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Water hyacinth (*(Eichhornia crassipes [Mart.]solms)* Chopper cum Crusher : A Solution for Lake Water Environment

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Abstract

Water hyacinth was originated in tropical South America and listed as one of the most productive and worst aquatic plants on Earth. Its rapid spread has a significant influence on Lake Environment, water availability, food security, human health and national economics. It is an international pest that respects no national boundaries. The greatest problem of processing of water hyacinth is its volume and weight. Control methods like chemical control, Biological control and mechanical means were tried by various scientists. The results show that the biological method is slow whereas chemical methods are not advocated for fresh water lakes. The only solution was to control this weed by means of mechanical method. Available water hyacinth chopper cum crusher was found superior as highest volume (66%) and weight (32%) reduction was achieved at maximum capacity (1.35 t/h) in comparison to other forage choppers but it has problem of frequent chocking and unbalancing. Therefore, new mechanical system for chopping and crushing of water hyacinth was designed. The performance of the developed system was evaluated on the basis of its ability to volume and weight reduction. With the increase in feed rate, no. of blades and speeds of cutting cylinder and crushing roller the apparent specific volume decreased and weight loss increased. The developed machine can reduce the specific volume up to 73 per cent and weight up to 45 per cent from its initial level at 2 t/h feed rate (capacity) with 36 blades mounted on cutting cylinder and operating the system at cutting cylinder speed of 13.33 m/s and crushing roller speed of 6.66 m/s. The capacity of the developed system was found to be 2t/h and 65.7 per cent reduction in cost of transportation can be achieved with the introduction of mechanical system.

Key Words: Chopper cum crusher, control methods, weight and volume, transport, Cost

1. Introduction

The total global supply of water is astronomical. "But from the consumer's point of view, it is a pity that more than 97% of this is found in the oceans and can, therefore, not be directly used for drinking. Of the remaining amount, approximately one-eighth is suitable for drinking. Unlike other natural resources, such as coal and oil, water is infinitely renewable. But in spite of efficient natural recycling, we are facing a global water problem, mainly because the world's population has been growing at an exponential rate for decades. According to the World Health Organiz (WHO), about 2.4 billion people do not have access to basic sanitation facilities, and more than 1 billion people do not have access to safe drinking water. About 86% of all urban wastewater in Latin America and the Caribbean, and 65% of all wastewater in Asia, is discharged, untreated, into rivers, lakes, and oceans. In India, about, 1.1 million liter of raw sewage is dumped into the Ganges River every minute. This fact is startling, WHO observes, considering that 1 g of feces in untreated water may contain 10 million viruses, 1 million bacteria, 1,000 parasite cysts, and 100 worm eggs.

It has been reported that, diarrhea, which kills about 1.8 million people worldwide each year, 1.6 million of whom are children under the age of five. And every year, diarrhea strikes about 4 billion people, causing about 4.5% of the global burden of disease. Unclean water also causes cholera, dysentery, guinea worm infection, typhoid, intestinal worm infection, and trachoma. WHO statistics relating to water supplies are alarming, “One-sixth of humanity currently lacks access to any form of improved water supply within 1 km of their homes." An improved drinking water source, according to WHO, is any type of water supply facility--ranging from a protected well to indoor-piped water--that is likely to provide sufficient quantities of safe water to a community or individual. Municipal and industrial demands for water, and its quality, vary from country to country. The electronics industry, for example, requires ultra pure water with only a few parts per trillion impurities for computer chip manufacture. Whereas, people in poor countries drink untreated water from sources also used for bathing and the care of their animals.Chemistry lies at the heart of water-quality issues, both

positively and negatively, observed Dennis L. Hjeresen, manager of the pollution prevention and sustainability program at Los Alamos National Laboratory and former director of the American Chemical Society's Green Chemistry Institute.

