PERFORMANCE EVALUATION AND MODIFICATION OF A PROTOTYPE DIGESTER FOR SOYABEANS.

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DEDICATION

This project work is dedicated to my late dad, Mr. J.N.Akudo and to my late brother, Onyebuchi Paul Akudo. I know that we shall soon be together.

CERTIFICATION

This is to certify that this project work was carried out by Akudo Christopher Osita in the department of Agricultural Engineering, Federal University of Technology, Minna.

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ABSTRACT

This project aims at evaluating the performance of prototype digester fabricated locally for blanching soyabeans. In order to accomplish this evaluation a comprehensive test that involved the processing of soyabeans into flour was done. This work examines the constructional features of the prototype digester, which includes a cubic water tank made from mild steel incorporating the heater, the steam transmission pipe made from galvanised steel and cylindrical feed digestion chamber made from mild steel, and its suitability for blanching soyabeans. The digester has a capacity of 10kg/batch of soyabeans with a dimension of 34cm x 34cm x 34cm for the water tank and 40cm diameter feed chamber with a depth of 68cm. The water tank and the feed chamber are connected through the pipe. The performance test carried out showed that a stem temperature of 85^0C and pressure of 0.58 bars and with a holding time of two hours, soyabeans could successfully be blanched. Dry seed samples with moisture content 10.5% each introduced into the digester had a moisture content 35.0%, 36.83% and 36.33% for samples A, B, and C, respectively. The soya flour produced had more than 97% o its weight for all three samples passing through sieve No 100.

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CHAPTER ONE

INTRODUCTION

Soyabeans has been grown in Nigeria for the past 50years. British administrators introduced a Malayan variety as an export crop during the 1940 s, in an area farmed by the Tiv people in Benue state where agro-ecological condition favored production.

In 1987, the international Institute of Tropical Agriculture (IITA) launched an ambitious effort in Nigeria to combat widespread malnutrition. With support from the International Development Research Center, IITA embarked on a project to encourage using nutritious, economical soyabeans in everyday food.

Few Nigerians knew about soyabeans until the IITA initiative provided information on everything from their nutritional benefits to how to plant, harvest, store and prepare them. Since then, soyabean production and consumption has increased dramatically, improving nutrition particularly among the urban poor and middle-income groups.

The production of flour from cereals is a well-established industrial activity, which is being accomplished by milling. Production of soyabeans flour differs, remarkably, from that of cereals in that elaborate heat treatment is normally involved in the processing of seeds to fine flour.

The processing plant for the production of soyabean flour comprises a digester, an oven dryer, and a mill. The seeds are steam-cooked for a short time in the digester to inactivate harmful enzymes; oven drying them takes place from where the seeds are then crushed to a fine powder using a mill.

1.1 Objectives

The objectives of this work are:

i. To evaluate the performance of a prototype soyabean digester

ii. Determine what modifications (if any) that can be made to improve on the performance of the digester.

iii. To process soyabeans into flour

1.2 Justification

The vast majority of the African populace are rural dwellers who cannot afford a continuous balanced diet and as a result, the continent is faced with increasing problems of malnutrition especially protein deficiency.

Following the recent recognition of soyabeans as a very rich source of protein, it is evident that one very economical way of preventing under nourishment is through the consumption of protein in the form of soyabean products.

The processing of soyabeans into edible forms requires heat treatment of the seeds since they contain a high percentage of trypsin inhibitors. However, direct heat treatment by boiling lowers the protein content of legumes like soyabean hence, the need to develop a blanching technique using steam.

Difficulties like rapid storage when soyabean is processed in liquid form, long cooking time and its characteristic "beany" odor calls for the need to process into a form more long lasting and with no reduction in nutrient value.

1.3 Scope of work

The project work is mainly on assessing the constructional features and performance of a prototype soyabean digester. It also entails the processing of whole soyabean to soyaflour fit for consumption without any serious further treatment of the flour.

CHAPTER TWO

LITERATURE REVIEW

2.1 History of soya beans

Soyabean (Glycine max) is an oil producing vegetable of the leguminous family. It is a cultigen that is believed to have probably originated from the North-eastern part of China. It was first recorded in Chinese literature. From China soyabean spread to the neighboring countries of Korea, Japan (Hymowitz and Kaizuma 1979) and Southeast Asia and finally around the world. As a cultivated crop, it remained basically confined to Asia, until the beginning of the 21st century when the USA developed soyabean into a major commercial crop (Probst and Judd 1973).

It is presently the word most important grain legume in terms of total production and international trade.

2.2 Morphology

Soyabean is an annual herb that grows up to between 20cm and 180cm in height. It is normally bushy, erect, much branched, with well-developed roots, usually yellow, brown or black seeds. The fruit is dehlscent, which are generally 2-3 seeded. Soyabeans can range in weight from about 100-300mg each, with a diameter of 4-8mm.

The morphological features of the whole bean are the hilum (point of attachement to the pod), the microphyte (a small opening through which the germ tube grows), and the chalaza (a small groove opposite the hilum from the microphyte) as shown in fig 1. (Encyclopaedia of Food Science,Food Technology and Nutrition, vol. 6, 1997.)

The seed coat makes up about 9% of the weight of soyabeans and tightly encloses the two cotyledons and embryo. The seed coat is not easily separable from the intact dry seed but if the seed is broken or if it imbibes water, it separates readily.

