TECHNOLOGIES FOR EXTRACTION OF OIL FROM OIL-BEARING AGRICULTURAL PRODUCTS: A REVIEW

A. Ibrahim[1] and A. P. Onwualu[2]
[1]University of Calabar, Calabar, Nigeria.
[2]Department of Agricultural Engineering
University of Nigeria, Nsukka.
E ï mail: ponwualu@yahoo.com

ABSTRACT

A critical appraisal of technologies for oil extraction from oil-bearing agricultural products is presented. Different types of oil- bearing agricultural products are discussed. The products include; groundnut, coconut, sheanut, castor, sunflower, sesame, oil-palm, etc. This work has also discussed the pre-processing conditions including the removal of hulls and shells, pre-processing conditioning such as size reduction, moisture content adjustment, heat treatment and pressure application, as well as the methods employed in the extraction, namely; traditional and modern (improved) methods. The improved method include; oil expeller, screw press, and solvent (chemical extraction). Problems (technical, socio-economic and institutional) associated with each method and the need for more research for the improvement of the methods are analysed. It has been shown that for any developing country to effectively adopt modern methods in the production of edible vegetable oils, improvement on the existing traditional methods, environmental factors, government policies, socio-economic and cultural considerations of the users need to be studied. This can be achieved through more research in the recommended area of need.

KEYWORDS: Vegetable oil extraction, oil bearing agricultural products, oil expression.

1. INTRODUCTION

Oil extraction is the process of recovering oil from oil-bearing agricultural products through manual, mechanical, or chemical extraction. The agricultural products are classified into oil-seeds (cotton, castor, sunflower, etc), nuts (coconut, groundnut, sheanut, etc) and mesocarps or fruits (oil palm). Plants bearing these agricultural products have greatly contributed to the economic development of many countries especially the development of West African countries where the products are grown for commercial purposes. Of the many types of oil that can be obtained from these products, only few are very significant in terms of world production and traded as major commodities (Robbelen *et al,* 1989). However, the oil extracted from these products have diverse domestic and industrial uses. The oil serves as a major source of vegetable oil that constitutes a good percentage of meal in the diets of common people. The oil as well as the by ïproducts are also very useful as food and non-food materials for the production of snacks, cake, margarine, biscuit, cosmetics, detergent, plastics, etc. Oil production is important not only among small-to-medium scale industrialists, but also to rural populace, employing quite a substantial workforce serving as a source of income to many communities engaging in the exercise (Abalu, 1978; UNIFEM, 1987).

Extraction of oil from oil-bearing products could be done in two major ways; traditional and improved methods. The traditional method is usually a manual process and involves preliminary processing and hand pressing. The improved method consists of chemical extraction and mechanical expression. The chemical extraction method requires the use of organic solvents to recover the oil from the products. Mechanical method involves the application of pressure to already pre-treated oil-bearing products. It employs the use of devices like screw and hydraulic presses as a means of applying the pressure (Gunstone and Norris, 1983). Other mechanical devices include oil expellers and improved ghanis which are used for seeds and nuts because of the high pressure required to express the oil (UNIFEM, 1993). Whichever method is employed, researchers (Norris, 1964; Ward, 1976; Khan and Hanna,

1983; Adekola, 1991) reported that the yields and quality of the oil extracted depend on the content adjustment, heating time, pressure application, operating temperature, etc.
Although processing of oil-seeds, nuts, and fruits for oil production is achieved by both traditional and improved techniques, oil extraction techniques have not changed significantly over the years as the bulk of this trade is still in the hands of rural women employing traditional systems only. Apart from discouraging many oil producers from continuing with the trade especially at old age, this difficult task also limits the capacity and oil yields of those determined to continue with the trade (IAR, 1992). Accessibility to modern equipment and spare parts, degree of complexity of the equipment, maintenance, and the availability of power source constitute other major setbacks.

In most of the developing countries, there has been a steady rise in the demand of edible oil both for domestic and industrial uses. Therefore, continuous review of existing methods of oil expression or extraction from oil-bearing agricultural products will no doubt continue to reveal the current state of the art especially on aspects that require further improvement. This in turn will sensitize engineers towards developing better machines and techniques to increase both the quality and quantity of oil yield to meet the increasing demand. It is to this end that this work has been conceived. Therefore, the specific objectives of this paper are: to review the techniques of oil extraction from oil-bearing agricultural products, and to analyse the constraints to and prospects for oil extraction techniques.

2. OIL- BEARING AGRICULTURAL PRODUCTS

2.1 Oil-Seeds and Nuts

Oil-bearing seeds and nuts are found in the roots, stems, fruits and leaves of some tropical and sub-tropical plants. They are mostly grown as annual crops and constitute the major source of vegetable oil for domestic and industrial uses. Some of the most common oil seeds and nuts cultivated in the tropics, subtropics and temperate regions include; groundnut, coconut, sheanut, castor, sunflower, sesame, oil palm, etc.

2.1.1 Groundnut (Arachis hypogaea L.)

Groundnut is the most common oil nut grown as an annual crop on about 19 million hectares in tropical and subtropical regions and in the warmer areas of temperate regions of the world, principally for its edible oil and protein rich kernels or seeds. It thrives best on sandy loam soil (Oke *et al*, 1975). It is considered to be the second most important source of vegetable oil in the world. In 1985, the recovered output of groundnut worldwide contained about 14.4 million tons of groundnut kernels, corresponding to the production of about 21 million tons in their shell (at shelling percentage of 70%) with about 7.2 million tons of oil (FAO, 1986).

The yield of kernels generally ranges from 0.5 to 4.0 tons per hectare. In developing countries where 80% of the crop is produced, the average yield is about 1 ton per hectare. The major world producers of groundnut are India, China, USA, Brazil, Senegal and Nigeria. The yield of about 900 kg/ha in India and 907 kg/ha in Nigeria have been reported (Irvine, 1969; Miller, 1983; Adeeko and Ajibola, 1990). According to the reports of TPI (1971) and Miller (1988), groundnut contains about 25% protein and 38 ï 50% oil in its seed.

2.1.2 Coconut (Cocos nucifer L.)

Coconut is cultivated all over the world in the humid tropics, mostly close to the seashore. The world leading producers of coconut are Philippines, Indonesia, India, Malaysia and Thailand. In tropical Africa, the crop is mostly produced in Mozambique, Cote dÎIvore, Tanzania and Nigeria (de Neve de Roden et al., 2001).

The matured coconut plant produces fruits after pollination. The fruit is a drupe consisting of seed (coconut) covered by thick fibrous envelope or husk. The husk (mesocarp) is covered by thin leathery epidermis (exocarp). The coconut has hard thick shell (endocarp), which contains thick layer of firm, white, oily endosperm or albumen, called copra and a central cavity partly filled with sugary coconut water (Salunke and Desai, 1986).

World production of copra (dried coconut meat) has been estimated at 3.3 millions per year. This corresponds to 2.3 million tons of coconut oil (Essiamah, 1985). Green copra consist of 40% oil, 43% water and 17% non-oil products (de Neve de Roden *et al,* 2001). Studies have shown that oil contents of white meat coconut can be increased from 40% to 71% when dried to copra (Khan and Hanna, 1983; Adekola, 1992). The oil contains about 91% saturated fatty acids (44.1-51.3% lauric acid, and 5.4-9.5% coprylic acid, 4.5-9.7% capric acid 13.1-18.5% myristic acid, 7.5-10.5% palmitic acid and 1.0-3.7% stearic acid). The unsaturated fatty acid (9%) constitute about 5.0-8.2% oleic acid and 1.0-2.6% linoleic acid, while the copra cake contains 20% protein (de Neve de Roden *et al.*, 2001). The oil is used in margarine, baking, biscuit production and cooking. In addition, it is also used for making soap, detergent and candle. The by-product of the copra, the coconut cake, is sold as a valuable animal feed (TPI,1971; Adekola, 1992).

2.1.3 Sheanut (Butyrospermum paradoxum (gaertn.F.) Hepper)

In Africa, sheanut grows in the wild. The largest sheanut populations are found on the dry soil of Mali, Burkina Faso, Northern Togo, Ghana, Niger, Nigeria, Cote dô Ivoir and Benin. Burkina Faso could produce about 460,000 tons of sheanuts per year, while the annual production of Cote dô Ivoir and Mali range from 17,000 to 20,000 tons (Michael and Ban Koffi, 2001).

Vegetable fat (oil) called butter are extracted from the kernels. The butter (oil) contents range from 34 to 55% in a kernel with high content of saturated (palmitic and stearic) fatty acids in comparison with unsaturated oleic and linoleic) fatty acids. The average saturated / unsaturated fatty acids ratio is 60:40 (TPI, 1971; Michael and Ban Koffi, 2001). Sheanut butter is used in manufacturing chocolate, cosmetics and as a medicinal substance for skin treatment.

2.1.4 Castor (Ricinus Communis L.)

Castor is grown as an annual crop in Tropical and Mediterranean climate zones. The major producers of castor seed and oil are India , Brazil, China, USA and Thailand with small contribution from African countries such as Ethopia, Tanzania, South Africa, Kenya, Nigeria, etc. (Gobin *et al*., 2001).

At maturity castor plant produce fruits which are globular with at least 3- lobed capsules. Each capsule usually contains three shiny seeds. The seed consists of brittle testa, a copious endosperm and a small embryo with papery cotyledons.

The primary products of castor seed are oil and seed cake. The seed contains about 40 to 55% oil and 14 to 21% protein (TPI, 1971). The oil constitutes about 90% recinoleic acid of the entire fatty acid. The proteins (pomace) contain the toxic substances ricin and allergen (Gobin *et al*., 2001). The oil is used as a purgative in medicine and as an illuminant. In industries, castor oil is used for making cosmetics, plastics, resins, dyes, paints and lubricants. The pomace is widely used as organic fertilizer (Gobin *et al*., 2001).

2.1.5 Sunflower (Helianthus annuus L.)

Sunflower is an annual crop that grows well in many regions of the world. The largest producers of sunflower seeds are ex-USSR, Argentina, France, Spain, China, India and USA. While in tropical Africa, the major producers are Zimbabwe, Sudan, Tanzania, Angola and Malawi (Ravagnan, 2001).

After pollination, the sunflower plant produces fruit consisting of a seed (kernel) and an adhering pericarp (hull). The average seed yield of traditional open-pollinated cultivars on small scale farms is

about 500kg/ha. Well managed crops of improved varieties have yield of 1.5 tons/ha with an oil yield of 700kg/ha (Ravagnan, 2001). The seed consists of seed coat, endosperm and embryo.
The seed contains about 25 to 40% oil, 40 to 60% protein and 10% to 14% fibre (TPI, 1971; Ravagnan, 2001). The oil contains about 90% unsaturated fatty acids and 10%saturated fatty acids of which are oleic and linoleic acids. Sunflower oil is used in the production of margarine, salad oil, cooking oil, as well as non semi-drying oil in paints (Ravagnan, 2001).

2.1.6 Sesame (sesamu indicum L)

Sesame is an annual plant grown in tropical and sub ï tropical regions. It is probably the most ancient oil seed known and used by mankind. It is stated that sesame has its origin in Africa and spread through west Asia, India, China and Japan (Kafiriti and Deckers, 2001).

Sesame is grown as an intercrop system or pure stand. Upon maturity, the crop produces fruits which are erect capsules. Each capsule has about 70 seeds. Under good management, seed yield can be as high as 3000kg/ha. A yield of 2000kg/ha is considered necessary for profitable commercial production (Kafiriti and Deckers, 2001).

Sesame seed contains about 45 to 55% edible oil, 19 to 25% protein and 5% water (TPI,1971; Kasfiriti and Deckers, 2001). The oil is used in industries for manufacture of margarine, cooking fats, soaps, paints, lubricants, illumnants and insecticides, as well as for medicinal drugs (Kafiriti and Deckers, 2001).

