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Design And Fabrication of Lead Actuator-based Millet Milk Extractor for Food Applications

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Abstract: **Millets, often considered "poor man's food," are rich in nutrients but contain anti-nutritional factors and high fiber content. These fiber-rich millets when consumed cause gastroesophageal reflux disease, irritable bowel syndrome and other digestive disorders. The Millet Milk Extractor addresses these concerns by processing millets into a milk form, reducing anti-nutritional factors and increasing nutrient bioavailability. This project introduces the Millet Milk Extractor, an innovative device designed to extract milk from millet grains efficiently. The equipment incorporates a lead actuator, stainless steel components, a load cell, pH sensor, DC motor, and Node MCU PCB Board for automation. The device's working principle involves the lead actuator converting rotary motion into linear motion to extract millet milk. This equipment presents a sustainable and health-conscious solution, encouraging millet consumption for its nutritional benefits. The equipment's efficiency has been tested with two types of millet. Also cost estimation and potential applications in both household and commercial settings are discussed.**

Keywords: **Millet milk, Lead actuator, Bioavailability, Nutritional factor, Fabrication**

I. INTRODUCTION

Millets are highly nutritious and play an essential role in the diets of people in many parts of the world [1]. Formerly known as "poor man's food" or "poor people's crop" in rural India, Millets were traditionally consumed by impoverished members of the community as an energy-dense and healthful food, especially during drought and famine [2]. Millet is a primary food component in many traditional dishes and beverages, including bread and porridge, are also a good source of carbs, proteins, and other phytonutrients [3]. Especially, essential amino acids are found in large amounts in typical millet protein are sulfur-containing amino acids (methionine and cysteine). Millet foods have the potential to be prebiotics and can improve the functionality or viability of probiotics with important health benefits. Being a mainstay and eaten at processing needs to be taken into account at the home level at both conventional and commercial levels, encompassing entrepreneurs on a small, medium, and large scale [4] Notably, because of its high fiber content, it should not be consumed by young children or the elderly since it may create digestive issues [5].

Grinding the millet will help to reduce the fiber content. This process removes the fiber- and phytochemical-rich bran and germ layers, which results in a major loss of fiber content. Glycated flavonoids and phenolic acids are two types of antioxidants found in millets. By processing it into millet milk it reduces anti nutritional factors and can increase the bioavailability of nutrients it also reduces the fiber content which makes it suitable for children and elder people for better digestion aspects. The traditional method involved in millet milk extraction are cleaning and washing, drying, crushing & winnowing, soaking, grinding, filtration [6]. A common method to improve the nutritional value of millet is to soak it, which breaks down several components into simpler compounds and changes the texture, flavor, aroma, and taste [7]

The Millet Milk Extractor was developed in order to supply the millet milk (nutritional elixir) both commercially as well as for household applications. Considering its potential this innovative device specifically extracts milk from millet grains, guaranteeing maximum yield and top-notch quality. It can measure the pH and quantity of the milk. This automated environment works in the principle of Linear actuator which yields more milk. It is an automatic operation and can be used for both household and commercial. Through the development of this device, the public is indirectly encouraged to consume millet by raising awareness of its advantages for their health and the environment.

I. OBJECTIVES AND METHODS

To design and develop the millet milk extraction equipment and to test its efficiency by extracting milk from Eleusine coracana (Finger millet) and Pennisetum glaucum (Pearl millet).

A. Materials

Stainless steel 304 - Stainless steel was the only material taken into consideration when building this machine. This reduces the risk of food poisoning from contaminated milk [8]. Durability, affordability, strength, availability of materials, and ease of maintenance were other considerations in the fabrication process. Consideration was also given to the machine's techno-economic factor;

20kg load cell - An electrical device called a load cell is an indirect two-stage transducer that uses electricity to transform mechanical force into an electrical signal;

pH sensor – According to the Arrhenius concept of acids and bases, the concentration of the hydronium (H3O Í) and hydroxyl (OH) ions determines the acidity and alkalinity of aqueous media, which are the environments in which most processes in nature take place [9];

DC Motor - The field winding connection has a wide variety

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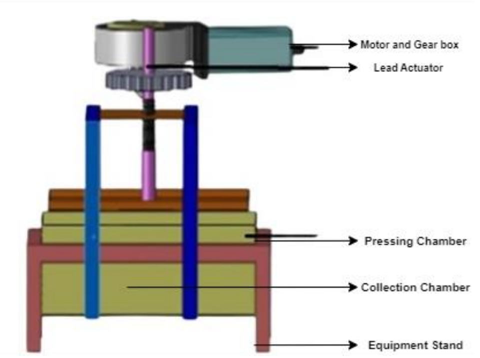
of winding schemes. Two fundamental electromagnetic interactions underpin the operation of DC machines, which include DC motors and DC generators. A conductor moving in a magnetic field will experience an electromotive force, and a conductor carrying current and lying in a magnetic field will undergo a mechanical force [10].
Node MCU&PCB Board - An open source IoT platform is called Node MCU. It consists of hardware built around the ESP-12 module and firm ware running on Expressive Systems 'ESP8266WiFiSoC' [11];
15mm ball bearing - Analytical explanations of contact deformations, stresses, and load distributions can be found in Ball Bearing [12]. These materials have been brought from Coimbatore's local market.



