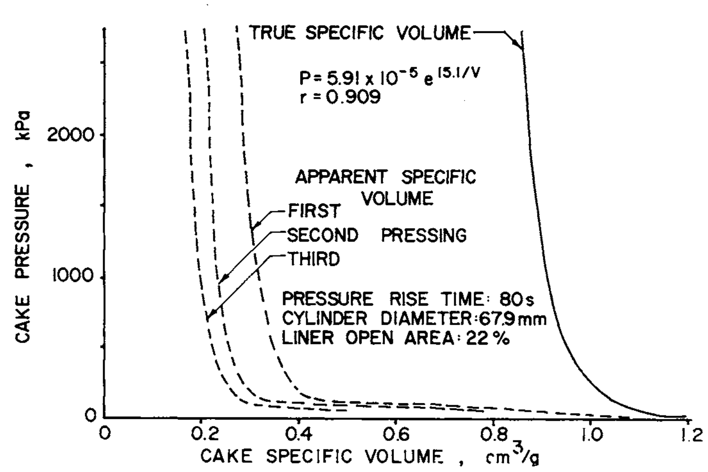

Figure 3. Compression characteristics of minced waterhyacinth.

As the time required to reach maximum pressure increased, up to 40 sec, the fluid expression increased (Figure 4). Prolonging rise time above 50 sec did not appreciably increase expression. As rise time decreases fibers nest and interlock more rapidly, blocking drainage channels which have time to form and develop at lower compression rates.

As cylinder radius increased, fluid expression decreased, as shown in Figure 5. Increasing the distance the fluid must travel in the fiber matrix decreases the pressure gradient and increases the resistance, both of which reduce flow rate. Production presses should be designed with minimum mat thickness consistent with adequate production rate and minimum equipment cost.

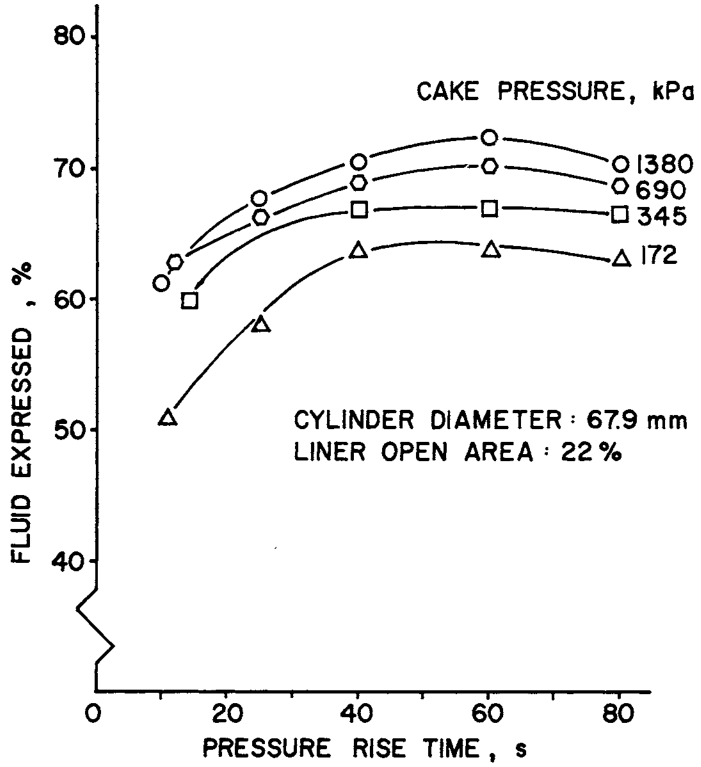

Figure 4. Effects of compression rate and pressure on fluid expression from minced waterhyacinth.