2.1.7 Other Oil –Seeds and Nuts

Other oil-seeds and nuts include cotton, melon, breadfruit, neem, coconut, rubber, mustard, lin, cashewnut, palm kernel nut, etc., each contributing about 3.5 to 5.1 million tones of oil world-wide in a year, depending upon the amount of the products being produced (FAO, 1986). They also have oil content in the range of 15 to 30% in their respective seeds and nuts and are mostly glycerides of unsaturated fatty acids oleic acids with linoleic acids, which are useful for industrial and domestic purposes (TPI, 1971; Fasina and Ajibola, 1989). Table 1 shows the percentage of oil content in some oil- seeds and nuts and their uses.

Table 1: Percentage of oil content in some oil –seeds and nuts and their uses

Agricultural Product	Oil content (%)	Uses
Oil Seeds		
Castor	35 ï 55	Paints, lubricants,
Cotton	15 ï 25	Cooking oil, soap making
Linseed	35 ï 44	Paints, varnishes
Niger	38 ï 50	Cooking oil, soap, paint
Neem Kernel	45	Soap making
Rape / Mustard	40 ï 45	Cooking oil
Sesame	35 ï 50	Cooking oil
Sunflower	25 ï 40	Cooking oil, soap making
Nuts		
Coconuts: Dried copra Fresh nut	 64 35	Cooking oil, body / hair cream, soap
Groundnuts	35 ï 50	Cooking oil, soap making
Palm kernel nuts	46 ï 57	Cooking oil, body / hair cream, soap making.
Sheanut	34 ï 44	Cooking oil, soap making.

Source: TPI (1971)

2.2 Oil - Mesocarps

These are oil-bearing fruits mostly grown in tropical regions of Africa. The most common oil fruit grown is oil palm (Elaesis guineensis) which is found growing in forest and swampy areas. The main producing countries are India, Malaysia, Indonesia, Nigeria, Zaire, Sierra Leone, Cameroon, Angola, Ivory Coast and Congo.

The oil palm is a single-stemmed plant growing to a height of about 8 m or more at maturity. The leaves or fronds are arranged spirally on the trunk and it has an extensive root system. However, the ovaries of the female inflorences of the oil palm develop into large bunches and each bunch may contain about 800 to 1000 fruits. Each fruit (Fig.7) is a drupe. The drupe pericarp is made of three layers an outer exocarp, a middle fibrous mesocarp and an inner endocarp (shell). The kernel comprises of a testa (skin) a solid endosperm and embryo.

Palm oil is the major product obtained from the oil palm fruit and it constitutes one of the main sources of edible oil with vitamin A precursors (ECA, 1983). It is also used for industrial purposes such as in the manufacture of soap, margarine, candles, etc.
FAO (1986) also reported that in 1985, the recorded worldwide production of oil from oil palm fruits ranged from 3.5-5.1 million tons. The percentage of oil content in the oil palm fruit range from 42-56% (TPI, 1971; Khan and Hana, 1983; Adekola, 1989).

2.3 Composition of Oil in Some Oil-Bearing Agricultural Products

Groundnut and oil palm are the two major oil crops grown in Nigeria and most other African countries. A fully matured harvested groundnut seed and oil palm fruits consist of oil, protein, carbohydrate, fatty acid and water in different composition (Tables 2 and 3).

Table 2 Composition per 100g edible portion of dried groundnut seed

Content	Percentage/weight
Oil	38-50%
Water	7.3%
Protein	23.4g
Fat	45.3g
Carbohydrate	21.6g
Ash	2.4g
Calcium	5.8g
Iron	2.2mg
Thiamin	1.0mg
Riboflavin	0.13mg
Nicotinic acid	16.mg

Source: FAO, 1982.

Table 3 Composition of palm kernel fruit

Content	Percentage (%)
Oil	47-50
Protein	7.5-9.0
Extractable non- Nitrogenous	23-24
Cellulose	5.0
Ash	2.0
Water	7.5-9.0

Source: Hartley, 1971.

It is clearly indicated that the percentages of oil content in the groundnut seed and palm kernel fruit as shown in Tables 2 and 3 respectively, is higher than the other components which implies that these products contain oils in large quantities. Therefore, proper choice and selection of an efficient expression methods and /or devices will be required to express-oils from these products in order to obtain high oil yields. The oils being expressed from these products contain some percentages of acid concentrations and other constituents in various compositions as shown in Tables 4 and 5 respectively. Thus, due to the presence of high concentration of acids and other constituents in the oils, the oils being expressed need to undergo clarification and refining processes.

Table 4: Composition of Groundnut Oil

Oil content	Percentage (%)
Percent Saturation	17.7
Percent Oleic	5.65
Percent Linoleic	25.8

Source: Hartley, 1971

Table 5: Composition of Palm Kernel Oil

Content	Percentage (%)
Free fatty acid	3.0 ï 4.0
Volatile matter include water	0.15 ï 0.20
Impurities	0.05 ï 0.10
Peroxide (Inch Equivalent, kg)	2.0 ï 4.0
Saponification value	242.0 ï 222.0

Source: Hartley, 1971

3. OIL EXTRACTION TECHNOLOGIES

3.1 Pre-Extraction Process

Oil-bearing agricultural products need to undergo certain preliminary processing to get the seeds or nuts ready for oil extraction. In some cases, oil expression devices are assembled as a complete unit with pre-processing equipment included. This preliminary processing aids is easy and efficient oil extraction, and involves removal of hulls and shells and pre-treatment conditioning such as size reduction, optimum moisture content adjustment, heat treatment and pressure application.

3.1.1 Removal of Hulls and Shells

This involves cleaning (removal of foreign matter) and decorticating (removal of hulls and shells). The cleaning process consists of the removal of sand, stalks, plant debris, and any other foreign matter in the seeds or nuts. The cleaning can be done by rotary or table sieves, usually with air separators by fans, and cyclones for dust removal from the air. According to Galloway (1976), mechanical system that consists of sieves and/ or shakers, both with perforated metal or screen are employed. In these machines, the material flows over the drum or tray, thus cleaning the seeds or nuts.

Decorticating or shelling is the process of freeing oil-seeds and nuts from the shells or pods by cracking the shell using a device known as decorticator. The decorticators are of two major types, hand-operated and power decorticators, both work with the same principle. They consist of the following main units; loading, beating and separating units. The seeds and nuts are loaded in the loading unit and passed to the beating unit where they are cut and cracked or broken by rotary action of the beater bars. The decorticating operation is then followed by separation of the cracked seeds by means of sieves and air separators.

3.1.2 Pre-treatment Conditioning

Pre-treatment conditioning is a preliminary processing activity that involves size reduction, moisture content adjustment, heat treatment and pressure application. These activities depend on the nature of the oil-bearing material and the methods and devices to be adopted in the oil extraction.

The purpose of size reduction is to expose a greater area of oil-bearing cells to the moisture and heat during cooking. However, excessive size reduction is not desirable as it reduces extraction efficiency. Higher oil yields were obtained from coarsely ground groundnuts compared to the finely round samples (Ward, 1976; Adeeko and Ajibola 1994, and Hanna, 1984). Finely ground melon seeds on the other hand, gave higher oil yield than the coarsely ground samples (Ajibola et al., 1990).

The moisture content of seeds is an important factor that affects the yield and quality of the oil extracted. Cloudy oil is obtained from seeds with high moisture level; therefore, moisture adjustment of the seed is necessary before pressing. For example, a moisture content of 6% (wet basis) was found to be optimum for extraction of oil from peanuts and sunflower seeds (Bongiwar et al., 1977; Singh et al., 1984).

Oil-seeds are subjected to heat treatment in order to lower the viscosity of the oil to be extracted, coagulate the protein in the meal, and also adjust the moisture level of the meal to the optimum level of extraction. Sivakurarah et al. (1985) reported that heating temperature, heating time and moisture content were interactive factors that influenced the yield of oil extracted. Adeeko and Ajibola (1990) also observed that prolonged heating time beyond 25 minutes for groundnut samples heated at temperature above 90^{o}C did not improve oil yield. Pressure has also been shown to have significant effect on oil yield (Dedio and Dorrell, 1977; Adeeko and Ajibola, 1990).

3.2 Traditional Oil-Extraction Methods

Before attempts are made to introduce improved methods of oil expression/ extraction, effort should be made to understand the traditional methods employed. Improved technologies, which are not based on an understanding of traditional processing, tend to have low acceptance rate. The various steps involved in traditional methods of processing, differ somewhat from place to place, thus it will not be feasible to record all the minor variations. Therefore, examples are given of fairly standard processing methods which can serve as a basis for comparison with the system used in any particular area. the procedure for the extraction is divided according to raw materials/agricultural products being used.

3.2.1 Oil-Seeds

Oil-seeds (cotton, castor, sunflower, etc.) in most cases, are ground to a paste without removing the husk or outer covering. In some instances sunflower seeds are husked. The seeds are ground manually and the paste is heated alone at first and then with boiling water. The mixture is stirred and brought to boil. After boiling, the mixture is allowed to cool and the oil settles at the top and is scooped off. With this method of processing, the extraction efficiency is about 40%, that is percentage of oil extracted based on the total theoretical content. (NRI, Unpublished information).

3.2.2 Oil-Nuts

The processing methods of oil-nuts vary because of the variation in the procedures. The most common oil-nuts grown in most countries are groundnuts and coconuts. Groundnuts are shelled, cleaned and roasted lightly. The roasted nuts are skinned by placing them on a mat and rolling a wooden block over them, and winnowing them to separate the skin from the nuts. The skinned nuts may be pounded with a mortar and pestle or ground using grinding stones to a smooth paste. The paste is kneaded and pressed by hand to remove the oil-water mixture. Then the oil-water mixture is fried to remove most of the water.

3.3.1 Oil-Expellers

Expellers use a horizontally rotating metal screw, which feeds oil-bearing products into a barrel shaped outer casing with perforated walls. The products are continuously fed to the expeller, which grinds, crushed and presses the oil out as it passes through the machine. The pressure ruptures the oil cells in the product and oil flows through the perforations in the casing and is collected in a trough underneath (Gate, 1979). The residue of the material from which oil has been expressed exits from the unit, and is known as the cake. With some types of expellers takes place. This allows for greater oil expression and reduces wear and tear on the machine.

Most expellers are power-driven, and are able to process between 8 and 45 kg per hour of product depending upon the type of expeller used. Bigger units processing greater quantities of oil are available for use in larger mills. The percentage of oil expressed by expellers is as high as 90% depending upon the type and kind of products as well as the expeller being employed (Gate, 1979).

The friction created by the products being expressed wears down the worm shaft and other internal parts. With small machines this occurs often after expressing as little as 50 tons, after which parts must be replaced or repaired through resurfacing by welding. Maintenance of an oil expeller, therefore, calls for machinery and equipment rarely found in small repair shops and local manufacture of expellers would be most unlikely at the village /small town level.

3.3.2 Oil-Plate Presses

Plate presses are normally used for expressing oil from mesocarp (fruits) like oil palm, but depending upon the amount of pressure applied, oil-seeds and nuts can also be expressed. With oil plate presses, the expression efficiency is about 90%, depending upon the nature and the amount of product being expressed (Gate, 1979). Generally, oil-plate presses are of two types; screw presses and hydraulic presses.

In screw press that is manually operated, the substance from which the oil is to be expressed is pressed slowly and with maximum pressure by plunger (round steel plate), forced down by a screw, and into a cylinder with a large number of small holes (Gate, 1979). Capacities of the screw press depend upon the size of the cage which holds the products, an average being about 15 kg per batch. The screw press consists of worm shaft, cage chain drive speed, bearings and other accessories.