A. Methodology:

A lead screw is a linear actuator with a metal pipe with a helical projection resin-molded on its exterior and a ball for a pivot bearing welded to the metal pipe's distal end is disclosed[13]. There may be some variations depending on the manufacturing process tolerances, the strain or wear on the components from the applied loads (the tangential and radial forces caused by the external torque and other factors. Finding out how large the tolerances can be without affecting the condition is a major concern [13].

A. 3D Model designing

Solid Works software is used to design the equipment. This Solid Works 2021 software, supports testing and simulations, to build three-dimensional models using computer-aided design (CAD) [14]

A. Preparation of sample for testing equipment efficiency:

Two millets namely finger millet (Eleusine coracana (L)) and pearl millet (Pennisetum glaucum (L)) are being chosen for the efficiency test. Required amount (250gms) of finger millet and pearl millet has been taken. Selected millets have been cleaned and washed using cold water for about 7 to 8 times until all the dirt and dust particles removed. Then it is dried for about 2 hours at the room temperature. After drying crushing and winnowing are done to remove the husk, soaking is important to extract milk. The millet has been soaked for about 8-12 hours, this process loosens the cellular structure of the millet and it removes the phytic acid from it.

B. Millet milk extraction:

The soaked millets have been grinded in the mixer for about 1 to 2 minutes. Millets are being grounded for extraction. This equipment takes around 2 to 3 minutes to extract the millet milk from it. The pressure of this lead actuator is about 15 MPa during the extraction process. The extracted millet milk has been collected in a glass beaker to measure to identify the pH and quantity of the milk.

C. Millet milk filtration and bottling:

Sock and sleeves are used to separate the millet milk from the millet cake/dust particle. Followed by bottling which has done in sterilized bottle to increase the shelf life of millet packaging and stored for further purpose.

I. RESULTS:

The millet milk extraction machine has been designed using Solid works software V2021 and designed 3D model front view and side view has been shown in the figure 1(a) and figure 1(b). The millet milk extraction machine has the following parts: lead actuator, pressing vessel, motor, and gear box. The pressure vessel serves as a container for millet from which the milk is extracted. The lead actuator crush, press and squeeze the milk from the millet. The basic working principle of electric linear actuators is converting the rotary motion into a linear one. This conversion of motion is done with the help of a gear box and a lead screw.

Figure 1(a)

Figure 1(b)

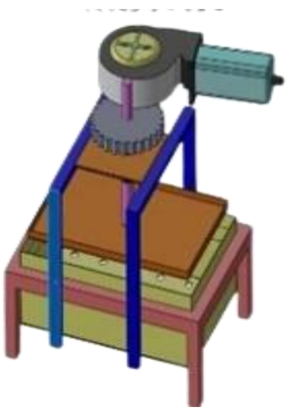


Figure 1(a). Front view of designed millet milk extractor equipment. Figure 1(b). Side view of designed millet milk extractor equipment using SolidWorks V2021 Software.

A. Development of equipment using different components

This machine had been fabricated using stainless steel 304, SS pipe, 40Kg load cell, DC motor, 15mm ball bearings, Node MCU, PCB boar, SMPS

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and the pH sensor to detect the pH of the milk.

Figure 2. Front view of fabricated millet milk extractor using different components

B. Testing equipment for efficiency

For 5-10 minutes prepared (*Eleusine coracana* (L)) and pearl millet (*Pennisetum glaucum* (L)) samples have been grinded well. The grinded millets subjected into the developed equipment are being pressed where the lead actuator method is used to break the millet's cellular structure and release starches, proteins, and other compounds into water thus turns into a milky liquid known as millet milk. This has been shown in figure 3.

Figure 3. Millet milk extractor using lead actuator principle

The pH and the quantity of the milk can be detected by attached sensors along with the equipment. Figure 4. Shows the ability of the sensors to calculate quantity and pH accurately.

Figure 4. Sensors detecting quantity and pH of the extracted millet milk

The efficiency of fabricated equipment has been explained in table 1 below.

Table 1. Efficiency test results

S. No	**Millet Type**	**Quantity of millet (in gram)**	**Quantity of millet milk extracted from sample (in ml)**	**pH measurement using pH sensor**
1	Finger millet (*Eleusine coracana* (L))	250	70 ml	8.600
2	Pearl millet (*Pennisetum glaucum* (L))	250	62 ml	9.784

The milk extracted from the millets were filtered using Sock and sleeves which has been shown in figure 4 and 5. Filtered milk has been bottled under sterile condition for further purpose.

Figure 5. Filtered finger millet milk

Figure 6. Filtered pearl millet milk

I. CONCLUSION AND DISCUSSION

Millets are considered as the nutritional rich diet all over the world. Although it is rich in nutrition, bioavailability of the millet for infants are very low. This is especially due to high fiber content. Processing it into milk has the chance of reducing the fiber content and also some anti-nutritional factors. Developed Millet Milk Extractor is more than a mere device; it's evidence of how custom, health, and technology can coexist. Such innovations are not only welcome but crucial as the world shifts towards sustainable and health-conscious food choices. It can be used in small-scale and large-scale industries. This millet milk can be used for culinary purposes. With additional investigation and market integration, millet milk may soon take its proper place among other well-liked plant-based milk.

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