FABRICATION OF A MILLET WASHING MACHINE

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ABSTRACT

A millet washing machine was fabricated to address and improve the hygienic conditions and reduce the drudgery involved in the traditional method of washing millet to improve timeliness before further processing. The major components of the millet washing machine include the washing chamber, the wastewater exit, the machine frame and the stirring system. The washing chamber consists of perforated vessel with vertical height, top and bottom diameters as 12", 19.5" and 16" respectively. The machine frame has a vertical height of 28". The stirring system is run by a 1.5 HP variable electric motor.

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CHAPTER ONE

1.0 BACKGROUND INFORMATION

1.1 Introduction

Cereals and grains after harvesting from the field need to arrive in a state that is acceptable to the consumer. Although traditional farms still serve as a source of income, the increasing demand for all year-round supplies from urban dwellers and international markets requires an increased level of handling, transportation, and storage of products. Millet by virtue of its nature and structure carries with it debris which needs to be cleaned before consumption. Due to increased safety and quality consciousness of consumers, washing of millet before selling has become paramount. Currently, there is the absence of a primary processing machine such as the case of vegetable washers for vegetables readily available on the market for small and medium scale farmers and processors. Such a machine must be designed to reduce drudgery and improve timeliness for processors with the intention of increasing profitability and productivity. The washing machine would eventually reduce the time spent sorting, grading and selling on the market.

1.2 Importance of Washing Agricultural Products

The term 'washing' is generally used where an unwanted constituent is removed in a stream of water (Earle, 2002).

The following factors influence the washing operation:

- area of contact between the streams
- time of contact
- properties of the materials so far as the equilibrium distribution of the transferred component is concerned
- number of contact stages employed

Washing whole fruits and vegetables in clean water only achieves an insignificant reduction in microbial populations. The use of sanitizers such as chlorine, peroxyacetic acid, hydrogen peroxide, acidified sodium chloride or ozone can provide an additional 1-2 log reduction in the initial population of microorganisms on the surface of fresh produce (Heard 2002).

The following promote the importance of washing

- Removes dirt and other foreign materials
- Reduces the bacterial load from raw food materials.
- Increases the sterilization efficiency considerably.
- Improves the appearance and quality of food products in general

Generally, different kinds of foods are washed either by agitation or by sprays, etc. In fruits and vegetables, soaking and spraying in combination can be applied. Common washers are revolving drums in which food products are tumbled and sometimes high-pressure water sprays are used. Sensitive food like tomatoes is washed by dumping and floating in water tanks. The selection of washing and other processing equipment for a particular kind and variety of a

vegetable or fruit depends on factors such as size, shape and fragility (Chakraverty and Singh, 2014).

It is important to wash produce as soon as possible after harvest to remove damaged tissues. Water flumes and tanks are used in large operations to wash fresh fruits and vegetables prior to cutting and trimming. Potable water is a key requirement for washing in order to preclude the transfer of contamination from water to the produce. Hence washing fresh produce is helpful and the water used should also be clean and free of contaminants. Recycled water must be continuously treated and monitored.

1.3 Millet Production in Ghana

Millets refer to a group of annual grasses mainly found in the arid and semiarid regions of the world. These grasses produce small seeded grains and are often cultivated as cereals. The type of millet grown in Ghana is Pearl millet which is cultivated in the three northern regions of Ghana namely Northern, Upper East and Upper West regions of Ghana. The crop is grown mainly by smallholder farmers covering an area of 177,000 ha under rain-fed conditions with annual production of about 218,952 metric tons. The mean annual production from 2008 to 2010 is also estimated to be 219,000 MT (MoFA, 2011). It is an annual crop which serves as a subsistence and a food security crop, especially for nutritive and cultural value (Holt, 2000).

Figure 1. Pearl Millet (Source: Infonet biovision)

The most widely cultivated species of millet across the world include the following: Pearl millet (*Pennisetum glaucum*), Foxtail millet (*Setaria italica*), Common millet or proso millet (*Panicum miliaceum*) and Finger millet (*Eleusine coracana*). In Ghana, the Pearl millet species is most common. Varieties of the Pearl millet include Arrow, Bongo Short head, Bristled Millet, SOSAT, B9_Tabi, Tongo Yellow and Manga Nara (Kanton *et al.,* 2015).