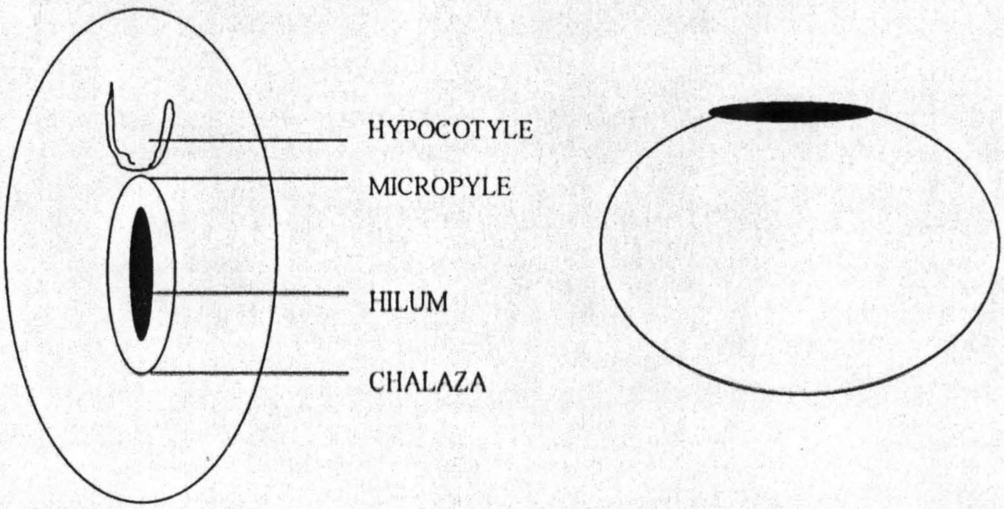

Fig 2.1: Morphological features of whole mature soyabean.

2.3 Recommended varieties

Good soyabean varieties for Nigeria include:

i. Samsoy 2

ii. TGx 1448-2E

iii. TGx 1485-1D

These have been recommended by the International Institute of Tropical Agriculture (IITA)

2.4 Cultivation of soyabeans

2.4.1 Climatic requirement

The seed adapts to a wide range of climatic conditions for germination and growth. Soyabean is highly photoperiodic, and this is a major constraint on selection (Summer field et al.1979), since a variation of 15 minutes in day length may be sufficient to inhibit flower development in a specific variety. In general, a minimum of 120 frost-free days, with a mean summer temp above 21°C, is needed to produce acceptable yields.

Optimum yield of soyabeans requires from 76-102 cm of moisture in the form of either precipitation or irrigation. Adequate available moisture at the time of germination and during flowering and imme4ddiately thereafter is especially critical. (Weiss, 1983)

2.4.2 Soil requirement

Soyabean is tolerant of a wide range of soil types, with the highest yield obtained on well- drained fertile loams.

Soyabean has low salinity tolerance. Soil reaction can vary from fairly Acidic to slightly alkaline. A pH of 6.0-7.0 is optimum. (Weiss, 1983}

2.4.3 Seedbed preparation

The pre-planting cultivation necessary for cotton or maize is suitable for soyabean, with the qualification that on heavy clay soils and those with a hardpan or laterite layer, deeper cultivation may be necessary to ensure free drainage or root penetration. It should such that even depth and spacing are easy. (Weiss, 1983)

2.4.4 Planting material

Soybean is seed-propagated. Good quality seed is uniform in size and weight, and flows easily through the drill or planter. Seed should be sown 3-5 cm deep, and generally not more than 7.5 cm, although in sandy soils or where the top few centimeters are dry, up to 10 cm is possible into moist soil. Germination is epigeal and under optimum condition cotyledons can be above ground in 3-5 days. They are fully open 1 day after emergence; the primary leaves unfolding by the fifth to seventh days. The first trifoliate leaf unfolds in 9-11 days, and reaches full expansion by the fifteenth to seventeenth day. (Weiss, 1983).

2.4.5 Time of planting

In most locations in the country, planting should be done in June or July with about 300,000 plants per hectare.

2.4.6 Weed control

Young soyabean seedlings are unable to compete with many fast growing Tropical weeds, and their control at this period is most important. Since it is difficult to cultivate soyabeans immediately prior to and just after emergence, every effort should be made to reduce the weed population before planting. Soyabean plant depends more on their vertical than lateral root, and over deep weeding operations are not as damaging in terms of yield production as might be expected (Russel et al, 1971). This factor should be considered when weighing the advantages of mechanical operations in weeding mature crops against possible yield reduction caused by weed competition.

Rotary hoes or finger weeders give excellent results in row crops with little damage to plants, and two or three cultivation are usually sufficient. Flame weeders can be effective, but require skill operators and a ready supply of fuel.

The chemical control of weeds using compounds available for pre-emergence use includes a lacchlor, bentazone, butralin, chloramben, fluchloralin, glyphosphate, linuron, metribuzin, nitralde, prometryne andd trifluralin. Some require to be soil- incorporated pre-sowing, with others this technique allows them to be used at slightly higher active ingredient levels which improve weed control.

Soyabean appears to be immune to plant parasites, but has the ability to germinate seeds of witch-weed, strige spp. It can thus be a valuable cleaning crop in cereal rotations where this weed is a serious pest.