In hydraulic press that can be manually or power operated, pressure is exerted by hydraulic device such as a lorry jack. They require a heavy, rigid frame structure. Because of the weight of such a structure the press must be stationery and cannot be moved as easily as a screw press. Hydraulic presses can process mesocarp (fruits), oil-seeds and nuts as they generate greater pressure than a screw essential to ensure that hydraulic fluid, which may be toxic, does not come into contact with the food stuff (Gate, 1979).

In most cases, oil presses can be manufactured locally in rural areas with the exception of the screw which needs a special lathe. It is generally recommended that the nut (through which the screw operates) should be of softer metal so that it will be subject to wear and tear rather than the screw, which is expensive to replace or repair. Hydraulic press can be manufactured locally if lorry jacks are available. The screw presses also exist in different types and makes some of which are TCC press and Kit spindle press.

3.3.3 Improved Ghanis

Ghanis originated in India where they are primarily used to express oil from mustard and sesame seeds, although in some cases they can be used for coconut and groundnut processing. Traditionally ghanis are operated by animals and can be manufactured locally. They consist of a wooden mortar and wood or stone pestle. The mortar is fixed to the ground while the pestle, driven by one or a pair of bullocks or draught animals is located in the mortar where the seeds are crushed by friction and pressure. Oil runs through a hole at the bottom of the mortar while the residue or cake is scoop out. Depending on the size of mortar and type of seeds, an animal ï powered ghani can express about 10 kg of seeds every two hours.

Mechanized versions of the traditional animal-powered ghanis are common. In these power-driven ghanis the pestle and mortar units are usually arranged in pairs with either the pestle or mortar held stationary while the other is rotated. Power ghanis have a greater capacity than the traditional ghanis and can process about 1000 kg of seed per day (Srikanta Rao, 1978). Power ghanis yield an oil with a lower pungency.

3.4 Solvent Extraction

Solvent extraction method involves the use of organic solvents such as straight chain hydrocarbons, chlorinated hydrocarbons, alcohols and ketones to recover the oil from the sources. The process for solvent extraction of nut (groundnut) is similar to that of seeds (soyabean, cotton, etc). Generally, nuts or seeds are shelled and winnowed to remove fibre-rich shells, and whitened by removing the tannin-containing the skins. Next, the nuts or seeds are cracked into piece and conditioned 10-11 percent moisture at $70^{o}C$ or more, an then flaked by passing through rolls. Sometimes the nuts or seeds flakes are cooked before they are converged to the extractor. In the extractor, the oil is removed by means of a solvent. The solvent ladden flakes are then passed through a desolventizer, which recovers the solvents. The defatted and desolventized cake may undergo further treatment before it is used as feed. The crude oil may be clarified by passing it through a filter press.

Solvent extraction is capable of removing nearly all the available oil from oil-seeds or nuts. About 98% of the oil is being extracted by solvent method. (Ngoddy and Iherokoronye, 1985; Cecoco, 1988). In addition to the high yield of oil, the method produces oil with better qualities, and a higher protein meal (Khan and Hanna, 1983). The method generally requires more capital expenditure, and refining the oil before use. There is also possibilities of toxicity from the solvent used and danger of fire explosion from the use of volatile organic solvent.

3.5 Clarification and Refining of Oil Extracted

The extracted oil contains a suspension of finely divided seed debris, which needs to be cleared. Clear oil can be obtained by allowing the oil to stand for a few hours or days in a clean container. The finely seed debris then settle at the bottom of the container leaving an upper layer of clear oil which can be decanted. Alternatively, the oil should be filtered through a filter press, or locally by using a plastic funnel fitted with a cloth. The refining process is basically the same for most vegetable oil. The procedure can also be applied to crude oil expressed using a hydraulic or screw press. Refining consists of alkali-refined, to neutralize the free fatty acids, using sodium hydroxide, bleaching, to improve flavour stability and odour, using steam distillation under vacuum.

4. PROBLEMS AND RESEARCH NEEDS

4.1 Technical Problems

In the traditional methods of oil extraction from oil-bearing agricultural products, almost all the stages involved are manual and labour intensive. The processing stages are therefore, strenuous, arduous, tiring, time consuming and particularly inefficient. Also, some of the operations have been reported to be hazardous to human health. The crude nature of the processing procedures, no doubt affects both the quantity and quality of oil recovered at the end. This is as a result of the inefficiency of the traditional methods and techniques. Often times a certain percentage of the oil extracted is found containing some quantity of free fatty acid, water, etc, resulting from the chemical breakdown of oil giving it unpalatable flavour.

Although the improved methods provide greater efficiency in oil extracted (high oil yield), they have a lot of problems. Technologies (oil-expeller and plate presses) have normally been introduced with the intention of improving traditional methods. However, many have had limited success because they have tended to ignore important considerations such as friction created by the products being expressed which wears downs the worm shaft and other parts, the degree of complexity of the equipment and its maintenance, accessibility of the spare parts, and availability of the power source inputs (fuels, diesel, water and electricity) for powering the mills. The oil being produced also contains some debris, high percentage of free fatty acid and sometimes mixed with the hydraulic fluid or fuel being used.

4.2 Socio-Economic Problems

It has been discovered that both those who use traditional processing methods as well as those who use modern technology often run into the problem of selling their oil at lower (uneconomic) prices in order to meet up with urgent needs. This occurrence has been noted to be as a result of the level of abject poverty of most of the farmers who produce oil. No doubt, the effect of this is multiplied. The farmer incurs losses, is not able to pay for the next production, equipment repairs and maintenance and eventually runs at a lost. All these will result in cumulative low quantity and poor quality of oil produced. In addition, certain technological innovations do not go down well with people in some cultural and environmental settings, either due to their inherent beliefs, superstitions or the local environment, which are not conducive or very difficult to handle.

Furthermore, another major problem, which need to be considered, is that the technology should be such that the local producers (mostly women) should be able to afford it or have access to credit, otherwise they will be reluctant to accept it particularly if it is capital intensive. The technology should be able to pay for itself in a given time through sales of its products and even create a secondary enterprise by making use of the by-products. Moreover, the improved technologies have an adverse effect on local producers because some of them produce and sell at loss, since the returns from oil, produced do not justify the cost of production.

4.3 Institutional Problems

Local farmers who are into agricultural oil production have also suffered serious setbacks in that the support services which they should get from institutions such as Agricultural Development Programmes (ADP), Ministries of Agriculture, government and private functionaries are either not there at all or denied of them by some unscrupulous officers. Also credit facilities which should aid the farmers in improving their production are either not in existence or the farmers may lack the collaterals required to benefit from such credit facilities.

Furthermore, there is an inadequate provision or maintenance of the existing research centres, either from the universities or other related institutions that are actively in production and processing of oil-bearing agricultural products. Lack of careful and strategic planning such as the provision of training through the extension workers in the use and maintenance of equipment, in order to make new or improved technologies understood and accessible to the rural farmers added to the problems. Government policies have not also addressed specifically the problems of these local producers of agricultural oils.

4.4 Research Needs

In view of the considerable range of technologies and devices for traditional and improved methods of oil expression / extraction and processing, selection of the most appropriate method for a given environment requires a research into traditional methods employed, in comparison to the improved methods under a given condition. The research study under the traditional method should cover areas that will improve the equipment and techniques being used, pre-processing conditions, socio-economic problems and the existing government policies.

In introducing new technologies, it is important to make comparisons between the proposed improved technology and traditional methods existing. Introduction of any new improved methods to rural areas requires a thorough understanding of the socio-economic and cultural relations of the users. Research into the socio-economic needs should be conducted. A careful study and examination of the above factors can help to determine which of the various stages of oil extraction require improvement as well as offering maximum benefits to the intended beneficiaries. Therefore, continuous research effort and efficient use of human resources and technical inputs are essential pre-requisites for improving the yield and quality of the oil being extracted from oil-bearing agricultural products.

Besides this, there is a need to establish an institutional framework of network of all those involved either in agricultural oil research or production (such as NIFOR, Risonpalm, Sunseed, etc.) to enhance net working and easy access to useful research findings or developments in this area. Such a network will no doubt help in reducing or possibly eliminating the problems of slow rate of development and repetition of the same mistakes, which others have made and improved upon.

5. CONCLUSION

The extraction of oil from oil-bearing products has been reviewed. It is obvious that the oil yield from these products depends on two major factors, that is pre-processing conditions and the methods or techniques being adopted. It has been observed that higher oil yields could be obtained from oil bearing agricultural products that are well pre-processed such as removal of hulls and shells, heating, moisture content adjustments, etc. Considering all other factors, the quantity and quality of the oils being expressed / extracted by improved methods are better compared to the traditional methods.

However, the adoption of simple machines by small oil producers needs more attention before Nigerian and other developing African community-based Agro-allied activities can be viable and sustainable. The adoption of these simple machines will no doubt develop the capacity of local artisans in the oil extraction business who are quite talented but hardly diversify due to lack of new and adaptable technologies that they can copy and add to their cost of productions.

REFERENCES

Abalu, G. O. I. 1978. An economic analysis of groundnut production in Northern Nigeria. Proceedings of National Seminar on Groundnut Production, Bagauda Lake Hotel, Kano. Nigerian Society of Agricultural Engineers (NSAE) proc. 19. 319-328.

Abubakar, S.Z. and Y.D. Yiljep 1997. Design and Development of a Groundnut paste Kneader (Paste Strirrer).proc. of the NSAE, Vol. 19. PP 319-328

Adeeko, K.A. and Ajibola, O.O. 1990. Processing factors affecting yield and quality of mechanically expressed groundnut oil. Journal of Agric Engg. Research 45:31-43.

Adekola, K.A.1989. Process design of mechanical vegetable oil extraction plant. B. Eng (Hons) Project Report submitted to Department of Agric. Engg, Federal university of technology, Akure, Nigeria. NSAE proc. 16:102-111.

Adekola, K A. 1991. Process optimization of oil expression from coconut (cocosuncifera L). An M. Sc. Thesis submitted to Department of Agric. Engg, University of Ibadan, Nigeria. NSAE Proc. 16: 102-11.

Adekola, K.A. 1992. Processing factors as related to coconut oil expression. Proc. of NSAE, 16: 96-101.

Adekola, K.A. 1995. Development of equation to predict coconut oil yield. Proc. of NSAE. 1995, Vol. 17. pp 96- 101

Ajiola, O.O., Bakare, F.A.,Adeeko, K.A. and Fasina, O.O. 1990. Effects of some processing factors on yield of oil expressed from rubber seeds. Journal of Technology Vol. 2.No. 2., pp 1- 7

Ajiola, O.O., Eniyemo, S.E., Fasina O.O. and Adeeko, K.A. 1990. Mechanical expression of oil from melon seed Journal of Agricultural Engineering Research, Vol. 15. pp 45 ï 53.