1.4 Major Pests and Diseases of Millet

The African armyworm, S. exempta is an occasional pest of millets in Africa. Its outbreaks occur periodically and results in extensive damage to cereals and pasture grasses. The larvae are gregarious during the outbreaks. The eggs are laid in batches on the under surface of leaves, which hatch in 3-4 days. The larval period lasts for 10-20 days (Schmutterer 1969).

Millet head miner (*Heliocheilus albipunctella*) (de Joannis) (Lepidoptera: Noctuidae), is one of the most important pest of millet in Sub-Saharan Africa. Its immature larval stages feed on the panicle and prevent grain formation (Ndoye 1991). Yield losses range from 40 to 85% (Gahukar et al. 1986; Krall et al. 1995; Youm and Owusu 1998).

In the USA, rust and blast have been reported to severely affect pearl millet and extensive research have been carried out on these two diseases to assess their impact on grain and fodder yield and quality (Wilson et al., 1996). In India, Western and Southern Africa there is a lot of reporting on downy mildew [Sclerospora graminicola (Sacc.) Schroet.] (Hash et al., 1999; Singh, 1995) as being the most important pearl millet disease in Asia and Africa (Williams, 1984).

1.5 Economic Importance of Millet

Millet is an important source of food security in developing countries since it is a major food, feed and fodder source for the people and their livestock (Plaza-Wuthrich and Tadele, 2012). Flour from millet is used for making mush, porridge, flat bread or chapatti. The flour is also used for making wine or beer. The grain is a feed for animals (Robert, 2013). The green plant is used as forage. Brooms are made from the straw. Starch from the grains is used for sizing textiles. Millet is fast becoming a popular baby food because the grains are rich in vitamins, calcium, iron, potassium, magnesium and zinc (Leder, 2004).

1.6 Types of washing machines

The term washing machine brings to mind clothes. However, there are several other uses of a washing machine besides washing clothes. Some of the sectors where the use of washing machines are applicable include the following; chocolate manufacturing, pharmaceuticals, fish and meat processing, vehicle manufacturing, healthcare equipment cleaning and waste management.

Crate and pan washing machines are used predominantly in the food processing, bakery, agriculture and pharmaceutical industries. Moulds used in the diary and chocolate industries are washed using the mould washing machine. Also, pallets used for storage and transportation require regular washing. Pallet washers have a large capacity and allow for both washing and drying activities.

Factors considered during selection of washing machine include the following:

- Handling capacity of machine should meet the washing requirements
- Chemical that will be used during washing
- Size or space requirement of washing machine within processing plant

Figure 2. Fruit and vegetable washer

Figure 3. Wheat washing machine

Figure 4. Chocolate mould washer

Figure 5. Pallet washer

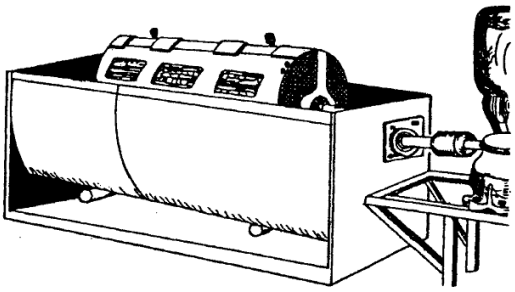

Figure 6. Cassava washing machine

Figure 7. Potato washing machine

1.7 Washing Methods

During the process of washing, the inert material is the required product, and the solvent used is water which is cheap and readily available. Washing by using sprays is one of the effective and satisfactory methods. The spray efficiency is dependent upon

- Water pressure
- Water flow rate

- Spray nozzle distance from the food material to be washed

In very small operations, washing in a sink or under a tap with running water is appropriate. Produce may also be washed at a small scale in large shallow tanks that allow operators to move the produce freely through the water. In situations where concrete tanks are used they should ideally be tiled. Frequent change of wash water is necessary in order to effectively remove soil and other foreign matter from the produce. A better method is to continuously circulate wash water through a filter. Ideally several tanks should be used for washing operations; the first for the removal of heavy soil and subsequent tanks with chlorinated water for final washing.

