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Development and Performance Evaluation of Soya Beans Milk Extracting Machine

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Abstract : ***Protein is required for growth, repair of muscles and nutritional balance. Carefully planned nutrition must provide energy and nutrient balance. To solve the problem of protein unavailability, Soya bean milk can be seen as an important and cheap source of feeding to make up for protein deficiency in the day to day nutritional requirement. This paper explicitly gives the details of the development and performance evaluation of a Soya beans milk extracting machine. it is fast, less expensive, convenient to use and the milk produced from it is hygienic. The major components of the machine are the grinding mill, filter, and boiler. The machine has a grinding rate of*** $4.151\ g/s$ ***and a production yield of*** $33.26 liters/hr$. ***Its performance was evaluated by comparing the volumetric yield of the machine with the volumetric yield of traditional methods.***

Key words: **Nutrition, Soya bean, Protein, Milk, Extracting Machine.**

I. INTRODUCTION

Soybean (Glycine max) is a species of legume native to East Asia, widely grown for its edible bean which has numerous uses. The plant is classed as an oilseed rather than a pulse. [8]. It also known as soy beans plant is sometimes referred to as greater bean (Chinese dadou and Japanese daizu). Both immature soybean and its dish are called edamamein Japan.[6]. Soy varies in growth and habit. The height of the plant varies from below $20\ cm$ up to $2\ metres$ The pods, stems, and leaves are covered with fine brown or gray hairs. Oil and protein content account for about 60% of dry soybeans by weight; protein at 40% and oil at 20%. The remainder consists of 35% carbohydrate and about 5%ash. Soybean cultivars comprise approximately 8% seed coat or hull, 90% cotyledons and 2%hypocotyls axis or germ. Most soy protein is a relatively heat-stable storage protein. This heat stability enables soy food products requiring high temperature cooking, such as tofu, soy milk and textured vegetable protein (soy flour) to be made. [2].Soy milk (also called soya milk or soybean milk,) is a beverage made from soybeans. A stable emulsion of oil, water, and protein, it is produced by soaking dry soybeans and grinding them with water. Soy milk contains about the same proportion of protein as cow's milk: around 3.5%; also 2% fat, 2.9% carbohydrate, and 0.5% ash. Soy milk can be made at home with traditional kitchen tools or with a soy milk machine. Soy milk has about the same amount of protein (though not the same amino acid profile) as cow's milk. Natural soy milk contains little digestible calcium as it is bound to the bean's pulp, which is insoluble in humans. To counter this, many manufacturers enrich their products with calcium carbonate available to human digestion. Unlike cow's milk, it has little saturated fat and no cholesterol. Soy milk contains sucrose as the basic disaccharide, which breaks down into glucose and fructose. Since soy doesn't contain galactose, a product of lactose breakdown, soy-based infant formulas can safely replace breast milk in children with galactosemiaa very rare condition. Like lactose-free cow's milk, soymilk contains no lactose, which makes it a good alternative for lactose-intolerant people. For patients without conditions that limit which sugars they can consume, there is no evidence to support any sugar-related health benefit or detriment to consuming soy milk instead of cow's milk. [9].

II. LITERATURE REVIEW

Soy bean originates from China in 2853BC, Emperor Sheng-Nung of china named five sacred plants; soya beans, rice, wheat, barley, and millet. Soybean plants were domesticated between 17^{th} and 11^{th} century BC in the eastern half of China where they were cultivated into a food cop. From about the first century AC to the age of discovery (15^{th} to 16^{th} century), soybeans were introduced into several countries such as Japan, Indonesia, the Philippines, Vietnam, Thailand, Malaysia, Burma, Nepal and India. The spread of soy bean was due to the

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establishment of sea and land trade routes. The earliest Japanese reference to the soy bean is in the classic kojiki (Records of Ancient Matters) which was completed in 712 AC. [7]. The first soybeans arrived in America in the early 1800s as ballast aboard a ship. It wasn't until 1879 that a few brave farmers began to plant soybeans as forge for their livestock. The plants flourished in the hot, humid summer weather characteristics of the north-eastern North Carolina. Around 1900 the US Department of Agriculture was conducting test on soybeans and encouraging farmers to plant them as animal feed.