Aneke, V.I. 1992. Design of a continuous screw press for groundnut oil extraction. B. Eng (Hons) Project Report submitted to Department of Agric. Engg., University of Nigeria, Nsukka, Nigeria.
Ani, A. O. 1999. Computer aided design of a pedal operated screw press. B. Eng (Hons) Project Report submitted to Department of Agric. Engg., University of IIorin, Nigeria.
Badmus, G. A. 1997. The Digester screw press and some other small scale palm oil extraction tools. Proc. of the NSAE, vol. 19 pp 329 ï 335.
Bongiwar, D. R., Pordwal ï Desai, S. R. and Sreeniyasam, 1977. Studies on the defatting of peanuts and soya beans, for developing ready-to-fat snak items. Indian Food Packer 31(3): 61 ï 67.
Cecoco, 1988. Cecoco oil expelling equipment for small scale and rural industrial purposes leaflet. NSAE Proc. 1992, vol. 16 pp 102 ï 110.
CIGR 1998. Handbook of Agric. Engg. vol. 6 edited by The Inter. Comm. of Agricultural Engineering, published by American Society of Agricultural Engineering Madrib.
Corbett, S. 1981. A new oil press design: But is it any better? Vita News, Vita Publications, Washington DC.
Dedio, W. and Dorell, D. G. 1977. Factors affecting the pressure extraction of oil from flaxseed. Journal of American oil chemical soc. 54 (8): 313. In Journal of Tech. vol. 2., no. 2, 1990.
De Novo de Roden, M., Deckers, J. and Ngatunga, A. 2001. Coconut in crop production in tropical Africa. (R. H. Raemaebers ed.), Directorate General for International Co-operation (DGIC), Brussels pp 733 ï 746.
ECA 1983. Traditional palm processing: Women role and the application of appropriate technology. ATRCW Research Series, Ethopia.
Ekwulugo, C. O. 2001. Design and fabrication of an improved palm kernel oil expeller. B. Eng. (Hons) Project Report submitted to the Department of Agric. Engg., University of Nigeria, Nsukka, Nigeria.
Essiamah, S. K. 1985. The utilization of palms in West Africa plant research and development. Journal of Agric. Engg. Research, 21: 45 ï 58.
FAO 1982. Food and Agricultural Organisation (FAO) Monthly Bulletin statistics vol. 9 July /August, Rome.
Fasina, O. O. and Ajibola, O. O. 1989. Mechanical expression of oil from conophor nuts (Tetracarpidium Conophonum). Journal of Agric. Engg. Res., 44: 275 ï 287.
Galloway, G. P. 1976. Cleaning, cracking, dehulling, decorticating and flaking of oil-bearing materials. Journal of American Oil-Chemical Society 53: 271 ï 274.
Gate 1979. Oil Presses: An Introduction. GATE/GTZ Publications, Eschborn, Germany. Gobin, A. M. L., Uguru, M. I. and Deckers, J. 2001. Castor. In Crop production in Tropical Africa. (R. H. Raemaebers ed). Directorate General for International Co-operation (DGIC), Brussels. pp 725 ï 732.
Gunstone, F. D. and Norris, F. A. 1983. Lipids in food; Chemistry, Biochemistry and Technology, Pergamon Press.
Hanna, 1984. Hartley, C. W. S. 1977. The oil palm, 2nd ed. London. longman Group Limited.
IAR 1992. Food Foundation Project. Terminal Report pp 50.
Idah, P. A. Manta, I. H. and Akin A. 1996. Development of continuous cottage groundnut oil expeller. Proc. of the NSAE vol. 18. pp 318 ï 321.
Ihekoronye, A. I. and P. O. Ngoddy 1985. Integrated Food Science and Technology for the Tropics. Macmillan Publishers Ltd. London and Basing-stoke.
Irvine, F. R. 1969. West Africa Crops. Vol. 2. Oxford University Press.
Kafiriti, E. M. and Deckers J. 2001. Sesame. In Crop Production in Tropical Africa (R. H. Raemaebers ed). Directorate General for International Co-operation (DGIC), Brussels. pp 797 ï 803.
Khan, L. M. and Hanna, M. A. 1983. Expression of oil from oil-seeds: A Review. J. of Agric. Engr. Research 28: 495 ï 503.
Khan, L. M. and Hanna, M. A. 1984. Expression of soyabena oil, Trans. of the ASAE, 27 (1): 190.
Michael, J. and Bankoffi, L. 2001. Shea. In crop production in tropical Africa. (R. H. Raemaebers ed.). Directorate General for International Co-operation (DGIC), Brussels pp 804 ï 808.
Miller, M. L. (ed) 1983. Peanut industry guide. Washington, DC. National Peanut Council.

Norris, F. A. 1964. Extraction of fats and oils. Bailyøs industrial oil and fat products. John Wiley and Sons, NY, pp 40.

Oke, O. K., Smith, R. H. and Woodham, A. A. 1975. International Biological Programme. Vol. 14 pp 105 ï 106.

Ravagnan, G. M. 2001. Sunflower. In crop production in tropical Africa (R. H. Raemaebers ed). Directorate General for International Co-operation (DGIC), Brussels, pp 828 ï 840.

Robbelen, G., Downey, R. K. and Ashri A. 1989. Oil crop for world, McGraw-Hill. New York pp 254 ï 256.

Salunke, D. K. and Desai, B. B. 1986. Post Harvest Biotechnology of Seeds, CRC Press. pp 35 ï 145.

Singh,M. S. Farsaie, L. E., Stewart, L. W. and Douglas, W. 1984. Development of mathematical model to predict sunflower oil expression, Trans. of the ASAE, 27(4): 1190.

Sivakumran, K., Goodrum, W. J. and Bradley, A. R. 1985. Expeller Optimization of Peanut Oil Production, Trans. of the ASAE, 28(1): 316.

Srikanta-Rao, P. V. 1978. A search for appropriate technology for the village oil industry. ATDA Publications, Lucknow, India.

TDRI 1984. Oil Palm News, No. 28.

TPI 1971. Oil and oilseeds crop and product digest No. 1, London.

UNIFEM 1987. Oil extraction. Food Cycle Technology Source Books No. 1, UNIFEM, New York.

UNIFEM 1993. United Nations Development Fund for Women. Oil Processing. Food Cycle Technology Source Books. Int. Tech. Pub., London.

Ward, J. A. 1976. Processing high oil content seeds in continuous screw presses. J. Am. Oil Chem. Soc., 53 (1): 261 ï 264.

COMPONENT DESIGN OF A 187kg/hr LOW-COST EXTRUSION COOKER FOR FULL FAT SOYMEAL

C.U. Orji
Federal Institute of Industrial Research, Oshodi (FIIRO)
P.M.B. 21023, Ikeja, Lagos.

ABSTRACT

The design of a motorized low-cost extrusion cooker for full fat soy-meal production from soybean is presented. The machine was designed based on the high shear single screw extrusion systems, with segmented screws, which has three major zones: feeding zone, compression zone, and melting zone. It has a capacity of 187kg/hr (1.5 tons/day), power requirement of 20hp, screw rotation of 450rpm and a cost of seven hundred thousand Naira (₦700,000.00) as against two million Naira (₦2,000,000.00) for imported unit. The Chemical and Microbial analysis of the full fat soy meal satisfies the standard (BIS).

KEY WORDS: Extrusion cooker, design, gelatinization, extrudate, full fat, shear, puff, soy-meal.

1. INTRODUCTION

An extruder is a machine, which shapes materials by the process of extrusion. Extrusion cooking combines the heating of food product with the act of extrusion to create a cooked and shaped food product. Cooking is accomplished through the application of heat, either directly by steam injection or indirectly through jacket and by dissipation of the mechanical energy through shearing occurring within the dough (Harper, 1979). The results of cooking the feed ingredient during the extrusion process are the gelatinization of starch, the denaturation of protein, the inactivation of many raw food enzymes which can cause food deterioration during storage, the destruction of naturally occurring toxic substance such as trypsin inhibitors in soybeans, and the diminishing of microbial counts in the final product (Harper, 1979, Osborne and Mendel, 1917). Extrusion cooking tends to maximize the beneficial effect of heating foods, improved digestibility and precooking, while minimizing the detrimental effect (browning, inactivation of vitamins and essential amino acids, production of off-flavors, etc).

Proper extrusion cooking can only be achieved with proper design of the various extruder components. Extrusion cooker consists of a flighted screw(s) or worm(s) rotating within a sleeve or barrel. The action of the flights on the screw pushes the plasticized material forward. As the moist hot material moves through the extruder, the pressure within the barrel increases due to restriction at the discharge end of the barrel. At this elevated pressures, boiling and flashing of moisture does not occur within the confines of barrel because the pressure exceeds the vapor pressure of the water at the extrusion temperature. Once the food emerges from the die, the pressure is released causing the product to expand with the flashing of moisture. The loss of moisture from the product results in adiabatic cooling of the food materials, which solidifies and sets, often retaining its expanded shape.

There is an ever-growing demand for soybean products in the market, especially full fat soy meal. This product formed using extrusion cooker is used in animal production, and could be consumed by man. Imported extrusion cookers are very expensive with attendant operational complexities, hence the need to develop a low cost extrusion cooker with minimal operational requirement.

The objective of this work was to develop a low cost extrusion cooker locally. The machine was designed based on the high shear single screw extrusion systems, with segmented screws, which has three major zones, Feeding zone, Compression zone, and Melting zone.

2. MATERIALS AND METHODS

2.1 Description of the Extrusion Cooker

The extrusion cooker consists of a flighted Archimedes single screw, which rotates in a tightly fitting cylindrical barrel by the aid of an electric motor. The raw soybean is introduced into the feed end of the extrusion screw from the hopper by gravity discharge. The action of the flights on the screw push the products forward and in so doing, work and mix the constituents into viscous dough like mass. Heat is generated for cooking the dough by viscous dissipation of mechanical energy. As the moist hot material moves through the extruder, the pressure within the barrel increases due to restriction along the process line (steam lock) and at the discharge end of the barrel. Once the food emerges from the die, the pressure is released, causing the product to expand with flashing of moisture. This loss of moisture from the product results in adiabatic cooling of the product, which solidifies and sets, often retaining its expanded shape.

Because the flights are usually full, the food product is subjected to high shear rates as it is conveyed and flows by the action of the screw. This results in the extruded foodôs unique texture. The porous, rigid structured product is then milled, sieved and bagged or used directly.

The major components of the extrusion cooker are; the extruder drive seed assembly, extrusion unit and extruder discharge.

The extruder drive comprises of electric motor, power transmission shaft, pulley, and transmission belt. The feed assembly comprises of a hopper, and feed control. The extrusion unit comprises of power screws, steam locks and barrel with grooved wall. The extruder discharge comprises of the die, nose cap and nose cone.

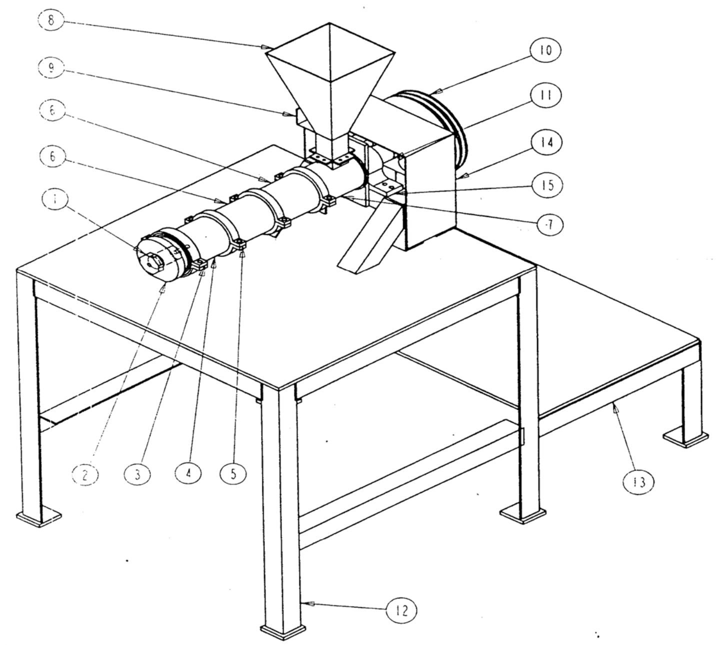
The machine offers many basic design advantages that enable it to be used for minimizing energy and process costs, like versatility, high productivity, low cost, ability to produce irregular shapes, high product quality, production of new foods and non-production of effluents etc. Figure 1 shows the low cost extrusion cooker. Description of the components follow.

2.2 The Hopper

The hopper houses the soybean kernels to be extruded and from here the kernels are fed into the extrusion unit at a regulated rate. The hopper as shown in Figure 2 has a shape, which facilitates loading, maximum volume utilization and reliable and complete gravity discharge through its outlet.

Volume of Hopper = $^{1}/_{3}$ HWL + hL = 19.0×10^{-3}m^{3}. é é é .(1)
Assuming a soybean density of 786.86kg/m^{3}. The weight of soybean it can hold
= 14.0kg.
Weight of hopper = Volume of hopper material × density of steel (Galvanized steel)
.é é ..(2)
= 1.18kg.