Use of nozzles with adequate water-jet characteristics is necessary, so that the mechanical action exerted on the surface to be cleaned is adequately distributed (size and distribution of drops of water, velocity and width of the opening angle of the jet, etc.). If possible, high-temperature vapor also could be used, thus saving a large amount of water; however, if the thermal action is increased, the mechanical action needs to be reduced considerably.

1.8 Different Washing Methods for Agricultural Produce

Cocoyam flour can be manufactured in several ways, but the key operations include peeling fresh or precooked corms and cormels, drying, and milling into flour. In commercial practice, the flour is made by peeling the corms and cormels, slicing them, and washing them thoroughly with water to remove adhering mucilage. After soaking in water overnight, the slices are washed and immersed in 0.25% sulphurous acid for 3 hours. Finally, the slices are blanched in boiling water for 4 to 5 minutes, dried thoroughly at 57 to 60°C, and then milled into flour.

During olive oil processing, when the olives arrive from the field to the processing plant, they must be cleaned in order to remove unwanted materials such as leaves, branch pieces, nuts, etc. Recently harvested olives carry soil, mud, and other residues, and require washing before their elaboration. Olives are washed twice, first with water when olives are in the hopper of the washing machine, and second with a water bath. Finally, olives leave the machine on a wire-mesh conveyor to remove the water. This is a crucial processing stage as it goes on to impact the quality of oil free from impurities (Bakker-Arkema et al., 1999).

During rinsing of pre-cut fruits and vegetables, it is recommended that only water of the highest quality be utilized. Many operations inject chlorine as a disinfectant along with acid in order to maintain a pH range of 4.5-5.5 and to assure the effectiveness of chlorine. Measurement and recording of the chlorine level and the pH of wash water is therefore a critical element of any quality assurance program. Ice used for reducing the temperature of water should be routinely tested in order to ensure that it is not a source of contamination.

CHAPTER TWO

2.0 DESIGN AND FABRICATION OF MILLET WASHING MACHINE

2.1 Introduction

Millet is a staple food of the northern regions of Ghana, and is used in the preparation of foods such as porridge, bread and wine. From general observation, traditional manual washing of millet is time consuming and laborious. However development of a washing machine to wash off the dirt is considered more viable due to the hygienic nature of the final product. The fabrication work addressed an effective, hygienic and faster method of washing millet. The major components of the washing machine include the washing chamber, the wastewater exit, the machine frame and the stirring system.

2.2 Technical Specifications

The following factors were considered in the design and material selection of the washing machine;

i. The material cost and availability
ii. The suitability of materials properties
iii. Maintenance
iv. Washing effectiveness
v. Capacity to be washed
vi. Possible integration of the washing machine to the drying and milling processing plant
vii. Time taken to wash millet

Mild steel was selected for the body frame because it does not come into direct contact with the food material

Table 1 Summary of materials selection

No.	Machine Component	Material used	Reasons for selecting the material
1	Body frame	Mild steel	Good tensile properties Low cost Resistant to shock
2	Stirring blades	Stainless steel	Corrosion resistant Good tensile properties
3	Electric motor	Standard	
4	Washing vessel (perforated-internal and solid-external) Solid vessel	Stainless steel	Corrosion resistant Good tensile properties Temperature and strength properties

The millet washer consists of the following functions and specifications:

- The vessel has 2 components
- The inner vessel which is perforated; suitable to the kind of crop to be washed
- The solid vessel which houses the inner vessel, surrounded with water
- Products to be washed are placed into the perforated stainless steel vessel

- 1 variable electric motors of 1.5 HP
- The dimensions of the outer (solid) drum diameter = 23”
- Height of the solid drum = 24”
- Frame vertical height = 28”
- Perforated vessel top diameter = 19.5”
- Perforated vessel bottom diameter = 16”
- Perforated vessel vertical height = 1ft

2.3 Construction Materials and Tools

The total project cost was estimated at GH 7,000.00 Below is the breakdown of the materials used for fabrication

Table 2: Material List for fabrication of millet washing machine

No.	Item
1	1.5 mm Stainless Steel Sheet
2	2.0 mm mild Steel Sheet
3	Gear motor with variable speed
4	Stainless steel shaft 1” ⌀
5	Stainless steel bolts and nuts
6	Stainless electrode
7	Fibre disc
8	Cutting Disc
9	Stainless steel mesh 450 & 1000 μm
10	Oil paint
11	Antirust paint