2.4.7 Fertilizer application

Soya bean a leguminous crop, required little or no nitrogen application, as it is able to fix atmospheric nitrogen. Rock and similar phosphate and potassium fertilizers usually give optimum results when broadcast and ploughed in, thus dispersing them throughout the root zone. For optimum results, fertilizer should be replaced approximately 10-15 cm deep, below or to the side of, and not in contact with the seed. Many crop residues and animal manure

The total uptake of the three major nutrients by soyabeans at two yield levels is shown in Table 1 below:

Table 2.1: Total uptake of NPK at two yield levels-USA (Weiss, 1983)

Nutrient	Seed yield (Kg/ha)	
	3500	6500
Nitrogen (Kg)	340	620
Phosphorus (Kg)	30	56
Potassium (Kg)	170	225

2.4.8 Harvesting

Recent research shows that soyabean is physiologically mature when the seed coat is completely yellow, irrespective of the pod's main color (Tekrony et al., 1979). It is considered ready for harvest when the majority of leaves have fallen; the lowest pods are yellowish and dry, and the seed wholly yellow.

In areas where labor is plentiful, plants are pulled by hand, thrown into heaps and threshed with sticks, or pulled by hand wind-rowed and threshed by a combine fitted with a pick-up reel.

Combine harvesting g is the simplest method, and provided the cutter- bar is set low enough and guides or air jet fitted, shattering losses during operation will be substantially eliminated. Harvesting is normally done 3 to 4 months after planting.

2.4.9 Storage

As soyabean is harvested and moved from the field into storage, conditions have to be controlled to minimize deterioration. Moisture content should not be more than 14% to prevent microbial growth. Also cleanliness of the beans is important to avoid insect or other contaminants, which may provide moisture and be a focus for microbial growth.

A most suitable packet for long-term storage of soyabean is laminated bag made of cellophane aluminum and polyethylene. In these packets soyabeans retained almost 100% viability after 30months at room temperature. When stored in paper or polyethylene bags, germination was zero after 15and 25 months respectively [AVRDC 1978].

2.5 Energy and nutrients content

Of the total amount of nutrient utilized by plants 70-80% of nitrogen and phosphate and 60% of potassium is usually in the seed at harvest. Work in Australia indicates that there is a difference between assimilates and nutrient movement into pods and seeds, although 80% of final nutrient content of seeds was present at the beginning of leaf senescence [Sale & Campbell 1980]. Analysis of a crop yielding 3400kg\ha is shown in table 2which also shows the main distribution within the plant.

Table 2.2: Analysis of soyabean plants to show nutrient distribution (Weiss, 1983)

COMPONENT	N	P_2O_5	K_2O	Mg	S(Kg/ha)
Grains	210	50	70		
Straw	70	17	45		
Stubble/roots	33	11	22		
Total	313	78	137	14	11
Per 100kg seed	9.2	2.3	4.0	0.4	0.3

In terms of food nutrient, soyabeans approximately contain 20% lipid, 40% protein, 35% carbohydrate and 5% ash on a dry weight basis.