3



1 ï NOSE CONE
2 ï NOSE CAP
3 ï BRACKETS
4 ï METERING BARREL
5 - LOCK NUT
6 ï COMPRESSION BARREL
7 ï FEEDING BARREL
8 ï HOPPER
9 ï FEED CONTROL
10 - 4-WAY PULLEY
11 - THRUST BEARING
12 - MACHINE STAND
13 - MOTOR STAND
14 - BEARING HOUSING
15 - BEARING SUPPORT

Figure 1. The low-cost extrusion cooker

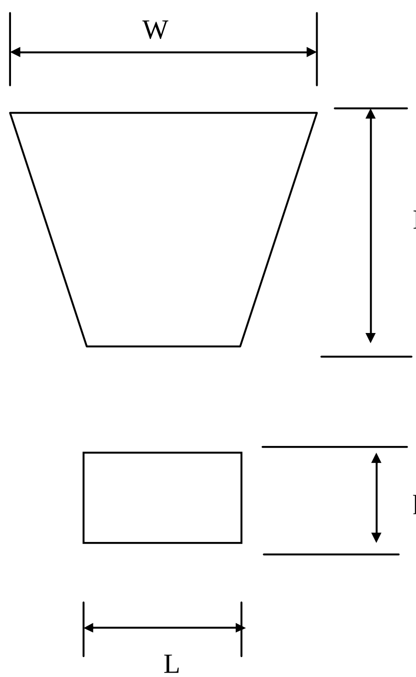


Figure 2 Side view of the hopper

2.3 The Screw

This is the central portion of the food extruder. It accepts the feed ingredient at the feed port, conveys, works, and forces them through the die restriction at the discharge. The screw is divided into

three sections whose names correspond to the function each section performs as shown in figures 1 and 3.
The screw as shown in Figure 4 has the following parameters.

Actual screw diameter, $D_s = D$ ï $2\delta = 98$cm. é é é (3)

Where δ is the clearance between the barrel and screw.
Flight height, $H_s = H - \delta = 0.7$cm é é é (4)
Root diameter, $Dr = D$ ï $2H = Ds$ ï $2Hs = 8.4$cm é é ..(5)

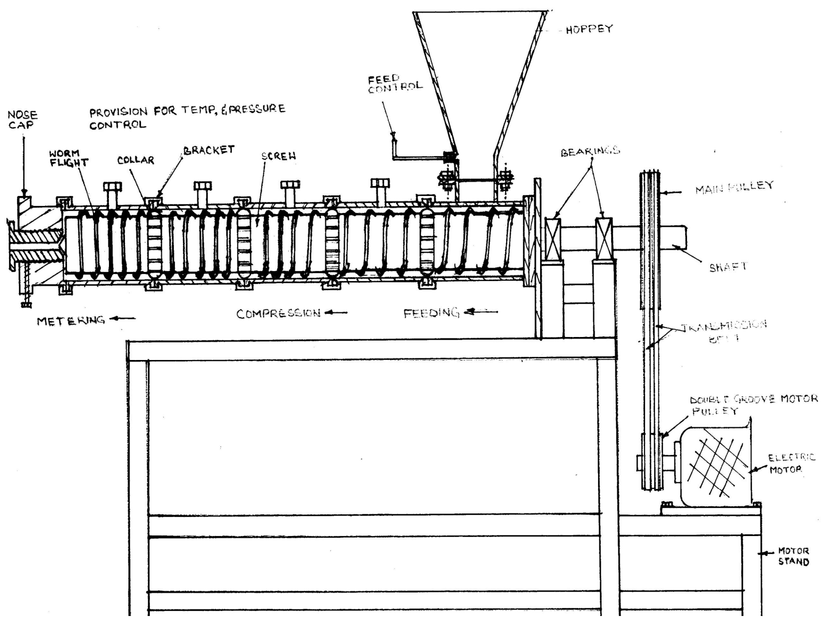


Figure 3. Sectional view of the extruder.

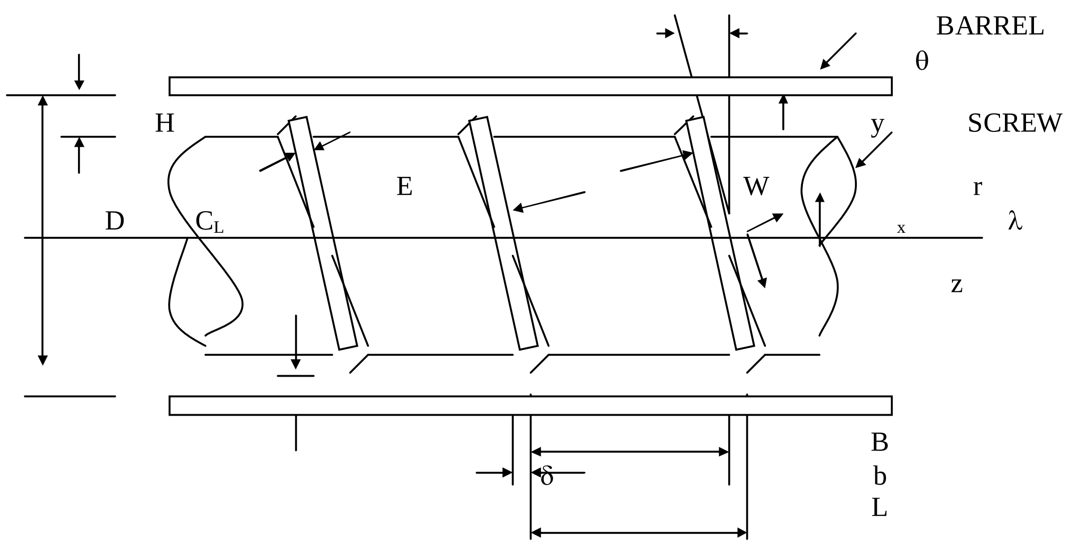


Figure 4 Geometry of the metering section of an extrusion screw

Lead, the axial distance from the leading edge of a flight at its outside diameter to the leading edge of the same flight in front of it, $L = 1.94cm$

Helix angle, $\theta = \tan^{-1}(L/\pi D_s) = 3.6°$ é é .(6)

$\theta = \tan^{-1}(L/\pi D_s) \cong \tan^{-1}(L/\pi D)$, for δ less than 0.1mm.

Axial channel width, $B = 1.5cm$

Channel width, $W = B/\cos\theta = 1.503cm$ é é .. (7)

Axial flight width, $b = L$ ï $B = 0.44cm$ é é .. (8)

Flight width, $e = b\cos\theta = 0.439cm$. é é .. (9)

Peripheral speed or tip velocity, $V = \pi D_s N \cong \pi DN = 2.3$ m/s é é . (10)

Height to diameter ratio, $H/D = 0.07$

Volume of screw = 1.75×10^{ï3} m^3

Weight of one screw = ρ x v =13.65kg. é .é (11)

2.4 Extruder Barrel

This is the cylindrical member which fits tightly around the rotating extruder screw as shown in Figure 5. The barrel is segmented. This makes it easy to alter the interior configuration of the barrel and to replace the discharge section, which wears the most rapidly. Harper, (1980) and Patil,, (1999), reported that the internal diameter, D, ranges from 5cm to 25.4cm.

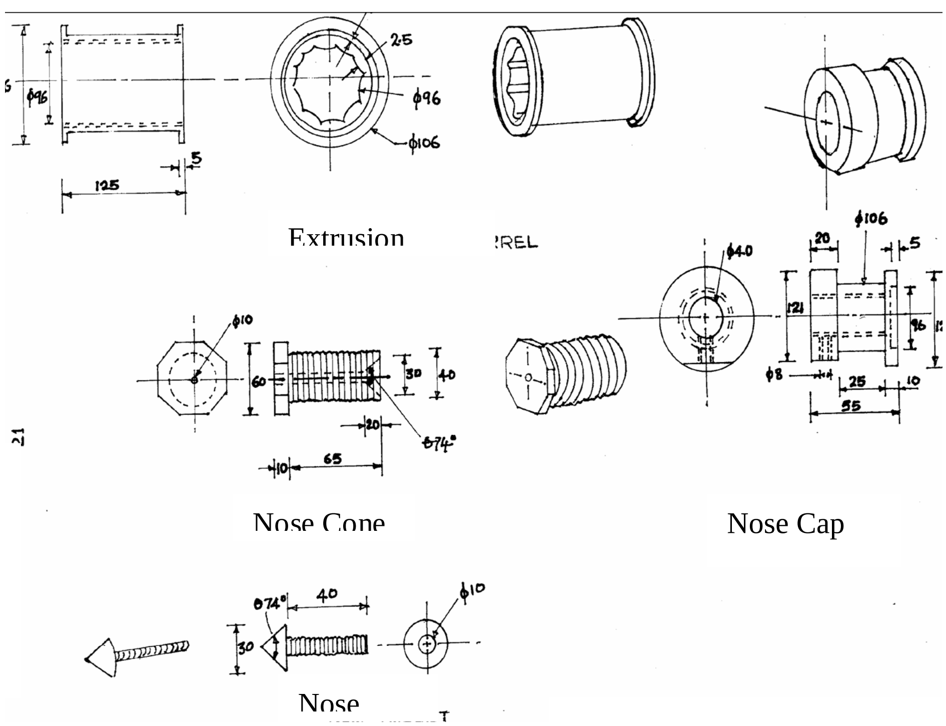


Figure 5. Other components of the extruder

Length to diameter ratio, L/D: Food extruders typically have L/D ranging from 1:1 to 20:1. The designed extruder has L/D = 5.56 : 1. The barrel was designed with grooved walls to prevent slippage of the material against back pressures.

The designed Width of groove is 0.5cm, while the Height is 0.2cm. Approximate volumetric capacity of barrel available for feed = 5.66 x $10^{-4}m^3$

Thickness of barrel wall = 0.5cm.
Length of barrel = 54.5cm
Diameter of barrel = 9.8cm
Weight of one barrel = 3.42kg (calculated)
Total weight of barrels = 13.69kg.

By symmetry, the three principal stresses in the barrel shell will be the circumferential or hoop stress, the longitudinal stress, and the radial stress. According to Ryder, (1982) and Nash, (1982), since the ratio of its thickness to internal diameter is less than about 1/20, it was assumed with reasonable accuracy that the hoop and the longitudinal stresses are constant over the thickness and that the radial stress is small and can be neglected, as shown in Figure 6.

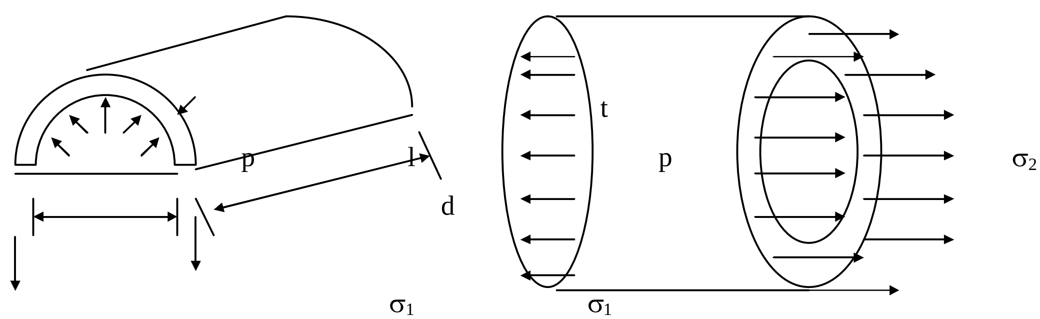


Figure 6. Hoop and longitudinal stresses in extrusion barrel

Hoop Stress, $\sigma_{1,}$ = pd/2t é é .(12)

=78.7 kN/m^2. This is safe, because it is less than the allowable shear stress.