Some selected tools and equipment used in the construction of the washing machine are as follows:

1. Drilling machine and drill bits (HSS, 1/8 ”)
2. Grinding machine
3. Sheet Cutter
4. Sheet metal bending machine
5. Metal hammer
6. Spraying machine
7. Welding machine

2.4 The Fabrication Process

The first phase of the project includes the precise joining/fabrication of body parts of the washing machine. The second phase includes the installation of the stainless steel washing vessels

2.5 Description and Operation of Some Selected Tools used in Fabrication of the Washing Machine

Equipment fabrication refers to the transformation of materials, supplies and hardware into an equipment that meets certain research specifications and has an estimated useful lifespan. It is an engineering term that refers to the many processes by which an equipment is constructed utilizing engineering and scientific principles. Metal fabrication involves cutting, bending and assembling processes leading to the creation of machines parts and structures from various raw materials.

2.5.1 Roller machine types and operation

One of the most common processes for sheet-metal forming is bending, which is used not only to form pieces such as L, U, or V- profiles, but also to improve the stiffness of a piece by increasing its moment ofinertia. Bending consists of uniformly straining flat sheets or strips of metal around a linear axis, but it also may be used to bend tubes, drawn profiles, bars, and wire Roll bending is the process of bending sheets to a curved form (Boljanovic, 2004).

Roll bending machine is a universal forming equipment for rolling metal plate into cylinder, cone curved and other shapes. Roll bending can be done by hand or power operated rolling machines. These machines usually have three-point roll in a pyramid formation, with the two lower rolls being driven and the position of the upper roll being adjustable. Different curves are obtained by controlling the distance and angle between the rolls.

The following illustrates the working principle drawing of symmetrical 3-roll bending machine.

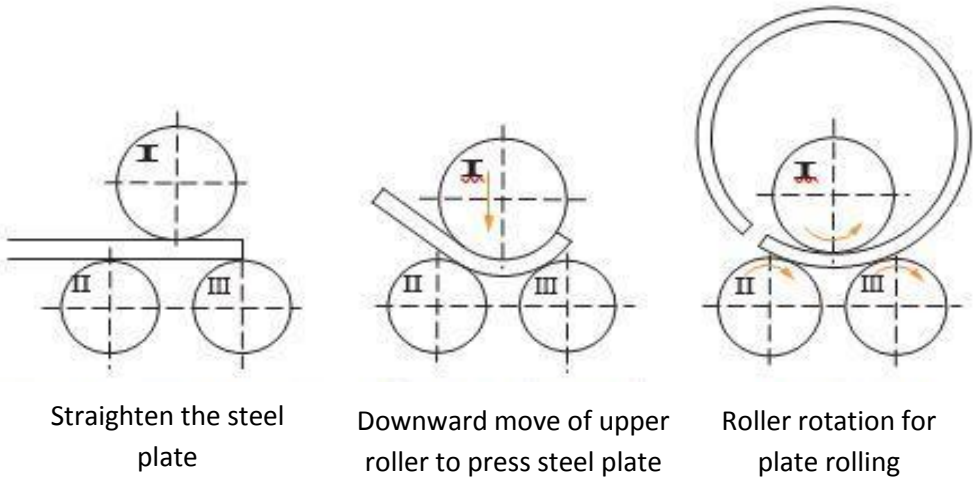

Figure 8. 3-roll bending principle

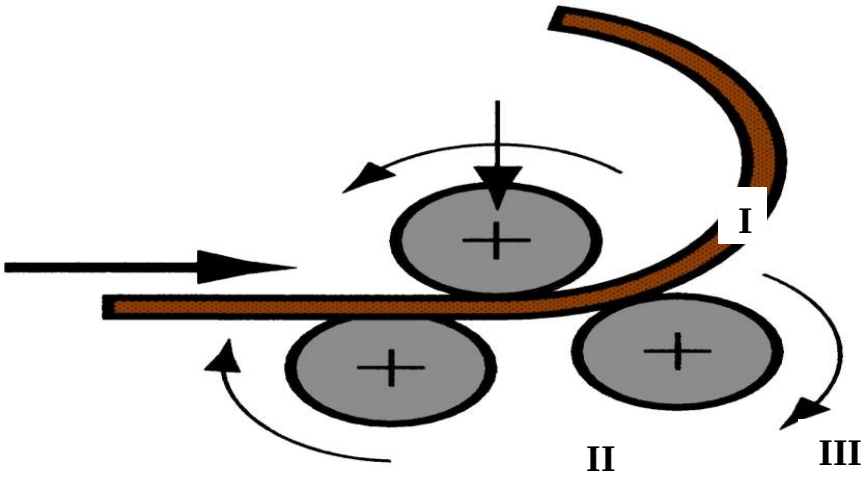

Figure 9. Roll bending principle

Steps to follow when using the roll bending machine:

Step 1: Introduce the metal sheet between the top and the bottom rolls.

Step 2: Adjust the gap between the top and bottom rolls as per the required diameter by regulating the screw rods.

Step 3: Rotate hand wheel to rotate the worm keyed to the shaft. This transmits power to the worm wheel. The stud gear which is fixed to the worm wheel also rotates. The two spur gears which are keyed to the bottom roll rotate in the same direction.

Step 4: Continue to adjust the top roller that presses the sheet until it gives the desired curvature.

Step 5: The formed material can be slipped off by removing the top roll.

Figure 10. Hand Roll Bending Machine

Figure 11. Electric Roll Bending Machine

2.5.2 Introduction to Welding Operation

Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding, the pieces to be joined (the workpieces) are melted at the joining interface and usually a filler material is added to form a pool of molten material (the weld pool) that solidifies to become a strong joint. The types of welding include arc, gas, resistance, energy beam and solid-state welding. Each type of welding has a specific machine used in undertaking such operation.

Arc welding is a fusion welding process in which the heat required to fuse the metal is obtained from an electric arc between the base metal and an electrode. An arc welding machine is described as a machine which converts 120-240 volt AC electricity to welding voltage, typically 40-70 volts AC, but also a range of DC voltages. It generally consists of a large, heavy transformer, a voltage regulator circuit, an internal cooling fan, and an amperage range selector.

Types of welding processes

Over 50 different processes are in existence however, the commonest include the following;

- Shield Metal Arc Welding (SMAW) also known as Manual Metal Arc Welding (MMAW)
- Gas Tungsten Arc Welding (GTAW) or Tungsten Inert Gas (TIG) Welding.
- Flux Cored Arc Welding (FCAW)
- Gas Metal Arc Welding (GMAW), also known as Metal Inert Gas (MIG) Welding or hand wire welding.
- Plasma Arc Welding (PAW), Plasma Arc Cutting (PAC) and gouging.
- Submerged Arc Welding (SAW)
- Resistance Arc Welding (RW) or spot welding.
- Air Carbon Arc Cutting and Gouging.
- Oxyfuel welding, cutting and heating (oxygen-acetylene [oxyacetylene] or oxygenpropane [oxy-propane] mixtures are the most common fuel mixtures used

Types of Welding Machines

- Mig welding machines
- Tig Welding Machines
- Spot Welding Machines
- Plastic Welding Machines

MIG welding machines

It is the best suitable welding machine to be used in the home, workshops, and industry. It can weld different types of metals like mild steel, stainless steel, and aluminum. It is used to weld the metal parts with a great speed and it is able to provide a long arc time even when the electrodes are not fully charged.

Thyristor Control Mig welding machines

It is used to fix the objects or mount on a suitable surface. It produces only a little amount of spark which seems to be easy to control the waves produced from the welding machines. It suits to weld the solid cored and flux materials. Mild steel, low carbon steel, alloy steel can be welded without any risk.

TIG Welding Machines

The specialty of this welding machine is that it can give a clean and pure welding without splatter, sparks and fumes. The metals which are used in the TIG welding machines are stainless steel, brass, gold, magnesium, aluminum, copper and nickel alloys. It is not suitable for site and field work and is the best one to repair damaged parts.

Spot Welding Machines

This welding machine is used to join the overlap steel sheets. Each sheet is of 3mm thick. The metal sheets can be protected by a pair of electrodes by passing the current through the sheets.

Plastic Welding Machines

It is used to weld the different kinds of plastic materials. To weld the plastic parts, the films need to be fused and the pressure has to be applied against them. It is used widely in the industrial applications.