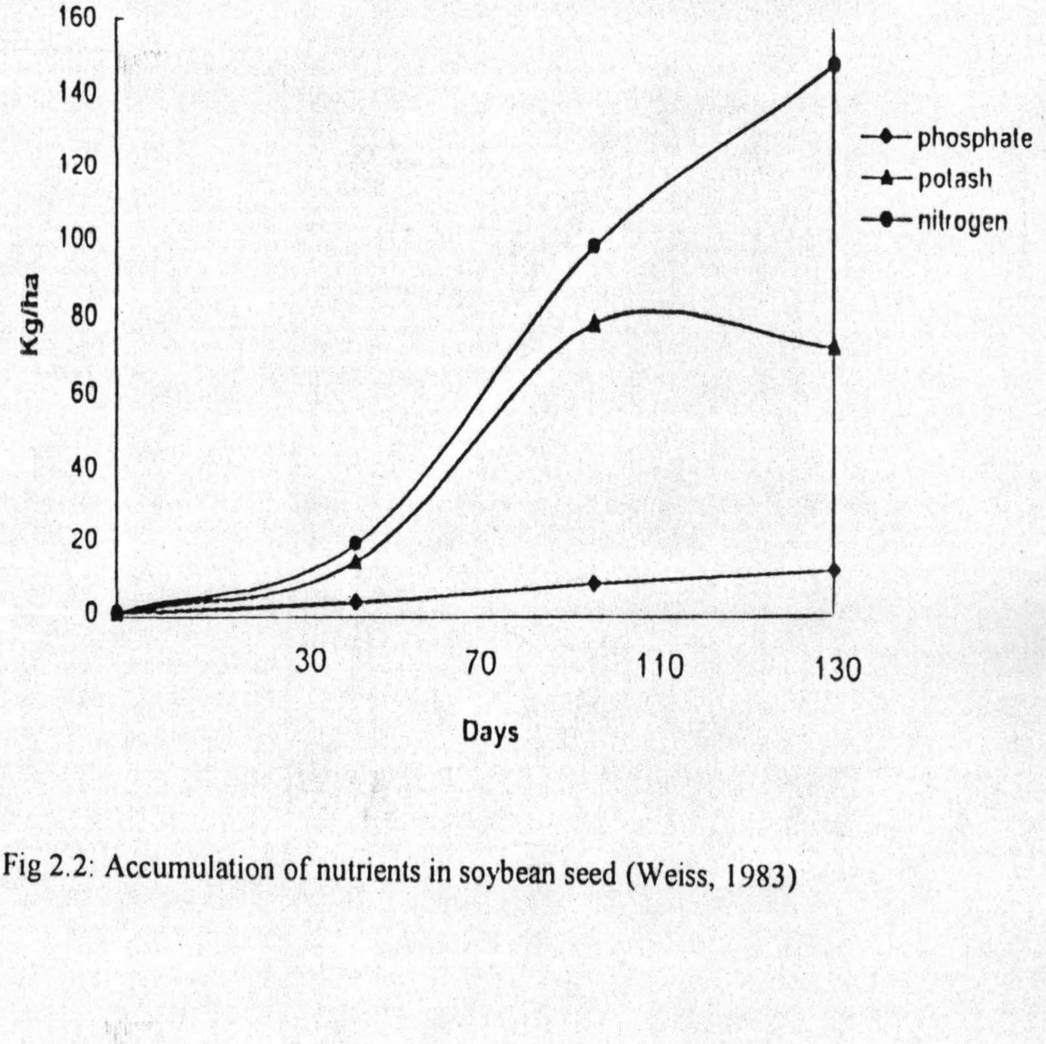

Fig 2.2: Accumulation of nutrients in soybean seed (Weiss, 1983)

2.6 Products of soyabeans processing

Soyabeans differs from many other oil seeds as the seeds themselves have few direct uses. They are seldom used as beans unless previously treated in some fashion, and need to be processed to obtain maximum benefits from the crop.

Edible use of soyabeans derivative is numberless, ranging from pure oil, margarine, shortening, and processed foods, meat and milk substitutes, and proteins. Flours, either defatted or straight, are a basic material for a wide range of protein foods, and together with cakes are a staple ingredient in livestock feeds (Caldwell 1973; Smith and Circle 1978).

2.6.1 Soyabean oil

Soyabean oil is highly unsaturated, and classified as semi-drying oil. It is used in food products including margarine, salad oils, and cooking oils. In industry, it is used in making of paints and varnish, resins, soaps and many other products.

Soyabean oil is a major source of high-purity stearic acid used in food emulsifiers and flocculation agents.

Solvent extraction is the main process used for the recovery of oil and meal from soyabeans, since it is most effective in terms of yield and energy use, and therefore more profitable. (Becker 1978)

2.6.2 Soya milk

Soya milk can be made from either soaked or dry soyabeans. Most commercial methods soak the beans overnight, since soaking greatly reduced the power input required for grinding, causes much less wear on the millstones or blades, leaches out Oligosacharides ensures better dispersion and suspension of the solids during extraction, increases yield, and decreases the cooking time. The milk can be used as such, or flavored with syrup and taken as drink.

The shelf life of Soya milk depends on the processing conditions and the type of packaging used. The product itself is an ideal medium for bacterial growth since it lacks the antibodies present in cow milk. Sanitary extraction, quick cooking, sanitary packaging and storage at low temperature (below 4^0C) ensure a reasonable life for the product.

Sterilization of Soya milk gives it an average shelf life of 4-6 months without refrigeration.

2.6.3 Soya foods

Foods made from soyabeans have been used for centuries in parts of Asia (the Orient) best known are probably the Japanese Tofu (soyabeans curd), Sufu (a cheese made from tofu) and shoyu (soy sauce). Recent research at Strathclyde University, Glasgow, has produced types of tofu resembling cottage cheese with a taste more acceptable to Western palates. Indonesian 'tempeh', made from partially mended and cooked dehulled soyabeans inoculated with Rhizopus Spp; is a highly nutritious protein food which is easily produced, and there are also many other similar foods (Encyclopaedia of food science, food technology and nutrition; 1997).

Table 2.3: Uses and macronutrient composition of some traditional Soya food (Encyclopaedia of food science, food technology and nutrition, vol. 6, 1997)

Number	Soya food and use	Macro-nutrient composition (g/100g edible portion; (%) Kcal			
		Energy (Kcal)	Fat	Protein	Carbonate
1	Tofu (soyabean curd), can be pureed for dressings dips and spreads or eaten directly	93	4.8 (52%)	8.1 (39%)	1.9 (9%)
2	Soya milk Often substituted for cows milk but should not be used as a replacement in the case of infant diets	85	1.9 (48%)	2.8 (32%)	1.8 (20%)
3	Tempeh (Fermented soyabean cake). Primarily used as a meat substitute (tempeh burgers) or cut into pieces and added to a variety of diet (such as mock chicken)	199	77 (32%)	170 (36%)	19.0 (32%)

Table 2.3 continued

3	Muso (fermented soyabean paste)	206	6.1 (22%)	11.8 (26%)	28 (52%)
4	Natto Often used as a topping for rice or added to miso soup or sautéed with vegetables. Can be sweetened and served as hors d'oeuvre	212	177 (44%)	11.0 (31%)	144 (25%)

2.6.4 Soyabean flours and grits.

Flours and grits are the simplest of all edible soyabean protein products.