Longitudinal Stress,σ_2 = pd/4t é é (13)

In the case of a long barrel, or barrels held by brackets, the longitudinal stress becomes too small and so is neglected (Nash, 1982).

2.5 Nose Cap

This is the component that houses the die (nose cone). It was designed to withstand the discharge pressure as well as help in pressure builds up. The bore at the center has a conical shape that tapers towards the discharge aperture as shown in Figure 5, this helps to raise the pressure and temperature of the extrudate, so enhancing discharge. High pressure will mean more force available to push out material, while higher temperature will melt the oil in the material and so helps flow. The Conical angle of the bore is 51.9^o

Actual volume of nose cap = 3.7x $10^{-4}m^3$
Weight of nose cap = volume of nose cap x density of mild steel = 2.89kg

2.6 Nose Cone

This is the last component through which the hot and plasticized extrudate is discharged. It plays similar role as the nose cap. Figure 7 is the sectional view of the cone.

Volume of cone = 8.4 x10^{-5} m3

Weight of cone = 6.58 x 10^{-1}kg (658g)

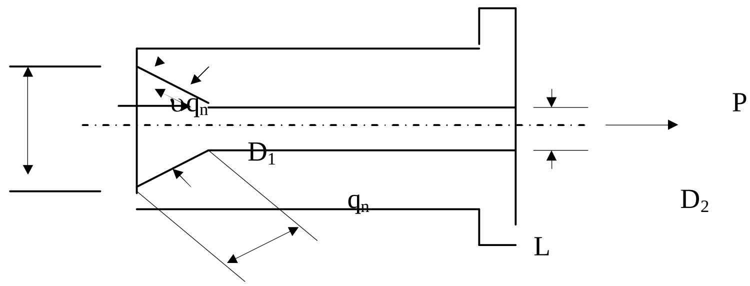


Fig 7 Sectional view of the Nose cone

The force, $q_{n.}$ exerted by the nose cone on the extrudate is given by the following expression (Jensen, 1957):

P ï $[(A_1$ ï $A_2)/ \text{Sin } \alpha](q_n \text{Sin } \alpha + \upsilon q_n \text{Cos } \alpha) = 0$ é é . (14)

Where υ is the coefficient of friction between cone and material and is given as 0.21 as indicated by Rossen and Miller, (1973):

A = Area, P = Pressure and α = cone angle

$q_n = 3.4$ kN

The splitting force between the two halves of the cone, F, is given as Jansen, 1957,

F = P/A = 2.4 7kN

2.7 Extrusion Drive

The transmission belt transfers drive from the electric motor to the power transmission shaft with the aid of a pulley. The size and speed of the pulley including forces acting on the belt (Figure 8) needs to be carefully analyzed for proper belt and pulley selection.

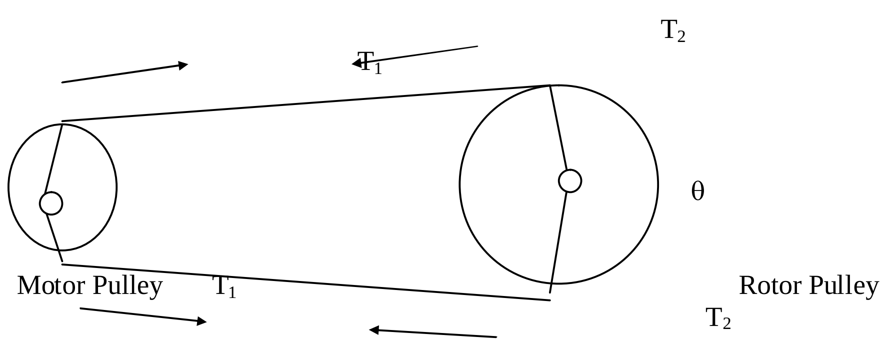


Figure 8 Belts ï Pulley Arrangement

$D_r = (N_m \times D_m) / N_r$ é é . (15)

Where N_m = Motor pulley speed (1250 rpm), D_m = Diameter of motor pulley; N_r = Rotor speed (450 rpm), D_r = Diameter of rotor pulley from equation 15, D_r = 280 mm

Minimum center distance C_m is given as (Nash, 1982; Jansen, 1957; Quayle, 1986):
$C_m = (D_m + D_r)/2 + D_m = 290mm$ é é (16)

Theoretical length of belt is given as:
$L = 2C + 1.57 (D_r + D_m)/2 + (D_r ï D_m)^2/4C$ é é . (17)
But $C < C_m$, (Shirgley, 1980)
With center distance C, as 350mm then L = 950.11 mm
Tension in the Belt:

Arc of contact made by the belt on the pulley θ_p, is given as;
$\cos \beta = (R_r ï R_m) / C$ é é (18)
Where β = wrap angle, R_r = radius of rotor pulley, R_m = radius of motor pulley.
So, $\beta = 14^o 9^1$ (0.25rad)

Angle of contact on belt on motor pulley (θ_m is given as);
$\theta_m = 180^o ï 2\beta$ é é (19)
$= 151.70^o$ (2.65rad)

Angle of contact on rotor pulley θr, is given as:
$\theta r = 180^o + 2\beta$ é é . (20)
$= 208.3^o$ (3.64rad)

Power transmitted is given as:
$P = (T_1 ï T_2) wr$ é é .. (21)

Where T_1 = tension at the tight side, N; T_2= tension at the slack side, N; W = angular velocity of motor pulley, 130.9 rad / sec; r = Radius of the motor pulley (50mm)

Evaluating the above yields the following;
T_1 = 8,202.28 N; T_2 = 3,280.91 N

Power transmission shaft:
Shaft design consists primarily of the determination of the correct diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions and so the shaft was designed from the stand point of strength and rigidity.

This shaft is subjected to both bending and torsional loads. The bending load is due to weight and moments of the screw shaft.

Bending moment M, $= {}^{-1}/_2 W/ Lx^2 = -64.09Nm$ é é ..(22)

According to Harper (1980), Shirgley (1980), Hannah and Stephens (1980) the required diameter of shaft from the ASME load equation is given as:
$D^3 = 16PS_s [(K_bM_b)^2 + (K_tM_t)^2]^{1/2}$ é é (23)

Where S_s = Allowable combined shear stress for bending and torsion for steel shaft. K_b = Combined shock and fatigue applied to bending moment = 1.5 to 2.0 for minor shock; K_t = Combined shock and fatigue factor applied to torsional moment = 1.5 to 2.0 for minor shock; M_b = Bending moment; M_t = Torsional moment. Hence D = 3.6cm, approximately 4cm.

The calculated diameter, d = 4cm is less than the diameter originally selected (d = 5cm). So the selection is in order because strength criterion is satisfied.

In order to design the required rigidity, it was necessary to determine the bending and torsional deflections (Harper, 1980). For steel shaft, the permissible deflection is 0.83mm/m. Also, the slope of a steel shaft subjected to cantilever force application must not exceed 1^o, Quayle (1986), and Shirgley (1980).

But deflection at the free end, δ, = -1/24 (W/EIL)(x^4 ï $wL^3x + 3L^4$) é é (24)
= -0.15mm/m

Slope, θ, = 1/6 WL^2/EI ..é ..(25)
= 0.02^o

This is less than the permissible deflection of 0.83mm/m and slope of 1^o. So bending deflection criterion is satisfied.

Torsional deflection is based on permissible angle of twist (3deg/m) as shown by Quayle (1986) and Shirgley (1980). But torsional deflection (δ) is calculated to be 0.24^o/m. This is less than the permissible value. Hence torsional deflection criterion is satisfied and so rigidity criterion is met.

2.8 The Bearing Unit

The machine has a pair of thrust bearings located at the inlet end of the screw. Static and dynamic conditions as well as the life requirements were considered in selecting these bearings. For combined radial and axial load,

$P_o = X_oF_r + Y_oF_a$ é é (26)

Where P_o = Equipment load, X_o = Radial load factor, F_r = Radial load on shaft Y_o = Axial load factor, F_a = Axial load
And P_o is found to be = 4,197.612N. Since the static load, C_o is unknown, employing trial and error, (Shirgley 1980), the right bearing was selected.
C = 6,070Ib (26,999.36N); C_o = 4,540Ib (20,193.92N)
Rating life, $R_r = (^C/_{Po})^3 \times 10^6$ revs = 2.66×10^8 revs é é ..(27)

Designing for short operating conditions (i.e. 4,000hr); Desired life, $D_L = 1.44 \times 10^8$ revolutions. Since the desired life $D_L < R_L$, the selection is in order.

2.9 The Frame

The weight of the screw shaft (W_a), the barrel (W_b), the hopper (W_h), the bearing (W_{bb}), cone and cap (W_{cc}), and the material, soybean (W_{sb}) are considered in designing the frame.

A 50 (50mm angle iron having a Young Modulus of 20GN/M^2 was chosen. The compressive stress on each frame is given as: $D_c = F/(4A)$ é é .(28)
Where, F = force (N); A = cross-sectional area of frame leg ($2.5 \times 10^{-3}m^2$); so, Dc = 39.94 kN/m^2.

The calculated compressive stress is much less than the Young Modulus (20GN/m^2) of the material. Therefore, there will be no bending of the frame. The standard minimum ratio of the frame lengths is given as $L_1/L_2 = 0.5$, (Shirgley 1980, Hannah and Stephens 1980). The designed ratio is 0.7, therefore the above condition is satisfied.

2.10 Performance Evaluation

The machine as shown if Figure 9, was designed to operate at a moisture range of 15.0% to 17.5%. Preliminary evaluation was performed to establish the best moisture level at which soybean seeds will be well extruded using the extrusion cooker. The machine extruded well at a moisture content of 16.55%, hence the actual evaluation was done at a moisture content of 16.55%.

The soybean was weighed and conditioned to the required moisture content. This was fed into the machine through the hopper. The temperature was recorded at 5minuites interval. This was used in establishing the temperature gradient at the four critical points on the machine; the feed section, compression section, metering section and the die.

Fig. 9. The extrusion cooker

3. PERFORMANCE EVALUATION RESULTS

The results of the performance evaluation are shown in Fig.10.

The low temperature gradient in the feed zone is due to the fact that no heat is generated in the zone. Since all it does is to convey the whole soybean. Hence little or no internal shear of the food takes place in the solids as contrasted to shear flow in the metering section.

The higher temperature gradient in the compression zone is attributed to the fact that the material is heated and worked into a continuous dough mass during passage through this section. Here the character of the feed material changes from granular or particulate state to amorphous or plasticized dough. This change in physical character is associated with a set of chemical reactions.

The relatively higher temperature gradient in the metering section is as a result of the shallow flights.

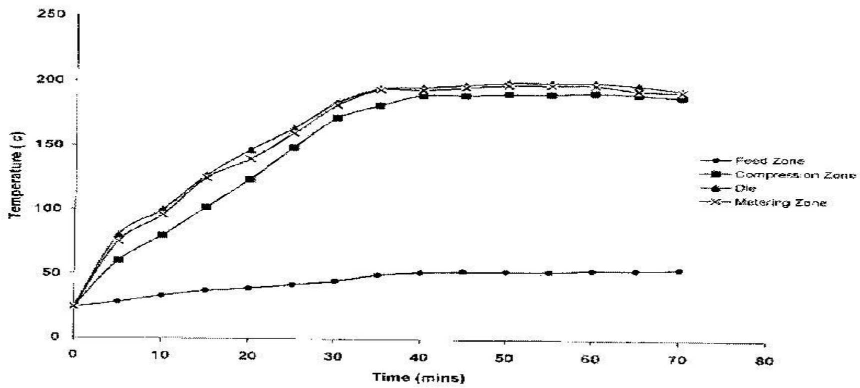


Fig. 10. Temperature gradient across the Barrels

The shallow flights increase the shear rate in the channel to the maximum level within the screw. The viscous dissipation of mechanical energy is typically large in the metering zone so that the temperature increases rapidly.