In 1904, the famous American chemist, G.W Carver discovered that soybeans are a valuable source of protein and oil. He encouraged farmers to rotate their crops with soy beans. To the surprise of farmers, this produced a better crop. The crop was not recognised as a very important crop in Nigeria until recently when it was discovered it could be planted on large scale for industrial uses [5]. At present soybeans is a minor crop in Nigeria [1].when it is predominantly produced in two production areas – Benin state and zonkwe – Abuja of Niger state. [1]. Experts have described the potential areas of production as existing around the middle belt stretching from Markurdi to Yola. Attempts are being made to grow soybeans in the western region of Nigeria in Ogun state in Ikene and Ajegunle by the International Institution of Tropical Agriculture (IITA) and the National Cereal Research Institution on experimental pilot. According to [2], the nutrients in 250ml of plain soymilk compared with whole cow milk and fat free cow milk are analysed in table 1 below:

Table 1: Comparison of Nutrients in 250 Ml Of Plain Soymilk With Whole Cow Milk, Fat Free Cow Milk and Light Soymilk

S/N	Nutrients	Regular Soymilk	Light Soymilk (reduced fat)	Whole cow milk	Fat-free cow milk
1	Calories (kcal)	90	70	149	83
2	Protein (g)	10.0	4.0	7.7	8.3
3	Fat (g)	4.0	2.0	8.0	0.2
4	Carbohydrate (g)	14.0	16.0	11.7	12.2
5	Lactose (g)	0.0	0.0	11.0	12.5
6	Sodium (mg)	120	100	105	103
7	Iron (mg)	1.8	0.6	0.07	0.07
8	Riboflavin (mg)	0.1	11.0	0.412	0.446
9	Calcium (mg)	80.0	80.0	276	299

Source: Blackman *et. al*, 1992

Soybeans must be cooked with wet heat For human consumption, to destroy the trypsin inhibitors (serine protease inhibitors). Raw soybeans, including the immature green form, are toxic to humans, swine, chickens, and in fact, all monogastric animals. Soybeans are considered by many agencies to be a source of complete protein. A complete protein is one that contains significant amounts of all the essential amino acids that must be provided to the human body because of the body's inability to synthesize them. For this reason, soy is a good source of protein, amongst many others, for vegetarians and vegans or for people who want to reduce the amount of meat they eat. Soy protein products can be good substitutes for animal products because, unlike some other beans, soy offers a complete protein profile. Soy protein products can replace animal-based foods which also have complete proteins but tend to contain more fat, especially saturated fat without requiring major adjustments elsewhere in the diet.[3].

The gold standard for measuring protein quality, since 1990, is the Protein Digestibility Corrected Amino Acid Score (PDCAAS) and by this criterion soy protein is the nutritional equivalent of meat, eggs, and casein for human growth and health. Soybean protein isolate has a biological value of 74, whole soybeans 96, soybean milk 91, and eggs 97. Soy protein is essentially identical to that of other legume seeds. Moreover, soybeans can produce at least twice as much protein per acre than any other major vegetable or grain crop besides hemp, five to 10 times more protein per acre than land set aside for grazing animals to make milk, and up to 15 times more protein per acre than land set aside for meat production. Consumption of soy may also reduce the risk of colon cancer, possibly due to the presence of sphingolipids. [4].