Soyabean flours are products obtained by finely grinding soyabeans. To be called soyabean flour, at least 97% of the product must pass through a 100- mesh standard screen Soyabean grits have essentially the same composition as flour but coarser granulation. They are usually classified into three groups, according to particle size:

Coarse: 10- 20 mesh

Medium 20 – 40 mesh

Fine: 40 –80 mesh

Smith and Circle (1978) have pointed out that the name soyabean flour is a misnomer in the accepted sense of flour since it does not contain gluten .it more closely resembles physically and chemically non-fat dried milk and is more correctly called '' soyapowder''.

Classification

Soyabean flours (or grits) are classified according to:

A. LIPID CONTENT: These are

1. Defatted soyabean flour: this is obtained from solvent extracted flakes; contain less than 1% oil

2. Full fat soyabean flour this is made from unextracted beans, contains about 20% oil

3. Low fat soyabean flour: made by adding back some oil to defatted soyabean flour. Lipids contains varies according to specifications, usually between 4.5 and 9%. The most common range is between 5% and 6%.

4. High fat soyabean flour produced by adding back soyabean oil to defatted oil. , Usually at the level of 15%.

5. Lecinthinated soyabean flour: made by adding soyabean lecithin to defatted, low fat or high fat soyabean flours in order to increase their dispersion and impart emulsifying properties. Lecithin content varies according to specification. Usually up to 15%.

B. NITROGEN SOLUBILITY INDEX (NSI) OR NITROGEN DISPERSION INDEX (NDI): These parameters indicate the extent of protein denaturation and hence the intensity of heat treatment that has been applied to the starting material. Flours made from "white flakes have NSI values of about 80% while those made from toasted flakes show NSI levels of 10 to 20%. Others grades are available over the entire range of intermediate NSI values. The specification of a specific value of NSI reflects in fact a compromise between the need to maintain the functional properties of the soyabean protein or some enzyme activity, and the desire to inactivate anti-nutritional factors and eliminate the beany taste, all in function of the end use. The index is also called protein solubility or protein disposability indices (PSI or PDI) (Food and Agricultural Organization, 1992).

Composition

The typical composition of different types of soyabean flours is given in Table 3. The basic composition of soyabeans is added for comparison. Since the moisture content of the products may vary during storage, the percentage figures are given on moisture- free basis. A typical level of moisture content is also shown.

Table 2.4: Typical analysis of soyabeans and soyabeans flours (Smith and Circle, 1978)

PRODUCT	PROTEIN (%) (N%*6.25)	MOITURE (%)	FAT (%)	FIBRE (%)	ASH (%)
Soyabeans	42.6	11.0	20.0	5.3	5.1
Full- fat flour	46.6	5.	22.1	2.1	5.2
Defatted flour	59.0	7.0	0.9	2.6	6.4
Lecithinated flour	48.6	5.5	16.4	2.2	5.3

2.6.4.1 Production processes of soyaflour

A. Traditional method

The traditional method of processing soyabeans into flour involves the following steps:

1. Cleaned soybeans are soaked in water, then cooked in boiling water.
2. The beans are then dried in the sun
3. The beans are cracked by hands and winnowed to separate the hulls
4. Finally the beans are ground into flour in a mortar or any other grinding device available.

The soyabeans can also be roasted for 20 minutes in a pan instead of sun drying before grinding into flour.

B. **Industrial methods**

The Food and Agricultural Organization, 1992 identified the following methods

1. WENGER PROCESS

This is available from the winger mixer manufacturing company. It involves dehulling the soyabeans and cracking into meat, and equilibrates with moisture in direct steam fed conditioner or tempering bin. It is then cooked under pressure in a continuous extruder. The extrudate is then cooled and then ground to flour.

2. POTCHEFSTROOM PROCESS

Based in potchefstroom, South Africa, the technology uses a natural, water-extraction process as opposed to chemical extraction methods employed by some manufacturers. The soyabeans is soaked in water at room temperature and the water extracted after soaking. The material is then cooked by passing it through a 500 m pipe structure, the method offering uniform cooking process (blanching) it is fed through colloid mills that grind it all into fine slurry.

The slurry is then fed to a centrifuge, which separates the liquid component from the non- soluble solids, or Soya fiber. The liquid decanted by the centrifuge is de-aerated then led into setting thanks, giving time for the proteins to realign. Conventional clarifying, homogenizing and pasteurizing then take place .The liquid is finally spray-dried to powder.

3-BUHLER PROCESS

Developed by Buhler Company in Switzerland, it is based on very fine grinding and fast heating. With this process the soyabeans is processed into soyamilk and then dried to powder using a spray drier or drum drier.

4- OIL-MILL RELATED PROCESS

This involves extracting oil from the soyabeans before grinding to flour.

The seeds are cleaned, cracked and dehulled. The heated crushed soyabeans are fed into an extractor, where at temperature of 50^0C for a period of two hours, oil is removed using N-hexane as solvent.

Dried and toasted meal from the solvent extraction operation is ground to flour and stored for sale as feed.

2.6.5 Soyabean flour processing machines

Since the production process of soyabean flour are so numerous and varied, only the basic machines are discussed below.

Screen cleaners

A screen cleaner performs separation bases on or according to size alone. The mixture of grain and foreign matter is dropped on a screening surface, which is vibrated either normally or machinery. The screening unit may be compared of two or more screen as per the cleaning requirement.