On the negative side, water pollution from industrial, agricultural, and other land-based sources is one of the most pressing environmental issues facing the world today, Hjeresen said. One source of water pollution is the chlorine used in water treatment and pulp and paper bleaching, metal processing, pharmaceutical manufacturing, textile dyeing and cleaning, corrosion control, and processes such as photography. Persistent, bioaccumulating compounds used in agricultural chemistry cause a significant biological impact. And nitrate residues from agricultural and other sources accelerate eutrophication, the nutrient enrichment of bodies of water that eventually leads to oxygen depletion.

On the positive side, green chemistry can provide the tools to protect water quality in the face of increasing global pressures on water quantity, Hjeresen pointed out. In combining environmental improvement, economic performance, and social responsibility in addressing global problems, green chemistry focuses on improving industrial processes so that they preserve water quality, he explained. The use of green chemistry to reduce water contamination at the source has proven more cost-effective than either abatement or remediation approaches.

Occurrence of weeds in water bodies has become a common problem nowadays and it is necessary to have weed free situation so as to keep the normal recreational activities and other economic oriented activities running. Indian Subcontinent ranks second to South America in the number of endemic aquatic plant species (Lavania *et al*., 1990). These plants are thought as aquatic weeds due to their negative impact on the beneficial uses of the water resources in which they grow. Accordingly all efforts so far, have been directed towards their eradication measures (Gopal, 1990). But complete eradication of noxious species has never been possible. Mechanical removal generates a large amount of plant biomass which, if not removed adds to the same problem. Therefore scientific interests have been directed towards the utilization aspects of these plants. Aquatic plants particularly water hyacinth have great potential for use in animal feed, biogas generation, handicrafts, paper industries, *etc.* In some part of the India it is also used as a medicinal plant.

1.1 The Water hyacinth *(Eichhornia Crassipes)*

Water hyacinth is an aquatic plant which can live and reproduce floating freely on the surface of fresh waters or can be anchored in mud. Plant size ranges from a few inches to a meter in height. Its rate of proliferation is extremely rapid and it can spread to cause infestations over large areas of water causing a variety of problems.

It grows in mats up to 2 meters thick which can reduce light and oxygen, change water chemistry, affect flora and fauna and cause significant increase in water loss due to evapotranspiration. It also causes practical problems for marine transportation, fishing and at intakes for hydro power and irrigation schemes. It is now considered a serious threat to biodiversity. The plant originated in the Amazon Basin and was introduced into many parts of the world as an ornamental garden pond plant due to its beauty. It was first introduced as an ornamental plant in India in 1896 from Brazil (Aquaphyte, 2001). It is particularly suited to tropical and subtropical climates and has become a problem plant in areas of the southern USA, South America, East, West and Southern Africa, South and South East Asia and Australia. The mature plant consists of long, pendant roots, rhizomes, stolons, leaves, inflorescences and fruit clusters. The plants are up to 1 meter high although 40 cm is the more usual height. The inflorescence bears 6 - 10 lily-like flowers, each 4 – 7 cm in diameter. The stems and leaves contain air-filled tissue which give the plant its considerable buoyancy. The vegetative reproduction is asexual and takes place at a rapid rate under preferential conditions. People of different countries have been campaigning for multiple application of water hyacinth in animal feed, as a fuel, for handicrafts, furniture, biogas production, compost, pollution abatement and paper pulp with some success. In some part of the India it is also used as a medicinal plant (Aquaphte 2001). However, in these applications one of the major problems is the high cost of transportation of freshly harvested water hyacinth from water bodies to the factories. A major contributory factor to the failure of water hyacinth harvesting machinery is the large volume and moisture content which slows down the harvesting operation by increasing requirements for handling and transport.

1.2 Problems

Water hyacinth can cause a variety of problems when its rapid mat-like proliferation covers areas of fresh water. Some of the common problems are listed below:

Hindrance to water transport: Access to harbors and docking areas can be seriously hindered by mats of water hyacinth. Canals and freshwater rivers can become impassable as they clog up with densely intertwined carpets

of the weed. To have an access through the water body vastly more fuel is required to break through the weed and as water hyacinth is crushed against the jetties, the ships are damaged. It is also becoming a serious hazard to lake transport.