Cultivation of soya bean is successful in climates with hot summers, with optimum growing conditions in mean temperatures of 20 to 30 °C (68 to 86 °F); temperatures of below 20 °C and over 40 °C (68 °F to 104 °F) retard growth significantly. They can grow in a wide range of soils, with optimum growth in moist alluvial soils with a good organic content. Soybeans, like most legumes, perform nitrogen fixation by establishing a symbiotic relationship with the bacterium *Bradyrhizobiumjaponicum*. For best results, though, an inoculum of the correct strain of bacteria should be mixed with the soybean (or any legume) seed before planting. Modern crop cultivars generally reach a height of around 1 m, and take 80–120 days from sowing to harvesting. [10].The dry beans are soaked in water overnight or for a minimum of 3 hours or more depending on the temperature of the water. The

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rehydrated beans then undergo wet grinding with enough added water to give the desired solids content to the final product. The ratio of water to beans on a weight basis should be about 10:1The resulting slurry is subjected to filtration to remove the insoluble residue.

III. MATERIALS AND METHODS

The development of a soya beans milk extracting machine is a flow process because the soya beans passes through two stages which are milling and compression. As the wet soya beans are grated they are passed to the compression chamber where the required milk are extracted with the help of a metallic sieve. The compression of the milled wet soya beans is achieved with the aid of a compressive force provided by the foot pedal, the filtrate is passed out to the reservoir where it is being packaged. Figure 1.0 shows the developed soya beans milk extracting machine.