Digester

A digester is an equipment used in steam cooking the soyabean seeds. It comprises a steam producing boiler and a feed chamber.

Steam produced from the boiler passes through a pipe to the feed chamber where the seeds or grains are and cooks the beams at reduced pressure for 2 hours. In some literature this process is called blanching (steam). The digester softens the seeds apart from destroying harmful enzymes.

Oven dryer

The digested soyabeans is spread out, generally quite thinly on trays in which the drying takes place inside the oven. The drying could be by heated air sweeping across the trays or by conduction from the heated trays or shelves on which the trays lie, or by radiation from the heated surfaces.

For drying of the digested soyabeans temperature should be at 110 ^{0}C for 3 hours in the vacuum oven or at 130 ^{0}C for 4 hours in an air oven.

If sun-drying, however, it takes about 2 full days of good sunshine.

Milling machine

The Burr (or plate) mill is used for grinding the soyabeans into flour.

The main principle here is the crushing of the soyabeans between two plates that are rubbed together. The plates have grooves (burrs) cut on one or both faces. While one of the plates revolves over the other, the grains is feed in at the center of the two plates and is crushed as it moves out towards the periphery.

The fineness of grinding is controlled by the size and quantity of burrs on the plates and the clearance between the two plates. One plate is usually attached to a hand wheel, which can be used to set the distance between the plates.

Sieve shaker

This is used to classify the ground or milled soyabeans into size range.

Standard sieve sizes have been evolving covering a range from 25mm aperture down to about 0.6 mm aperture. The mesh was originally of aperture per inch by suitable choice of sizes. For the wire from which the sieves are woven, the ratio of opening sizes being kept approximately constant in moving from one sieve to the next. A ratio of 2: 1 has been chosen for the standard sieves of sieves in used in the United States of America. The Tyler sieves series. However the ratio of 2:1 is rather large so that the normal sieves progresses in the ratio of $\sqrt{2}$:1and if still closer ratios are required, intermediate sieves are available to make the ratio between adjacent sieves in the complete set $\sqrt[4]{2}$: 1. The standard British series of sieves has based on the available standard wire sizes, so that, although apertures are generally of same order as the Tyler series, aperture ratios are not consistent. In the SI system, apertures are measured in mm.

CHAPTER THREE

METHODOLOGY

3.1 Processing of soyabeans to flour

The production of soyabeans flour begins with the cleaning of the beans during which foreign materials like stones, husks and other impurities are removed. Weighing to determine the quality of soyabeans being used follows this.

Digestion is the next stage in the process operation. This involves steam heating the soyabeans for 2 hours in a digestion chamber at a temperature of 85^0C and pressure of 0.58 bar, hydrolyzing the peptides bonds and hence denaturation of the enzyme protein, which would not function in its particular way.This is important as such enzymes cause undesirable changes in foods, making them unsightly and less nutritious. The weight of the digested beans is taken and noted.

Next in the process chain is the drying of the soyabeans in an oven at a temperature of 110^0C for 3 hours. After drying the weigh of the soyabeans is also taken.

After drying the soyabeans, it is then fed into a mill, which grinds it into flour. Again the weight of the milled product is taken.

After, cleaning, weighing, digestion, drying and milling, the flour is then passed through a set of sieves at the end of which a very fine powder is obtained.

Finally, the soyabean flour is stored in a cool and dry place.

PROCESSING STAGES

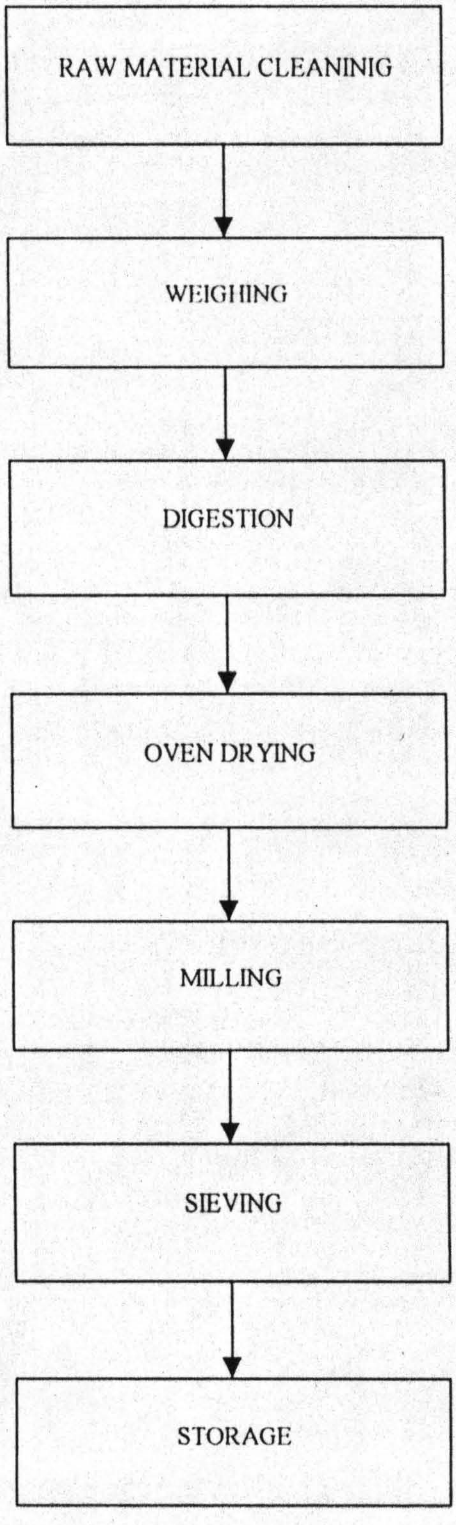

Fig: 3.1: flowchart for the processing of soyabeans into soyaflour.