Problems related to fishing. Water hyacinth can present many problems for the fisherman. Access to sites becomes difficult when weed infestation is present, loss of fishing equipment often results when nets or lines become entangled in the root systems of the weed and the result of these problems is more often than not a reduction in catch and subsequent loss of livelihood. In areas where fishermen eke a meager living from their trade, this can present serious socio-economic problems.

Flora and fauna. Where water hyacinth is prolific, other aquatic plants have difficulty in surviving, as water hyacinth smothers the beds of submerged vegetation which causes an imbalance in the aquatic micro-ecosystem and overwhelms the marginal plants which, in turn, affect the range of fauna that relies on a diversity of plant life for its existence. Also rooted water hyacinth increases the deposition of sediments which provide aid to the other aquatic weeds, such as hippo, to establish prominently. Also diversity of fish stocks is often affected, though with some benefiting and others suffering from the proliferation of water hyacinth, as water hyacinth have swamped the bays in which the fish spawn and start their lives.

Interruption in Hydro Power Generation. Many large hydropower schemes are suffering from the effects of water hyacinth. An increasing amount of time and money has to be invested in clearing the weed to prevent it entering the turbine, causing damage and power interruptions. Water hyacinth is now a major problem in some of the world's major dams - the Kariba dam which straddles the Zambia-Zimbabwe border on the Zambezi River and feeds Harare has pronounced infestations of the weed.

Health Problems. The diseases associated with the presence of aquatic weeds in tropical developing countries are among those that cause the major public health problems: malaria, schistosomiasis and lymphatic filariasis. Some species of mosquito larvae thrive on the environment created by the presence of aquatic weeds, while the link between schistosomiasis (bilharzia), caused by snails, and aquatic weed presence is well known. It is also suspected that the plants increase the risk of amoeba, dysentery, sleeping sickness and typhoid. Also for people suffering from allergic reactions, handling water hyacinth can cause skin rashes.

Quality deterioration of fresh water supply. Water intake points gets blocked, alongwith that the screens and filters of water processing plants become blocked with decaying plant residue leading towards the reduction in water supply. Also the decaying plant residue reduces the water quality, which affects directly people in rural and urban areas. The problem is more severe in the rural sector where lake is used as a direct source of drinking water.

Evapotranspiration Increment. Various studies have been carried out to ascertain the relationship between aquatic plants and the rate of evapotranspiration compared with evaporation from an open-surfaced water body. The rate of water loss due to evapotranspiration can be as much as 1.8 times that of evaporation from the same surface but free of plants. This has great implications where water is already scarce. It is estimated that, due to this effect, the flow of water in lower parts of Nile has been up to one tenth.

C*anals and river blockage.* Water hyacinth can grow so densely that a human being can walk on it. When it takes hold in rivers and canals it can become so dense that it forms an herbivorous barrage and can cause damaging and dangerous flooding.

Tourism. On the top of everything, the lake infested by water hyacinth is clearly unattractive for the tourists, as the place which could be used by then for bathing, swimming and water sports such as wind surfing and sailing, is unavailable. Thus, due to the infestation the lakes which could be developed into a popular area for holiday and tourism has been scarcely conducive to such a development, results in reduction in tourism which directly or indirectly affects people economically thriving on the income raised through these areas i.e. lakes.

Quantification of the problem is often extremely difficult. The real effect on fish stocks and flora is unknown. It is hard to calculate the effect on fishing communities. Satellite methods are the only accurate way of determining the spread of the weed. Success is hard to measure when the exact scale of the problem is not clearly defined and is anyway growing rapidly. In many areas of the world few studies have been carried out to quantify the basic effects of the growth of the weed on the surrounding communities and environment. This causes problems when trying to evaluate the scale of the problem, possible ways of combating its proliferation and the impact that any control or management programme may have.