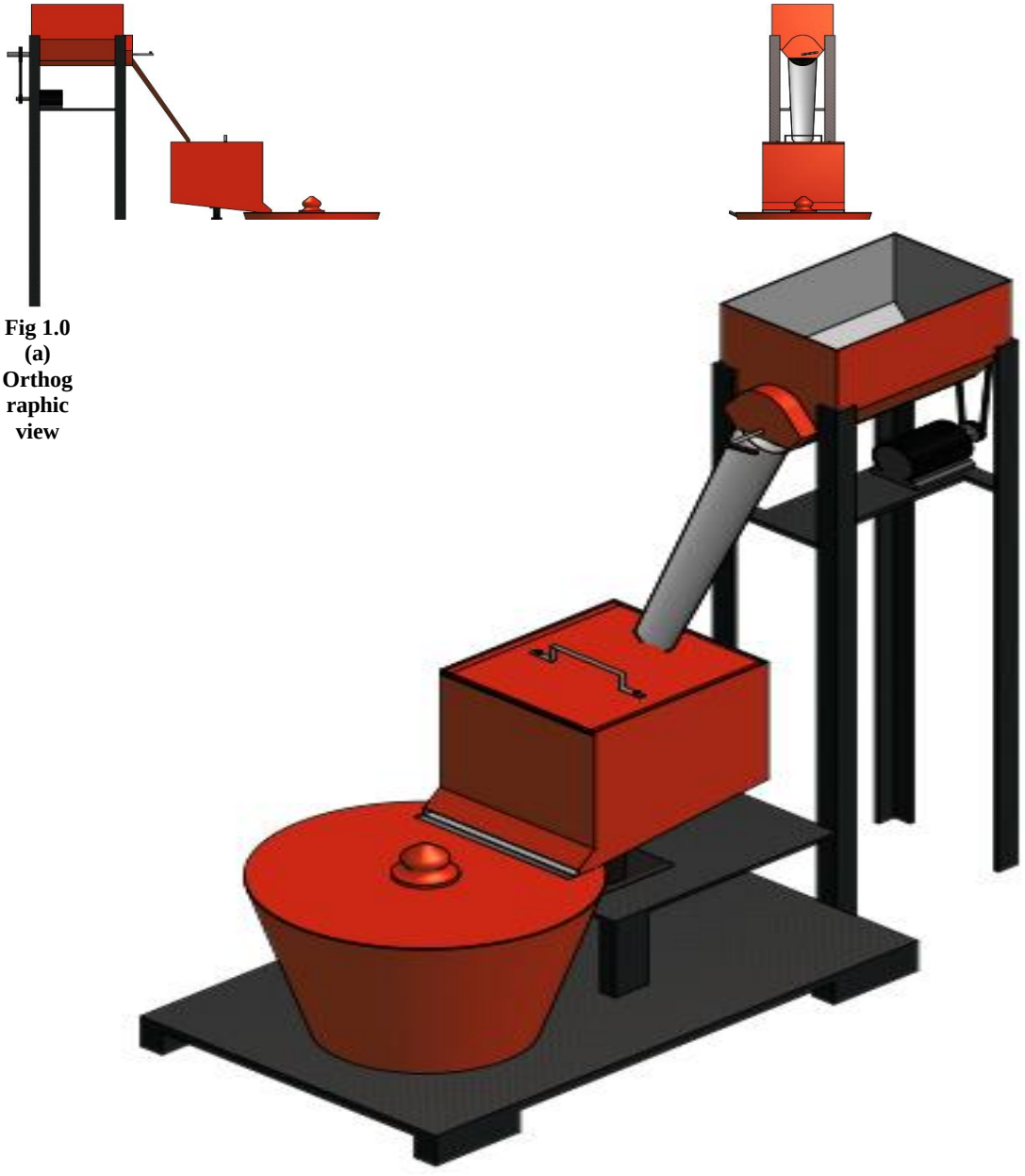

Fig 1.0 (a) Orthographic view

Fig 1.0 (b) Pictorial View

Fig 1.0: Orthographic and Pictorial View of the Soya Beans Milk Extracting Machine

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The cooked soya beans is poured into the hopper of the milling machine which mills the beans into moist form. The resulting slurry is passed to the sieving chamber where it is sieved with the aid of a jack which compresses it so as to extract the milk out of it. The extracted milk is delivered to the tank for storage.

The volume of the milling drum was obtained as $0.04m^3$ using equation (1)

$$V_{md} = \frac{\pi D_{md}^2 L_{md}^2}{4} \quad 1$$

Where;

V_{md}, D_{md}, L_{md}, are the volume, diameter and length of the milling drum.

The volume of the hopper in the milling machine was obtained as $7.82 \times 10^{-3} m^3$ using equation 2

$$V_{hopper} = \left\{\frac{1}{2} \times L_{u1} \times L_{u2} \times H_L\right\} - \left\{\frac{1}{2} \times L_{b1} \times L_{b2} \times H_{cut\ away}\right\} \quad 2$$

Where;

$L_{u1}\ and\ L_{u2}$are the dimensions of the width and breadth of the conveyor at the upper part.

$L_{b1} and\ L_{b2}$are the dimensions of the width and breadth of the conveyor at the base.

$H_L\ and\ H_{cut\ away}$are the height of the hopper for its full length and cut away section respectively.

The center distance 'C' between the pulley fitted to the shaft of the milling machine and the electric motor was obtained to be $247.5mm$ using equation 3.

$$C = \frac{3.55D_s + 4.55D_s}{2} \quad 3$$

Where;

D_s =diameter of the pulley fitted to the electric motor

D_s =diameter of the pulley fitted to the shaft of the milling machine

The power transmitted to the shaft of the milling machine was determined to be $1033.5\ N$ using equation 4

$$P = (T_{tight} - T_{slack})V_{belt} \quad 4$$

Where;

$T_{tight}\ and\ T_{slack}$are the tensions in the tight and slack side of the belt respectively

V_{belt} = Velocity of the belt

The metallic compression sieve used in the compression compartment was made from mild steel, it has a diameter of 365mm and its area was estimated as $0.105m^2$. Figure 2 shows the plan view of the compression sieve.

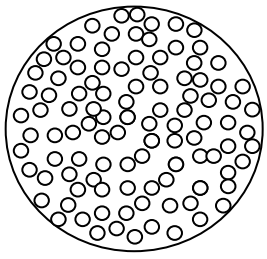

Fig 2: Metallic Compression Sieve

The cost of producing the machine was estimated to be ₦48 500. This amount is the summation of the bought out cost, cost of materials and the non machining job

The factors considered for selection of materials for the fabrication of the machine so as to enhance its sustainability, reliability, workability, stability and efficiency are cost of construction, availability of the material, rigidity and strength, overall weight, corrosion resistance and rust. Table 2 shows the materials selected for different component part of the machine.