3.2 Description and principles of operation of the digester

3.2.1 Equipment description

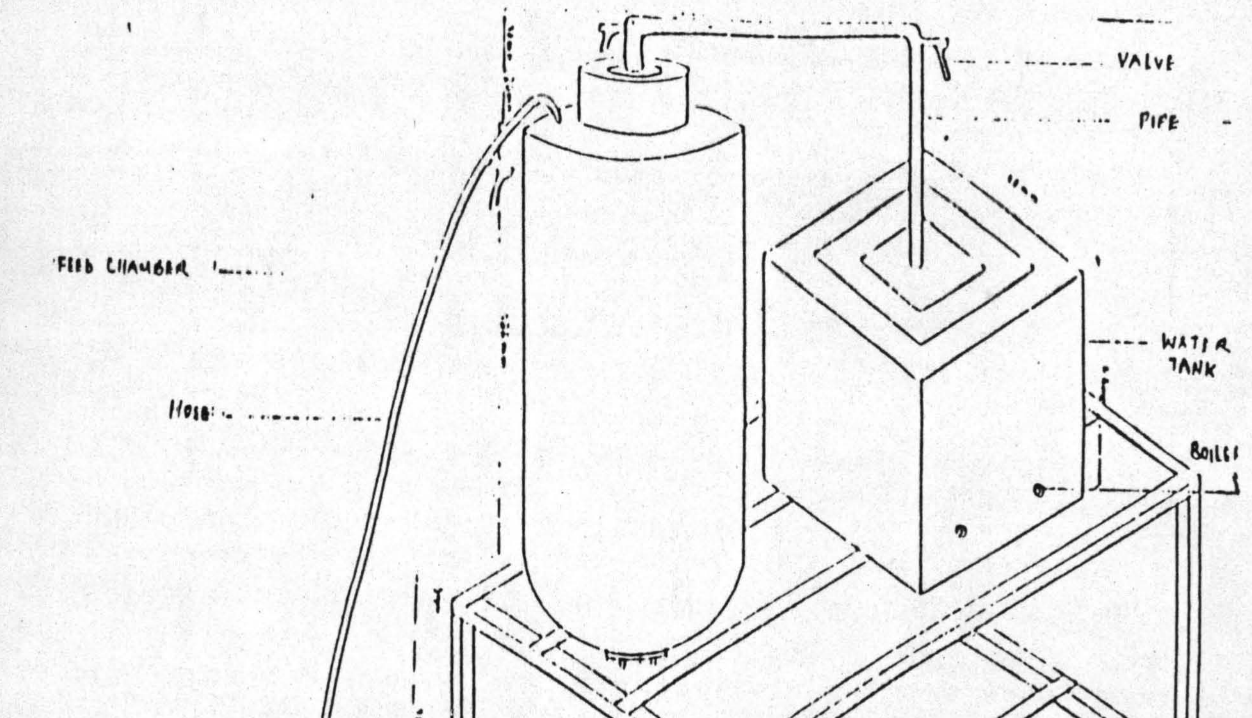

Fig 3.2: A prototype soyabean digester

Water tank

The water tank comprises two heating coils incorporated in cubic steel casing that contains the water to be heated to boiling point. Water is introduced by unscrewing the lid after which it is screwed back.

The dimension of the tank is 34cm x 34cm x 34cm.

Each of the heating coils has a power rating of 2000W.

Steam transmission pipe

This is a galvanized steel pipe of 20-mm diameter connecting the boiler and the feed chamber. It transports steam from the water tank to the digestion chamber.

Digestion chamber

This is made from mild steel metal sheets. It is a cylindrical shaped container constructed such that there is an opening through which air can be evacuated from the chamber using a vacuum pump so as to reduce the pressure in the chamber before digestion.

Lagging

The entire equipment is insulated with 5cm thick foam to minimize heat loss due to radiation.

3.2.2 Principle of operation

The digester is basically a heat exchanger equipment. It is based on the production of steam in a boiler, which flows through a pipe to the digestion chamber where the seeds are held ready for blanching. The digestion pressure is normally very low so as to increase the rate of heat transfer to the seeds.

Digestion is a function of time as much as temperature. This is important as over-cooking the product reduces its nutrient content.

3.3 Parts modification and testing methodology

3.3.1 Parts modification

A. Water tank
Problem

The introduction of water to the tank was tedious as it involves removing the lid before introducing water and then closing it after that.

Modification

A galvanized steel pipe with a stop bolt was incorporated on the lid of the tank to serve as inlet when introducing water into the tank.

B. Feed chamber

Problem

There was no pressure gauge to determine the exact pressure in the chamber after evacuating the air.

The evacuation of air from the chamber was not accurately possible, as the lid on the hopper was not airtight.

Modification

A pressure gauge having a range of 8 bars was incorporated on the chamber.