1. 3 Solutions

Control of water hyacinth

There are several popular control mechanisms for preventing the spread of, or eradication of, water hyacinth. The three main mechanisms used are biological, chemical and physical control. Chemical control is the least favored due the unknown long-term effects on the environment and the communities with which it comes into contact. Physical control, using mechanical mowers, dredgers or manual extraction methods, is used widely but is costly. It is not suitable for large infestations and is generally regarded as a short-term solution. Biological control is the most widely favored long-term control method, being relatively easy to use, and arguably providing the only economic and sustainable control. Mechanical control is viable when it is associated with the alternative uses of water hyacinth. Below is the briefly discuss each of these methods.

Biological control*:* Biological control is the use of host specific natural enemies to reduce the population density of a pest. Several insects and fungi have been identified as control agents for water hyacinth. These include a variety of weevils, moth and fungi. Biological control of water hyacinth is said to be environmentally benign as the control agents tend to be self-regulating. One major drawback is that it can take a long time to initiate such projects because it can take several years for the insect population to reach a population density sufficient to tackle the pest problem.

Chemical control: The application of herbicides for controlling water hyacinth has been carried out for many years. The common herbicides are 2, 4-D, Diquat and Glysophate. It has been found that there is a good success rate when dealing with small infestations but less success with larger areas. Application can be from the ground or from the air and requires skilled operators.

Physical control*:* Mechanical removal of water hyacinth is seen as the best short-term solution to the proliferation of the plant. Mats of water hyacinth can be enormous and can have a density of up to 200 tonnes per acre. Manual removal of water hyacinth is suitable only for extremely small areas. It is difficult, labor intensive work and in some areas there is serious health risks associated with the work (crocodiles, hippopotamus and bilharzia in Lake Victoria for example). Transportation of the harvested weed is also costly, because it has such high water content. Chopping can reduce the volume and the water content. Besides these three mainstream forms of control there is one more suggested method, namely the reduction of nutrient inputs to the water.

The simplest way to manage this weed is to harvest it and utilize it for useful products. The main problem of utilization and management of water hyacinth is its high cost of transportation to the disposable site or factories. To overcome this problem a water hyacinth crusher was designed and developed at College of Technology and Engineering, Udaipur, India which chops and crushes water hyacinth simultaneously in a single pass.

2. Review of Literature

Water hyacinth (*Eichornia crassipes* [Mart.] Solms) is a perennial fast growing aquatic weed. It is problematic in the management of water resource and controlling this weed is very difficult. This failure is coupled with the growing need to search alternative resources for various purposes, turned the attention towards finding ways and means for utilizing water hyacinth. Many researchers for various uses and composition of water hyacinth have carried out numerous studies. However the research work carried out by various scientists on various aspects to mechanical harvesting, handling and processing of forage, fruits and products similar to the Water hyacinth reviewed and the conclusions dawn are here below.

a. Cylindrical choppers give better results as compared to the flail and flywheel type choppers.
b. The power requirement for a cylinder type of chopper is approximately 7 per cent lower than in case of flywheel type chopper under identical conditions.
c. Force and energy requirement for cutting increased only after the blade bevel angle exceeds 30 degree.
d. The dewatering (weight reduction) process is facilitated by separating it into two sub-processes of; maceration (cell rupture) to release liquid from the plant cells, and fractionation (liquid expression) to remove the liquid from the macerated matrix.
e. Fractionation is a slow and time dependent process. Among different methods used for fractionation, cone press and the roller press gave better results. However, cone press requires a complicated drive system because of its geometric configuration.
f. Chopping immediately after harvesting reduces bulk and improves the material handling characteristics of the

plant.

g. Chopping and passing between the rollers can be the solution for rapid reduction in volume and weight of water hyacinth.

h. For faster and effective chopping and crushing of water hyacinth a system requires a cylindrical cutting followed by a roller type crushing along with a provision of automatic feeding and conveying unit.

2. Materials and Methods

The system was fabricated consisted of following major components. The complete machine is shown in Fig. 1 and describe under the following paragraphs.

Hopper: The hopper was made of 3 mm thick MS sheet. The shape of the hopper was trapezoidal. Slots of 30x26 mm were cut in both the side walls of hopper in front of center of cylinder. Similar slot of 26 mm height in the rear wall of hopper was made to facilitate fitting of shear plate against the cylinder.