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Table 2: Material Selection for the Fabrication of the Machine

S/N	MACHINE COMPONENTS	SUITABLE ENGINEERING MATERIAL	CRITERIA FOR MATERIAL SELECTION	MATERIAL SELECTED	REMARKS
1.	Hopper a. Side plates, partition plates, front and rear corver b. Frame	Galvanized sheet, stainless steel and aluminium sheet. Mild steel and square pipe Angle iron.	Corrosion resistance, workability and cost Strenght, rigidity and lightness	Mild steel Square pipe	High strength and cost effectiveness Lightness
2.	Shaft	Mild steel, stainless steel	Availability, machinability, cost and strenght	Mild steel	Availability and cost effectiveness
3.	Pulley	Cast iron, mild steel, wood, forged iron and aluminium	Strenght, Availability, and cost	Cast iron	Strong and readily available
4.	Belt	Rubber and leather	Strenght and flexibility	Rubber	Flexibility and strength
5.	Spring	Carbon steel, stainless steel wire, hard drawn wire, bronze and oil tempered wire	Strenght stiffness, deflection, buckling and corrosion	Stainless steel wire	High strenght, stiffness and corrosion resistance
6.	Bearing	High speed steel	Axial loading and radial loading	High speed steel	Accommodate both axial and radial loading
7.	Foot pedal	Mild steel	Availability cost effectiveness	Mild steel	Availability cost effectiveness
8.	Filtering chamber a. Side plates, front rear and bottom plates	Galvanized steel sheet Stainless steel, mild steel	Corrosion resistance, workability and cost effectiveness	Mild steel	Strenght and cost effectiveness

IV. PERFORMANCE TEST, RESULTS AND DISCUSSION

The performance of the machine was achieved by carrying out test on individual unit in the machine. To test the milling machine a basket of soya beans was boiled and dehulled, its weight was obtained and ground in the machine and the time taken to get a satisfactory grinding was recorded. Table 3 shows the results obtained for the grinding operation. The grounded soya beans was allowed to pass through all the stages i.e. grinding, filtering, boiling and the total time it took to get the final milk was also recorded as shown in table 4.

Table 3: Grinding Rate Analysis

ATTEMPT	WEIGHT OF SOYA BEANS (g)	TIME TAKEN TO GRIND (s)
1	512	126
2	531	129
3	526	123
TOTAL	1569	378

Table 4: Overall Rate of Production Analysis

ATTEMPT	MASS OF SOYA BEANS (g)	VOLUME PRODUCED (*l*)	TIME TAKEN (s)
1	512	17	1920
2	531	17	1860
3	526	17	1740
TOTAL	1569	51	5520

From table 3, the grinding rate of the machine can be obtained as follows:

$$G_{rate} = \frac{1569}{378} = 4.151\, g/s$$

From table 4, $51\ litres$ of soya beans is produced in $5220\ seconds$

$$\therefore \text{for 1 second} = \frac{51}{5520} = 0.00923\, litres/sec$$

The results of the test shows that the machine can grind 4.151g of soya beans in a second and produce $0.00923\ litres$ also in a second. This implies that the machine will produce can grind $4.151\ kg$ of soya

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beans in one hour and produce 33.26 *litres* of milk in an hour. From this result we can see that the rate of production is high and therefore the machine will facilitate high volume production of milk from soya beans.

V. CONCLUSION

The soya beans milk processing machine is a new design which facilitates the complete processing of soya beans milk in one machine thereby saving time and complexity of operation. The machine was constructed from locally made materials which can easily be sourced, having improved efficiency and providing easily available milk for the consumer which the available local methods cannot achieve. The soya beans milk processing machine is simple in operation, requiring no expertise, hygienic, safe and needs little or no further processing after its use.

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