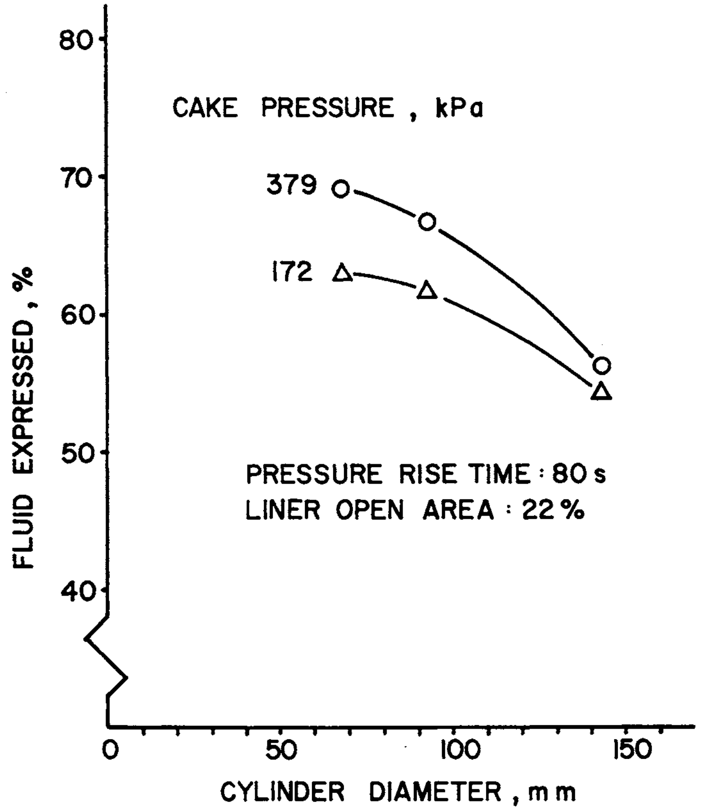

Figure 5. Effect of cylinder diameter on fluid expression from minced waterhyacinth.

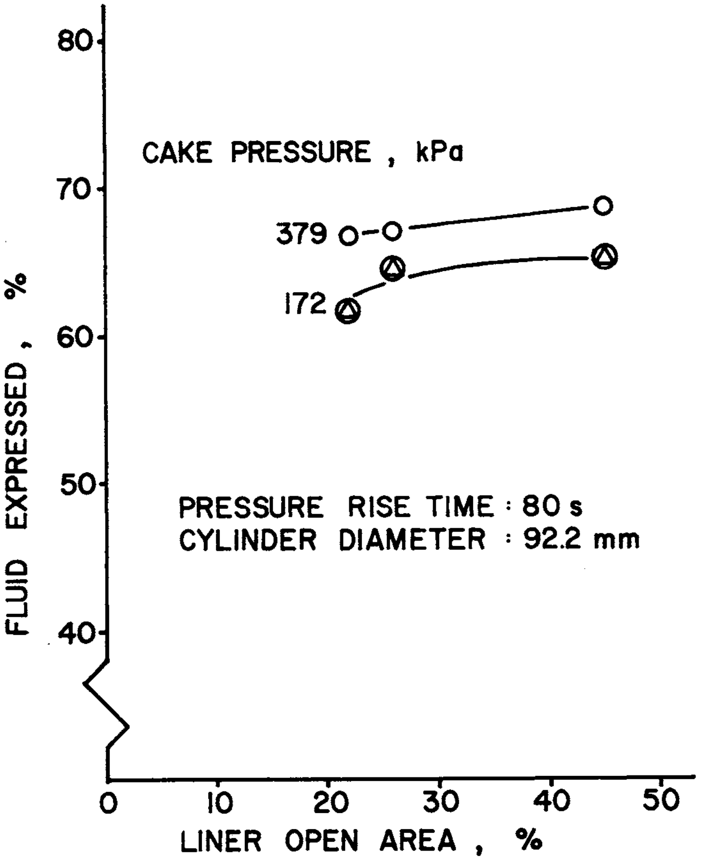

Figure 6. Effect of linear open area on fluid expression from minced waterhyacinth.