The relatively lower temperature gradient at the die is due to the rapid decrease in pressure and expansion with some loss in moisture due to flashing, and adiabatic cooling.

The full fat soy meal was subjected to chemical and microbiological analysis. The results shown in Table 1 satisfies the standard BIS specification (IS: 7837-1975) for full fat soy flour.

Table 1. Chemical and microbiological analysis of the full fat soy meal

CHEMICAL ANALYSIS		
% Moisture		6.16
% Crude Protein		38.87
% oil		19.01
Total Ash		5.94
PH (10 % Solution)		6.70
% Crude Fibre		5.54
Urease Activity	Nil	
% Carbohydrate	32.62	
MICROBIOLOGICAL ANALYSIS		
Total Plate Count		1×10^3
Yeast and Mould count	100	
Coliform count	Nil	

4. CONCLUSION

The development of any equipment requires a critical design of its components based on a operating loads and conditions. This will enable the designer eliminate or reduce to the barest minimal possible causes of failure of the components or equipment. With such detailed design, a reliable operating manual will be produced. The component design of a 187kg/hr soybean extrusion cooker was successfully carried out, and the machine fabricated. The low cost extrusion cooker for soybean processing was evaluated to establish its performance with respect to the temperature gradient across the barrels, the chemical and microbiological status of the full fat soybean flour. The result of the evaluation shows that the machine satisfies its objectives.

It is believed that with this equipment, processing of soybean into animal feed and possibly human food will be enhanced. This will encourage to a great extent, the development of livestock industry, which has great potentials in the country, and also the reduction in the level of calorie and protein deficiency in such meals.

REFERENCES

Hall. W.C, Ferral. A.W, Ripper. A.L 1986. Encyclopedia of Food Engineering 2nd edition, Avi publishing coy, Inc, West Port.

Hannah. J, Stephens. R.C 1980. Mechanics of Machines, Edward Arnold Publishers Ltd. London.

Harper. J.M 1979. Food Extrusion, CRC Critical Review, Food Science Nutrition Vol. 11: 155-215

Harper. J.M 1980. Extrusion of Food, Vol. 1 CRC Press Inc. Florida.

Jensen. A 1957. Applied Strength of Materials. McGraw-Hill books Coy, Inc, NY

Nash. W.A 1982. Strength of Materials, 2nd edition, Schaumôs outlines series. McGraw-Hill book Coy, NY.

Osborne. T.B, Mendel. L.B 1917. Journal of Biological Chemistry Vol. 32 pp.369

Patil. R.T 1999. Designing a Single Screw Food Extruder In a course manual on Specialized Training in Agricultural/Food Process Engineering Central Institute of Agricultural Engineering, Bhopal, India.

Quayle. J.P 1986. Kempôs Engineering Yearbook, 91st edition, Morgan-Grampian Book Publishing Coy, Ltd.

Ryder. G.H 1982. Strength of Materials, 3rd edition English Language book Society. The Macmillan Press Ltd London.

Rossen. J.L, Miller. R.C 1973. Food Extrusion, Food Technology, 27 (8): 46 ï 50

Shirgley. J.E. 1980. Engineering design 4th edition McGraw-Hill Coy, NY.

DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF A COWPEA THRESHER

A.S. Ogunlowo[1]and R. Bello[2]
[1]Department of Agricultural Engineering
Federal University of Technology, PMB 7004, Akure, Ondo State.
[2]Engineering Programme, Federal College of Agriculture
Ishiagu,, Ebonyi State.
E-mail: segemi2002@yahoo.com

ABSTRACT

The effective threshing of cowpea with minimum grain loss, improved threshing capacity and efficiency was achieved with a dynamically stable thresher designed and fabricated with a power rating of 2.9kW, belt speed of 12m/s and cylinder speed of 5.03m/s. A horizontal centrifugal fan was used with straight blades. The spike tooth (rubber beaters) were arranged spirally to serve as conveyor. The machine has an efficiency rate of 96.58% and the threshing capacity of 27.58kg/hr for cowpea; at an average moisture content of 13.16 %. (dry basis), and concave-beater clearance of 9mm ± 0. 5. Separation losses were minimal.

KEYWORDS: Threshing capacity, cracking efficiency, separation losses, cowpea.

1. INTRODUCTION

Cowpea threshing (which involves the detachment of grain kernels from the panicles) is one of the most critical post-harvest operations. Grain losses are experienced during threshing. Cowpea is the most susceptible leguminous crop to impact of loading, due to the di-cot nature of its kernels and is most affected in threshing with iron beaters. Threshing of cowpea is achieved mechanically or traditionally (manually). Manual threshing is mostly applied using cocoa bags, or spreading large clean cloth or tarpaulin on the floor, laying a bundle of cowpea on the cloth and beating with heavy sticks and clubs. Alternatively, animals (horses and bullocks) are allowed to trample on them (Igbeka and Oluleye, 1986). Mechanical threshing of cowpea employs various thresher mechanisms such as spike tooth, rasp bar and angle-bar mechanisms. (Claude Culpin 1987).

The performance of a machine is determined (to some extent) by the properties of the crop it is designed to handle. (Ige, 1978). Most designs in existence use a cylindrical drum, while others use drums with square cross section. It was felt that the cylindrical shape gave a little or no fanning effect to the discharge of the particles, also there are lots of carry over effect in such designs and this may encourage damage and high power consumption. (Ige, 1978). Large, portable threshing machines are suitable mainly for contracting and for large commercial farms. It is uneconomical for a small farm to have such a machine unless it produces between 250-300 hectares each season. Built-in threshers were designed for small farms with power requirement of 4HP and 28HP for larger machines.

The axial flow threshing machine can effectively thresh rice, soybean, etc over a wide range of grain moisture levels with low grain losses. A 7-10hp air-cooled gasoline engine can power the thresher and power is transmitted through a series of v-belts to the major components. The institute of Agriculture Research and Training in 1985 developed a thresher that employed the combine actions of beating and rubbing. The use of star beater threshing drum has also been investigated (Bolufawi 1989).

It has been widely reported that cylinder speed and concave clearance are major factors that determine the efficiency of a thresher (Ahaneku et al 2001). For efficient threshing, there are peripheral speeds and concave clearances specified for different crops along with the types and details of thresher cylinder and operating moisture level (Joshi 1981) In order to improve on the performance of the existing cowpea threshers, this paper reports a machine that employed the actions of impact, rubbing and transport of the threshed product along the threshing drum with adjustable rubber beaters to vary the concave clearance.

2. MATERIALS AND METHODS

The materials of construction were locally sourced, the bearings (ball type) and the belts were the bought-out materials. The threshing chamber, fan assembly and hopper were made of mild steel (18 & 20 gauge). The frame structure and the engine seating were made of angle iron (11/2ò x11/2ò x1/4ò). The beaters were made of rubber. The Construction of the machine was carried out by marking out the plate and sizing using scriber and share cutters. Shafts were turned on lathe machine while seams and various components were welded with gauge 10 electrodes; Assembly of parts was done with fasteners (bolt & nuts).

Two varieties of cowpea were used for the tests at two different moisture contents of 13.16% and 15.43%. The varieties are Ife Brown and TVX3236 (with red eye). Two clearances were also used; 11mm and 9mm

2.1 Machine Description and Operation

The machine consists of the following units: the hopper, threshing chamber, threshing unit, the delivery chutes, the fan assembly and frame (Figure 1 and 2). In operation, the material is feed into the threshing chamber through the hopper made of mild steel metal plate (gauge 18). Threshing and pre clearing (Grain/chaff separation) takes place within the threshing chamber. The threshing unit consists of the threshing drum, 76.2mm in diameter, the rubber beaters arranged in spiral form around the drum (to form a screw conveyor for transport of chaff and stalk) the lower concave screen and the side plate covers. The drum is 380mm long and 80mm in diameter. The beaters were space 40mm apart.

The delivery chute houses the lower concave (screen) and also serves as support for the fan assembly. The fan is centrifugal type and has three straight blades, (279.4mmx80mm) arranged at 120^0 to each other around the shaft. Threshed grains falls through the screen, while the chaffs were conveyed to the axial end of the threshing chamber where they were thrown out from the chaff outlet. Clean grains were collected through the outlet while the lighter particles were blown off from the fan assembly. The entire threshing components were mounted on a frame network made of angle iron, 844.6mm long. The overall height of machine is 869.6mm and the base area (153.0 x 460.0) mm^2.

2.2 Design Considerations

The following factors were considered in the design of the machine;

a. Properties of the materials to be threshed dependent on type, variety, moisture content, addition of green matter etc.
b. Technical conditions dependent on drum selection, peripheral speed of drum, number of beaters etc.
c. Delivery of material to the drum dependent on feed rate, positioning, point of contact on delivery with the circumference etc.

The design focused on reduction of power consumption and peripheral speed for threshing. A rubber beater with spiral arrangement round the drum (serving as conveyor) was selected because of the low resistance of cowpea to loading impact. A beater ï screen clearance suitable for threshing was considered. The beaters have provision for adjustments to suit variety of crops (grain sizes) to be threshed. The clearance can be adjusted between 25.4mm and 9.5mm at a belt speed of 12m/s.

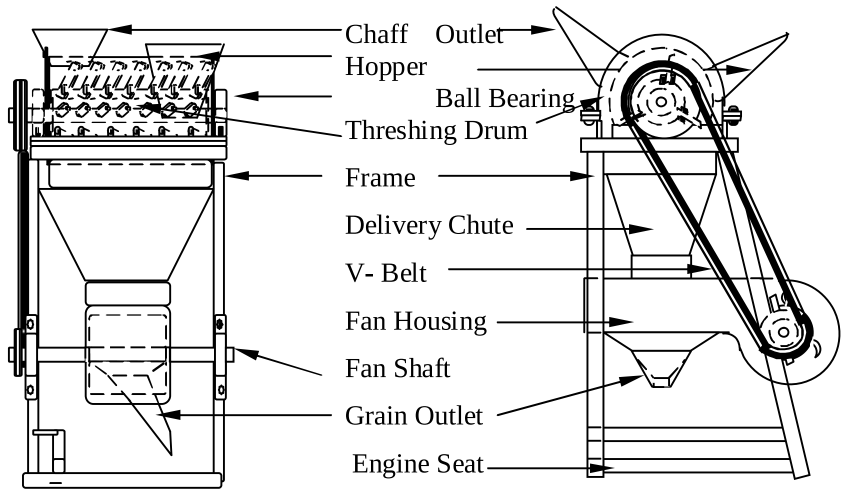


Fig. 1. Details of the thresher

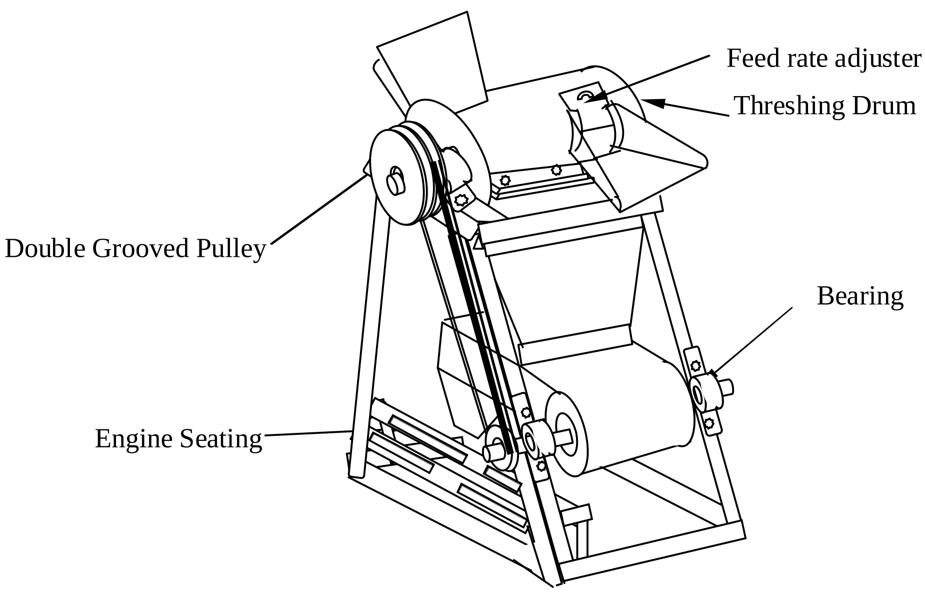


Figure 2: Isometric drawing of thresher

2.3 Design Calculations

Machine components were designed according to the procedures outlined in Design Data compiled by the Faculty of Mechanical Engineering P.S.G College of Technology, Coimbatore 641004 India (1982).