TIG Welding Process

The TIG welding process is in many cases the only practical solution to several necessary repair jobs on board. The most frequently used applications are welding of aluminium-brass (Yorcalbro), Cunifer, and stainless, heat resistant or acid resistant steels, but the process may be used with good results on all weldable materials. Among the unique advantages of using the argon gas protected TIG arc as heat source for welding include an easy-to-learn method which may be used in all positions and provision of a stable, intense and well directed heat supply which ensures deep penetration and small heat affected zones.

Apart from the welding machine, a complete TIG-equipment consists of a supply of argon gas with flow-meter, TIG torch and an accessories kit.

TIG ARC welding machine

Aluminium welding machine

CO2 welding machine

Three Phase MIG Welding Machine

Figure 12. Types of welding machines

Figure 13. Washing machine frame

Figure 14. Solid vessel with waste water exit

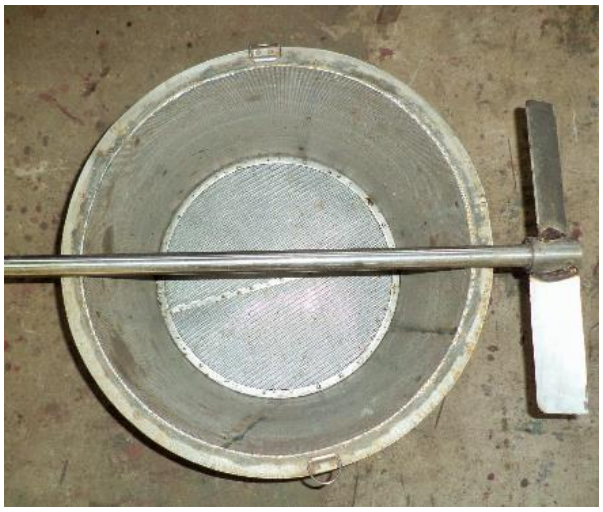

Figure 15. Stirring system

Figure 16. Perforated vessel

2.6 Performance Evaluation of a Washing Machine

The overall performance of the washing machine can be determined considering the washing capacity, retention time and skinning damage of millet as affect by rotational speed, operational time and loading weight.

3.6.1 Washing efficiency (capacity) WE

The mechanical washing efficiency of machine is determined as the ratio of the difference in weight of millet before and after washing to the weight before washing (Narender et al., 2018).

$$WE = \frac{weight\ of\ millet\ before\ washing - weight\ of\ millet\ after\ washing}{weight\ of\ millet\ before\ washing} x100 \quad \text{Eq. 1}$$

3.6.2 Skinning Damage/Efficiency (SD)

This occurs due to rubbing action among the millet itself or between millet and revolving drum (Narender et al., 2018).

$$SD = \frac{weight\ of\ skinned\ millet\ after\ washing}{total\ weight\ of\ millet\ after\ washing} x100 \quad \text{Eq. 2}$$

3.6.3 Retention Time (RT)

The time taken for a marked sample of millet to travel the entire length of the washing drum is the retention time inside the revolving drum (Narender et al., 2018).

$$RT = Time\ taken\ for\ predetermined\ weight\ of\ millet\ to\ travel\ length\ of\ washing\ drum \quad \text{Eq. 3}$$

The performance of the washing machine may be evaluated by measuring the rate at which the millet is washed and the time used to perform the washing activities. In determining efficiency of machine, the following parameters should be considered; duration, feeding rate, retention time, weight of millet before and after washing, weight of skinned millet after washing and the drum speed.

CHAPTER THREE

3.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

3.1 Summary

A millet washing machine was fabricated to address and improve the hygienic conditions and reduce the drudgery involved in the traditional method of washing millet to improve timeliness before further processing. The major components of the millet washing machine include the washing chamber, the wastewater exit, the machine frame and the stirring system. The washing chamber consists of perforated vessel with vertical height, top and bottom diameters of 12, 19.5 and 16 inches, respectively. The machine frame has a vertical height of 28 inches. The stirring system is run by a 1.5 HP variable electric motor.

3.2. Conclusions

A millet washing machine was fabricated to tackle the problem of hygiene, drudgery and long hours spent in the traditional method of washing millet before further processing.

3.3 Recommendations

A large scale version of the millet washing machine can be considered for industrial purposes. A solar-power system can also be considered as an alternative or additional power source to augment electric power from the national grid when operating the washing machine.