Cutting cylinder with blades: A MS pipe of 272 mm outer diameter and 9 mm thickness was used to fabricate a cutting cylinder. The length of the pipe was kept as 425 mm. Two sets of rings were fabricated and attached to both the ends of cylinders to accommodate different nos. of blades. Forty eight and thirty six (10 mm) square pieces (length of 25 mm) were welded on the rings to facilitate a change the number of blades on both the rings. Blades were made of 10 mm thick spring steel. The width of the sharpened blade was 24 mm. Blades were cut at both the ends to make them suitable to be fit in the MS square pieces provided on the rings. These blades were clamped by rings made from 25x10 mm MS flat through nuts and bolts. This arrangement will facilitate the resharpening or replacement of blade. Two circular plates having 254 mm diameter, made of 5 mm thick MS plate were welded at each end inside the cylinder. A shaft made of 50 mm EN round bar was welded at the center of cylinder.

Crushing roller: A MS pipe of 308 mm outer diameter and 6 mm thickness was used to fabricate a crushing roller. The length of the pipe was kept as 425 mm. For positive flow of chopped material, corrugations were provided on the periphery of roller using 56 pieces of 12x6 mm MS flat each of 425mm length. These flat pieces were welded on the periphery of the roller at equal spacing. Two circular plates having 296 mm diameter, made of 5 mm thick MS plate were welded at each end inside. A shaft made of 50 mm EN round bar was welded at the center of roller.

Pressing roller: MS pipe of 308 mm outer diameter and 6 mm thickness was used to fabricate a pressing roller. The length of the pipe was kept as 425 mm. Thick (6 mm) rubber lining was made through out the outer surface of roller which is rotating against crushing roller in opposite direction for crushing of chopped material. Thick (5 mm) circular plates of 296 mm diameter were welded at each end inside the roller and a shaft made of 50 mm EN round bar was welded at the center of roller.

Power transmission system: **A** variable speed electric motor of 3 phase, 960 RPM, 2.25 kW was used to drive the cutting cylinder, crushing roller, pressing roller and driving roller of delivery conveyor through suitable pulleys and V-belts. A three groove pulley of 100 mm size with 30 mm bore was fitted to the motor shaft. A single phase DC motor was used to drive the feeding conveyor through chain and sprockets of 17 teeth and 102 teeth to get the speed ratio of 1:6.

Frame and Machine supports**:** The frame and supports were fabricated by using 100x50x5mm MS channel, 50x50x5 mm MS angle and 35x35x5 mm MS angle. A Major portion of the system was made from MS channel and frame of the feeding conveyor was fabricated from MS angle. The platform for 3 phase variable speed motor was fabricated from MS angle such that its orientation can be changed as desired. The platform for single phase DC motor was also fabricated by using 10 mm thick MS plate. The complete machine has been shown in Fig. 2.

3. Performance evaluation

Performance of the machine was evaluated on the basis of volume and weight reduction of the water hyacinth. The average weight of each plant varied between 0.35 to 0.40 kg and the height varied from 400-700 mm. The material was fed to the machine through feeding conveyor at different levels of feed rate by changing the speed of feeding conveyor. The system was tested for different combinations of feed rate (1.25, 1.5, 1.75 and 2 t/h), no. of blades on cutting cylinder (36, 24, 18 and 12), speed of cutting cylinder (3.33, 6.66, 10 and 13.33 m/s), and speed of crushing roller (1.66, 3.33, 5 and 6.66 m/s). Each experiment was replicated three times. Data were analyzed statistically and relationships were developed among dependents and independents parameters.