2.3.1 Power Requirement

Power required to drive the drum is given by:

$P_d = F.v = mv^3/R$ é é é é (1)

$= 4.63 \times 5.03^3 / 0.04 = 2.9kw. (3.9HP)$

Where P_d = power required to drive the threshing drum (kW), $F = mv^2/R$ = centrifugal force, m = Total mass of the threshing drum = 4.6kg (45.38 N), R = Radius of shaft 0.04m. V= Velocity 5.03m/s g = acceleration due to gravity (9.81m/s.) From available motor standard sizes, a motor of 4.5HP was selected for the design.

2.3.2 Belt Design

Angle of contact for pulley belts is given by equation:

$\theta = \pi \pm 2 \sin^{-1} (D\text{-}d / 2c)$ radian é ... é é é é 2

d= pitch motor diameter (m) selected from table for design purpose, diameter D for larger pulley is calculated from $D = 60v/ \pi n$, n = Design rotational speed (rpm) for drum. c =centre distance between drum and motor shafts, π (rad) = 180^0. The conventional negative and positive signs indicating the contacts in the smaller (motor pulley) and larger pulleys (threshing head pulley) respectively (Design Data, 1982)

Centre distance is given by

$c = b$+ã $(b^2$ ï $32(D\text{-} d/16)^2)$ é é é é é .. 3

Where

$b = ¼ (4L^1$ ï $6.28 (D+d))$ é é é é é é 4

Where L^1 = pitch length of the belt selected from data table (Design Data, 1982),

Load Carrying capacity C is determined for both pulleys and the lowest value is taken to govern the design.

$C = e^{(\varepsilon\theta/\sin Ǚ2)}$ é é é é é .5

For V- belts where C = Load carrying capacity (3.47), ε = Coefficient of friction (friction factor, 0.4) for rubber belts. θ = Contact angle (2.8rad.) for smaller angle Ǚ= 40^0 (groove angle) degrees.
Power transmitted by belt is given by

$P = (T_1$ ï $T_2) V$ é é é é é é é 6

Where V = belt speed (m/s)
T_1 = Tension in tight side (347.43N) and T_2 = Tension in slack side (98.68N) is calculated from:

$T_1 /T_2 = e^{\varepsilon\theta / (\sin Ǚ2)}$ é é é é é é . 7 (Design Data, 1982),

Belt pull factor for V-belt is between 0.7 and 0.9 (above that, the belt will be unstable and wears at a faster rate). The belt pull factor calculated is 0.73

Stress in belt: Various portions of the belt were subjected to tension or stresses such as tensile stresses due to initial tension, tangential and centrifugal forces, bending stresses etc.

2.3.3 Shaft Design

The shaft is subjected to two types of directional loading: vertical loading and horizontal loading.
Vertical loads resulted from: Loads due to weight of pulley acting downward, Torque or radial force, load due to weight of drum and reactions at the supports (bearings)
Horizontal loading resulted from; Load due to tangential force, reactions at the support due to the tangential force.
These forces were determined as:

Weight of pulley = 4.9N

Radial force M_t	=	23.28N
Weight of drum	=	17.26N
Tangential force	=	243.75N

These forces were resolved into resultant forces by the following equations. (Design Data, 1982),

R_A = ã $(R^2_{av} + R^2_{ah})$, R_B = ã $(R^2_{bv} + R^2_{bh})$, T_p = ã $(T_t^2 + M_t^2)$ é é 8

Where:
R_{av} and R_{bv} are reactions at the bearings due to vertical loading
R_{ah} and R_{bh} are reactions at the bearings due to horizontal loading

Torsional moment in threshing shaft is given by: (Ademosun and Olukunle 2003)

$T_m = P/2\pi n =$ [9550 x P (Kw) / N (rpm)] (Nm)   ..é 9
= 2.93 x 9550/1200 = 23.28Nm

Maximum bending moment was obtained was obtained from a bending moment diagram for the loadings as $m_{B\ max}$ = 25.85Nm with a factor of safety K_t = 1.5. The shaft diameter that will withstand the loads is calculated from the maximum shear stress theory and the combine stress equation is used thus

$\pi d^3_s /16$ = ã $[(T^2_{max} + M^2_{max})] / S_{all}$ é 10

Where: T_{max} = maximum torsional (twisting) moment (23.28Nm), M_{Bmax} = Maximum bending moment (25.85Nm) S_{all} = Allowable design shear stress = (34.5mpa) 3.7921 x 10^7 N/m^2 , D_s = shaft diameter to be determined, the value of D_s calculated is 0.017 m. If a safety factor of 1.6 is assumed for the design the shaft diameter is 2.9cm. (Dobrovolski et al, 1974).

Assume that the torque is constant within limits of each shaft step the angle of twist as a result of torsion is given by the expression below.

$$\theta_t = \times_{i=1}^{n}\ m_t\, x l_i / J_{ti} \times G$$ é .11

Where:
M_t = critical torque applied to the shaft,
J_{ti} = ´ $d_s^4/32$ Polar moment of inertia of shaft (cm^4)
G= shear modulus or modulus of rigidity (8.1 x 10^{10} Nm^2 for steel), l_i = shaft length, θ_t = calculated is 2.33 x 10^{-3} rad (0.162^0). This is within the acceptable value range of 0^0 ï 5^0.

2.4 Performance Evaluation

The machine was evaluated using the following indicators:

Threshing Efficiency was measured by the ratio of threshed grains to expected weight of clean grains in %
Threshing Capacity was based on the ability of the machine to remove good and matured grains from the pods, measured by weight per unit time.

Cracking efficiency was measured by the ratio of number of cracked grains to the total number of grains loaded.
Unthreshed losses are the good grains not detached from the pod after passing through the thresher
Loses are associated with the wastage recorded during threshing operation. *Grain loss/ unit time* is the weight of grains in the reject per unit time spent in threshing.

3. RESULTS AND DISCUSSION

The results of performance evaluation indicators are listed below the test results. Tables 1 and 2 indicate the performance of the machine under the moisture content and beater ï concave clearance variables. From the tables, the most suitable conditions for threshing cowpea are with 13.16% moisture content at 9mm beater ï concave clearance and 11mm beater ï concave clearance respectively. The threshing efficiency and threshing capacity reduced with increase in beater clearance and moisture content. The threshing efficiency and threshing capacity for Ife Brown reduces from 97.98% and 30.91kg/hr to 82.05% and 22.42kg/hr respectively at 13.16% and 15.43% moisture contents at 9mm and 11mm beater clearances.

Grain loss in separation increased with increase in clearance and moisture content while unthreshed losses reduced with decrease in clearance and moisture content. A high percentage of grain is lost as unthreshed losses through the chaff outlet. Threshing capacity as a function of time increases as a result of a reduction in clearance hence, the capacity of the machine is a function of time of threshing, moisture content and beater- concave clearance. At higher moisture content, 15.43% performance efficiency of the machine decreases (Table 2) with an increase in grain loses irrespective of concave clearance. The di-cot nature and susceptibility to loading impact of the crop will make cracking efficiency significant (30%) above 15.43% moisture content and cracking efficiency less significant (6%) at 13.16% dry basis.

Table 1. Performance evaluation of thresher at 9mm concave clearance with 13.16% and 15.43% moisture content dry basis

	13.16% M.C		15.43% M.C	
Performance indicators	IFE BROWN	TVX 3236	IFE BROWN	TVX 3236
Threshing efficiency %	97.78	95.38	78.89	81.06
Threshing Capacity (kg/hr).	30.91	24.25	19.26	20.00
Grain Loss/Unit time (kg/hr)	0.22	0.52	21.19	0.33
Cracking Efficiency %	6.00	3.33	30.00	18.33
Unthreshed losses (kg/hr)	3.21	5.15	0.93	0.97
Grain loss %	2.30	2.85	11.12	14.51

Table 2. Performance evaluation of thresher at 11mm concave clearance with 13.16% and 15.43% moisture content dry basis

	13.16% M.C		15.43% M.C	
Performance indicators	IFE BROWN	TVX 3236	IFE BROWN	TVX 3236
Threshing efficiency %	82.05	87.35	81.30	79.23
Threshing Capacity kg/hr.	22.42	0.36	18.75	17.89
Grain Loss/Unit time kg/hr	0.19	0.10	0.85	1.49
Cracking Efficiency %	1.67	1.67	14.00	6.67
Unthreshed losses kg/hr	48.52	16.55	1.60	8.16
Grain loss %	12.00	17.01	11.68	24.21

4. CONCLUSION

The machine is dynamically stable and able to withstand vibration. The materials under test behaved in the same way under test conditions (parameters) but with slight variations due to size and some other parameters that often affect its mechanical properties such as resistance to impact loading etc. The Ife brown with bigger sizes suffered a higher percentage of grain loss in terms of cracking the grains. At relatively high moisture content above 15% more grains were lost, at lower clearance, threshing efficiency increased but threshing capacity was reduced for TVX3236 due to the small nature of the grains hence increase in time of operation.

Threshing capacity, cracking efficiency and unthreshed losses are directly affected by the concave – beater clearance and the grain moisture content. The best operating conditions for the thresher was when the clearance was set at between 0.0085m and 0.009m, and moisture content maintained at 13.16%.The machine capacity was dependent on the threshing efficiency and time of operation, thus the machine is rated at 27.58kg/hr. This is an improvement over existing cowpea thresher with rasp bar beater rated at 17 kg/hr capacity.

REFERENCES

Ademosun O.C. and Olukunle O.J. 2003. Development of an indigenous combine harvester NJERD, Vol. 2 No.3.

Ahaneku I.E., Kamala, A.R. and Ogunjirin,O.A. 2001. Design and Construction of a Multi-crop Thresher. Proc. of NIAE Conf. Vol 23, pp 343-347

Bolufawi S.J 1989. Design and construction of a cowpea thresher. Unpublished M,Sc thesis, Department of Agricultural Engineering, University of. Ibadan

Claude Culpin 1987. Farm machinery, 11th edition published by Collins professional and Technical books 1986 reprinted by BSP professional Books, 387 – 388.

Czkanafojski, K. T. 1976, Agricultural Machines, Theory and construction. Foreign scientific publications Dept of the National centre for scientific, technical and economic information Warsaw, Poland.

Dobrovolski,V., Zablousky,K., Mak, S.. Radchik,A., Erlich,L. 1974. Machine Element. A Textbook 2nd Ed. Mir Pub. Moscow.

Igbeka J.C and Oluleye, A. 1986. Some ergonomic consideration in operating a pedal thresher, Agricultural journal vol. 5, No.1 p 87

Ige M.T 1978. Threshing and separation performance of a locally built cowpea thresher. Journal of Agric Research vol.23 page 45 – 51.

Joshi, H.C. and Singh, K.N. 1980. Axial flow thresher with multicrop potential, IRRI Newsletter, Feb. – Mar.

Design Data 1982. Compiled by Faculty of Mechanical Engineering P.S.G College of Technology, Coimbatore 641004 India.