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APPENDICES

Appendix 1 - Power Consumption of Washing Machine

The main power consumption comes from the 1 Electric motor

Motor consumes power of 1.5 kW.

Assuming power losses through electric cables is negligible,

Hence, Total power consumption = 1.5 kW

Using the current tariff rating of GH1.06/kW, gives approximately

= 1.5 kW x 1.06

= GH1.59

Meaning the estimated cost of operating the washing machine for 1hour is equivalent to GH 1.59

Appendix 2 - Operational and Maintenance Manual

Operational Manual

Step 1: Pour the product (millet) into the perforated basket inside the main vessel.

Step 2: Fill the vessel with clean potable water until the whole product (millet) in the perforated basket is covered with water.

Step 3: Turn on the power supply switch for stirring to begin.

Step 4: Adjust the motor regulator till the required speed is attained.

Step 5: Allow continuous stirring of the product (millet) in the perforated vessel by the stirring shaft for at least five (5) minutes.

Step 6: After five (5) minutes, open the tap at the bottom of the vessel to drain the water from the product (millet).

Step 7: Simultaneously pour potable water into the perforated vessel while draining water from the vessel to ensure all dirt are removed from the product (millet) within the perforated vessel.

Step 8: After draining all the waste water out of the vessel, stop the motor and take off the stirring shaft from the vessel.

Step 9: Lift the perforated basket filled with the washed product (millet) from the vessel and pour the product (millet) into drying trays for drying.

Step 10: Place the perforated basket and the stirring shaft back in the vessel for the next batch of product washing.

Maintenance Manual

1. Periodically check the perforated basket to ensure that its holes are not clogged with remnants of previously washed product (millet).
2. Inspect the joint where the wastewater outlet tap has been attached to the vessel for any leakages.
3. Periodically inspect the stirring shaft and its flanges for cracks or bends.
4. Check the power switch cables for any abnormality.

Appendix 3 – General Guidelines and Description of a Food Processing Facility

Processing Area

Food processing area with mills, beaters, washing and cleaning machines, vertical centrifuges, pumps, etc., installed can have rectangular shaped buildings with enough space for the machines and staff activity. A height of 4m is sufficient. Because beaters need a heat supply, this is enough to heat the processing area. In the process room, the floor is constructed of materials that resist corrosion by liquids produced in the industrial processes. It must be also washable, nonslippery, and easily repairable. It must have sewers and suitable slopes (1%) to drain the washing water.

Walls must be constructed of smooth, washable and easily repairable materials. The lower 2.5 or 3m of walls should be tiled or with continuous coverings, such as epoxy resins, which are more effective but a little less esthetic.

Additional Facilities

Besides the main building, which serves as the processing plant, the following facilities must be available:

- A cabin for the scale arm and the person who controls it; entrance and unloading area must be controlled from it
- An office, size of which depends on the industry size and importance
- A laboratory for the necessary tests for oil elaboration and storage
- Bathrooms and changing rooms for the staff during the oil-production season and for the rest of the year.
- A room of suitable size where the water heating is located; hot water, at a temperature of $80^{\circ C}$, is essential for the elaboration process and for ambient heating.
- A separative sewer net, that is, vegetative water and rain water are piped separately; the first must be piped to a pond, with waterproof walls, from which it will be periodically extracted for depuration or removal to a suitable community installation; rainwater and wastewater from the bathrooms are piped to the town's sewers.

Machinery Selection

Selection of plant and machinery is crucial when setting up a food processing unit. All machinery and equipment used in the processing line should have the right efficiency. Matching the capacities of different machines and equipment in a processing line require expert guidance. Therefore, a suitable consultant/food technologist should be appointed to set up a processing plant. The machinery should not occupy more than 1/3rd of the total floor area for smooth operation of labour.

Facilities required in the processing room

- A changing room where clothing and shoes that are not worn for work can be stored.
- Separate hand-washing facilities for staff, with soap, clean water, nail brushes and towels.
- Toilets, which should be separated from the processing room by two doors or located in a nearby building.
- First aid materials.
- Protective aprons or coats washed regularly, hats/hairnets and if necessary, gloves and shoes.
- Cleaning chemicals, stored away from the processing room