4. Results and Conclusions

The performance of the developed crusher was compared with the available choppers and crushers. The developed chopper cum crusher reduced the specific volume of water hyacinth by 73 per cent at recommended 36 no. of blades on cutting cylinder, cutting cylinder speed of 13.33 m/s, crushing roller speed of 6.66 m/s and feed rate of 2t/h. 65.7 % reduction in cost of transportation can be achieved with the introduction of this mechanical system. The system is tested extensively and works satisfactorily. It is environmental friendly and no need of application of any chemical in fresh water lakes. The average no load power required to run the machine was 1.1 kW. The power required in chopping and crushing increased with the increase in feed rate and speeds of cutting cylinder and crushing roller.

The performance of the developed mechanical system was compared with the different types of choppers and crushers namely power operated flywheel type forage chopper, cylindrical crusher, roller type crusher, auger type citrus juicer, waste PVC grinder for their suitability for chopping and crushing of water hyacinth. Test data of tested choppers and crushers were analyzed and their test results are plotted in Fig 2.

The results of the comparative performance (Fig.2) indicated that flywheel type chopper and roller type crusher gave considerable per cent reduction in volume (55.21 and 54.15) and weight (10.19 and 16.92) after chopping but the capacity (0.207 and 0.369 t/h) of chopping was very less because those required forced feeding. The capacity of machine was higher with cylindrical crusher (1.29 t/h) and with PVC grinder (1.11 t/h) but per cent reduction in volume (28.81 and 35.23) and weight (8.13 and 9.91) were much less as compared to other choppers because of higher gaps between the crushing bars. Auger type citrus juicer gave sizable per cent reduction in volume (43.07) and weight (17.21) of water hyacinth but the chopping capacity was too low (0.006 t/h) as feeding was almost impossible and output material stick to the auger**.** The results also show that the cylindrical crusher, roller crusher, citrus juicer and PVC grinder are not suitable for the chopping and crushing of water hyacinth because of their low out-put capacity. The feeding of the water hyacinth in these types of choppers was also a problem. Flywheel type of chopper reduces the volume up to 55.21 % but it does not allow water hyacinth to crush, which allows it to re-grow even after chopping. It also shows that at the time of feeding water hyacinth entangled between feed rolls causing frequent chocking of the machine. Therefore a new water hyacinth chopper cum crusher was designed and fabricated. The test results of the developed system revel that the developed system reduced the specific volume of water hyacinth up to 73% with a capacity of 2 th^{-1}.

5. Conclusions

- Ease in handling and saving of labour in transportation
- Environmental friendly and no need of application of any chemical in fresh water lakes.
- The average no load power to run the machine was 1.1 kW. The power required in chopping and crushing increased with the increase in feed rate and speeds of cutting cylinder and crushing roller.
- Specific chopping and crushing energy and total energy requirement did not change with change in no. of blades.
- The developed chopper cum crusher reduced the specific volume of water hyacinth by 73 per cent and weight by 45 per cent at recommended feed rate of 2t/h.
- 66 % reduction in cost of transportation can be achieved with the introduction of mechanical system.
- The present innovation or developed system is suitable for chopping and crushing of water hyacinth on the site itself and this chopped material can be transported easily to the factories. With this innovation the cost of transportation and labour will be drastically saved. Other commercially available forage choppers are not applicable for chopping of water hyacinth plant due to its very high (92-94%) moisture content. Furthermore, this system will chop and crush the plants in a single operation and shall thus, save time, energy and money.