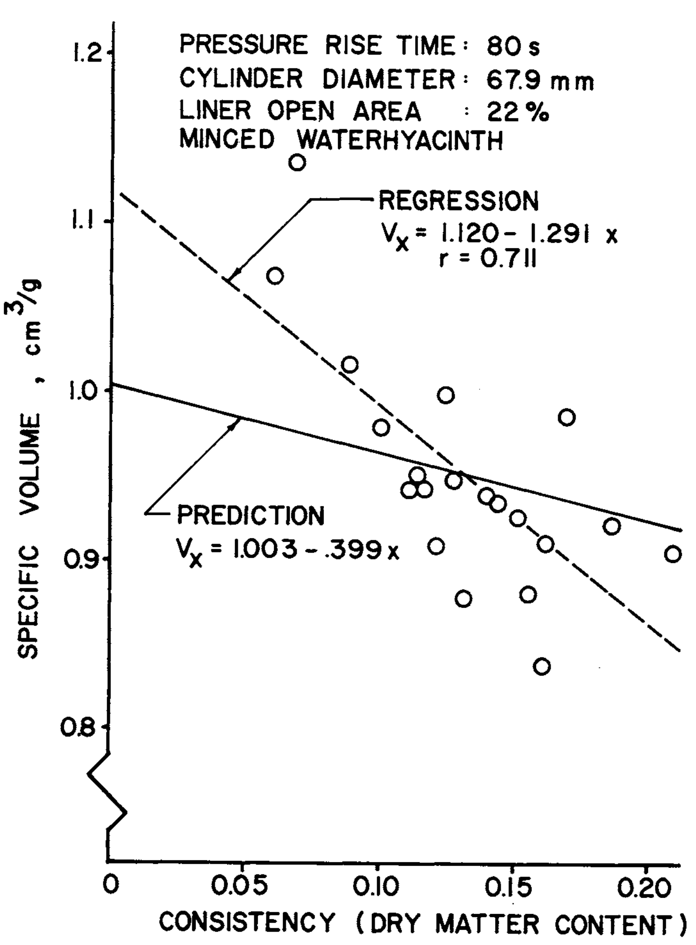

Figure 7. Effect of consistency on specific volume of waterhyacinth fibers.

There was a slight increase in expression with increasing available drainage area (Figure 6). The gain is so slight, however, that cost, strength and material availability considerations could offset the advantages of increasing open area.

Specific volume in the pressure-multiple pressings test decreased more rapidly with increasing consistency than was predicted by the formula developed for dry fiber (Figure 7). The difference is probably caused by the elastic properties of the matrix under pressure, as the original evaluation was essentially at no pressure. The correlation, though adequate to indicate a relationship, is too low to allow the data to be used with much confidence for design.

Some solids are removed with the juice and often, ac-

TABLE 2. ANALYSIS OF WATERHYACINTH CAKE AND FILTRATE PRESSED AT 172 TO 1380 KPA.[a]

Sample	Dry Matter (%, Wet)	Crude Protein[b] (% Dry)
Liquid	1.05 ± 0.20[c]	66.4 ± 12.8
Solid	9.57 ± 0.93	18.0 ± 0.9

[a] None of the analyses correlate significantly with pressure
[b] Macro-Kjedahl
[c] 95% confidence interval

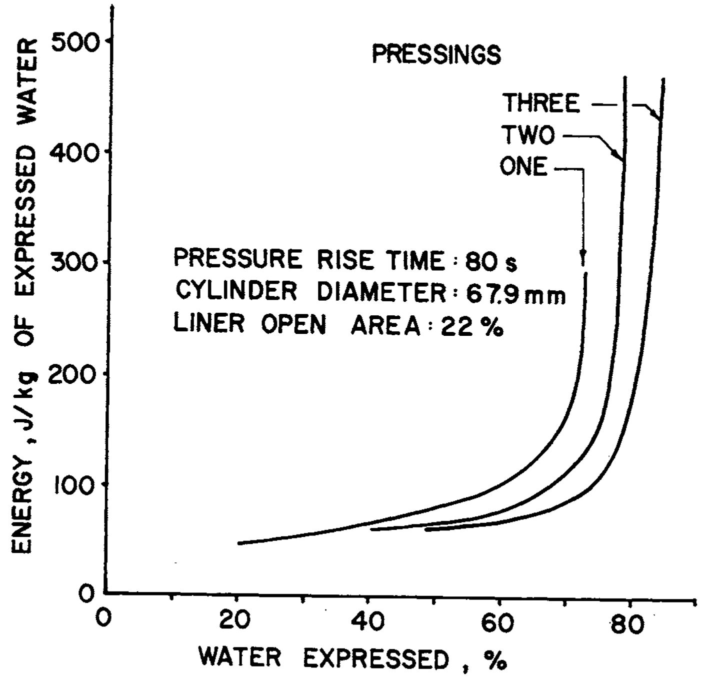

Figure 8. Energy required to express water from minced waterhyacinth.

cording to Pirie (11), these are high in protein. Analysis of the cake and juice, presented in Table 2, indicate that the juice contains less dry matter than that usually produced by a screw press and that it is very high in crude protein. Dry matter and protein contents of the samples were not significantly affected by pressing pressure.

About 70% of the water was expressed from waterhyacinth with an energy input of less than 100J/kg of water expressed, but the energy required increased rapidly as more water was removed. (Figure 9). Multiple pressing required less energy for a given level of expression. Energy levels were in the order of 1% of those found for screw presses.[3]

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