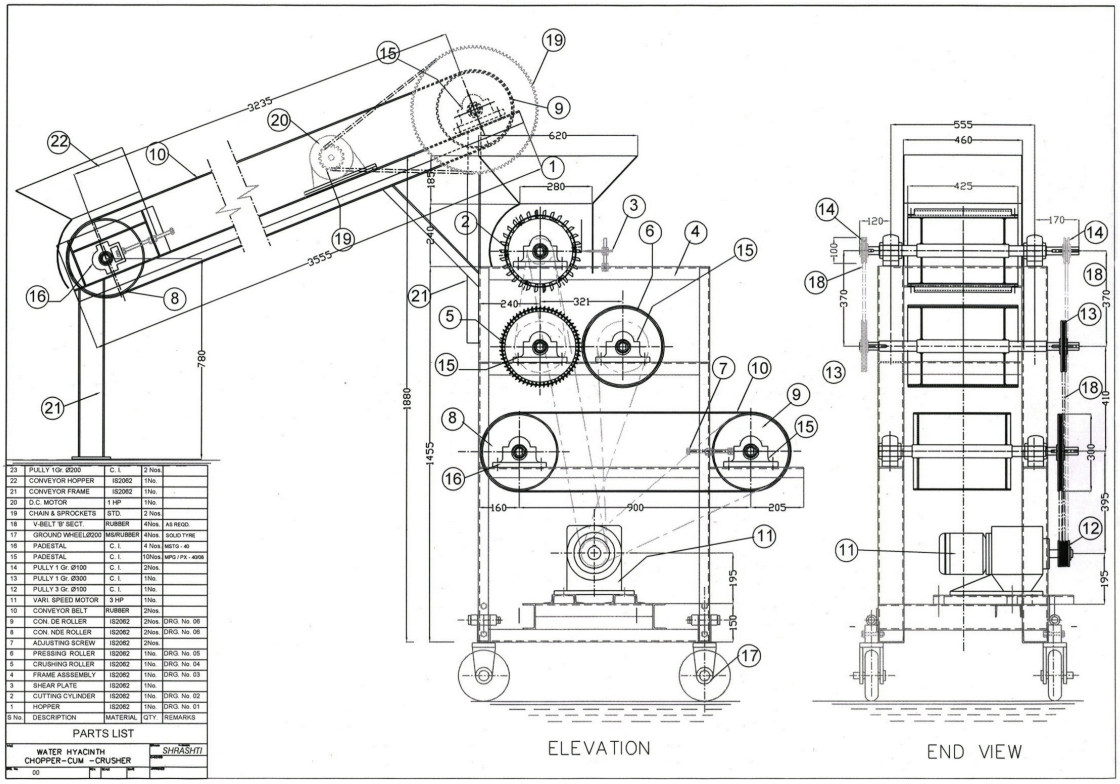

Fig.1: Constructional Details of Water hyacinth Chopper cum Crusher

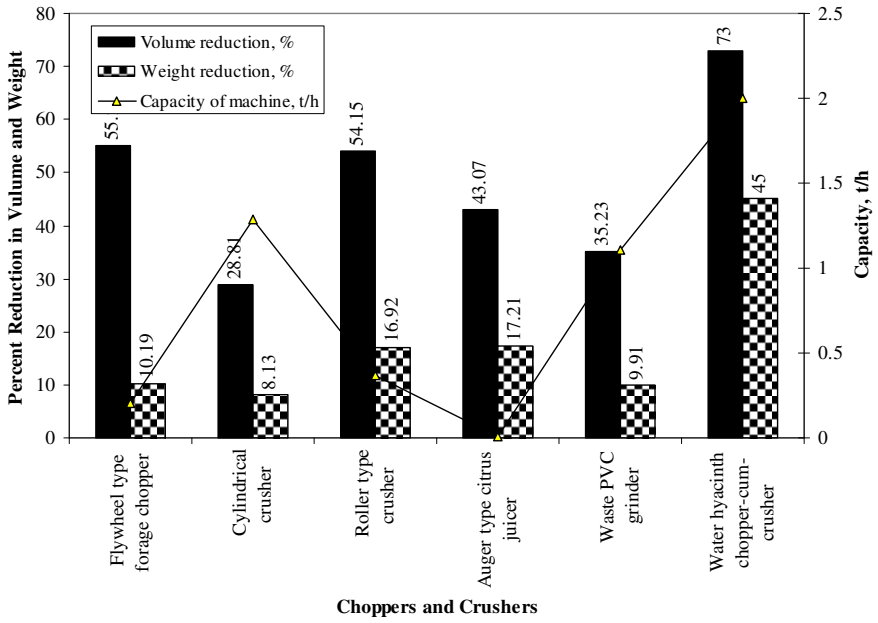

Fig. 2: Performance Results of Different Choppers and Crushers

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