A gasket made from boltex, a fibre-like material was glued to the lid of the hopper using "Abro-gum" so as to prevent air exchange between the feed chamber and the surrounding during the experiment.

3.3.2Testing methodology

The machine was tested by dry-running it. This was to ensure that the connections were correct.

Water was introduced into the water tank and the valves on the steam transmission pipe closed. Air was then evacuated from the feed chamber using the vacuum pump and hose until a pressure of 0.58 bars was attained after which the valve connecting the hose, through which air was evacuated, was closed. After these, the boiler was plugged to the mains and the switch turned on. The temperature of the boiling water was taken with a thermometer and the valves on the steam transmission pipes opened. Finally, temperature of the steam in the feed chamber was then taken and found to be 85°C.

3.4 Soyabean digestion

The digestion of soyabeans is necessitated by the fact that soyabeans contains a high percentage of trypsin inhibitor which needs to be denaturalized. Thus, the basic reason for soyabeans digestion is to make it edible and consequently, the seeds become softened and the characteristic beany odor removed. The soyabeans to be digested were cleaned and weighed and then poured into the digestion chamber. Water was introduced into the water tank and the steam control valve on the pipe closed to prevent vapor from entering the feed chamber during boiling. The heater was then put on. While waiting for the water to boil, the air in the digestion chamber was evacuated using a motor-powered vacuum pump. By evacuating the air the pressure in the chamber was reduced from 1 bar to 0.58 bars so that there would be little resistance to transfer of heat between the steam and the soyabeans. When the water begins to boil, the steam control valve is opened and steam passes onto the digestion chamber through the pipe. The soyabeans was left to cook for 120 minutes (2hours) after which the system was switched off and the soyabeans collected at the bottom of the feed chamber by unscrewing the bottom cover.

Digestion temperature and pressure

The temperature of steam leaving the tank was determined using a thermometer and gotten to be100°C but as it enters the digestion chamber, the temperature dropped to 85°C due to the reduced pressure in the chamber.

The pressure in the digestion chamber was 0.58 bars due to the evacuation of air from the chamber.

3.5 Material balance around equipment

BASIS: 6Kg/batch

3.5.1 Digester

F_1= Initial weight of soyabeans seeds =6kg

F_2= weight of soyabeans after digestion (Kg)

M_1= moisture gained by soyabeans (Kg) = $F_2 - F_1$

3.5.2 Oven

F_2= weight of soyabeans after digestion (Kg)

F_3= weight of oven dried soyabeans (Kg)

M_2 =moisture removed from soyabeans (kg) =$F_2 - F_3$

3.5.3 Mill

F_3= weight of oven-dried soyabeans (Kg)

F_4= weight of milled soyabeans (Kg)

M_3= weight of soyabeans lost during milling (Kg) = $F_3 - F_4$

3.4.4 Sieves

F_4= weight of milled soyabeans (Kg)

M_4= weight through sieve $N^0$100 (Kg)

F_5= weight of final soyabeans (Kg) = M_4

3.6 Particle size analysis

3.6.1 Fineness modulus

The fineness modulus indicates the uniformity of grind in the final product it is determined by adding the weight fraction retained above each sieve and dividing the sum by 100.

A simple method for determining fineness modulus is presented in the table below:

Table 3.1: Determination of fineness modulus

A	B	C	D	E	F
Sieve N°	Size of opening (in)	Weight of material retained (Kg)	% of material retained	Multiply by	Result of multiplication
4	0.185			6	
8	0.093			3	
14	0.046			4	
28	0.0232			3	
48	0.0116			2	
100	0.0058			1	
Pan				0	
			$\Sigma D = 100$		ΣF

Fineness modulus = $\Sigma F/100$ 3.1

Average size of particle, Dp, indicates fineness modulus and can be calculated using.

Dp (mm) = $0.135\ (1.366)^{FM}$ 3.2

Where, FM = Fineness modulus.

3.6.2 Uniformity index

Average size obtained by fineness modulus I any sample does not indicate distribution of fine and coarse size and it is not proportional to fineness modulus. This can be achieved by using uniformity index and can be demonstrated through tabular analysis as shown below.

Table3.2: Determination of uniformity index

Sieve N^0[A]	% material d[B]	Total/10 [C]	Nearest whole N°
3/8			X coarse
4			
14			Y coarse
28			
48			
100			10-(XY) fine.
Pan			

From the above, Uniformity index = X: Y: (X+Y); X+Y≤10

This implies that the total ratio must be 10.

In conclusion, to be called soyabeans flour at least 97% of the product must be pass through the 100-mesh standard screen.

Proteins generally have low solubility in water. Thus the smaller the solubility value, the higher the protein content and consequently the nutritional value of the soyabean flour.

3.7 Determination of moisture content

The moisture content of the flour is determined using an electronic moisture determination machine called Grain master 2000. It is used to determine the moisture content of flour and is equipment with a printer that prints out the moisture content value.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Material balance around equipment

Basis: 6 Kg/ batch

Samples: A, B, C

4.1.1 Digester

Sample A:

Fa_1= Initial weight of soyabeans = 6.00 Kg

Fa_2= Weight of soyabeans after digestion = 8.10 Kg

Ma_1= Moisture gained by soyabeans = $Fa_2 - Fa_1$

Ma_1= 8.10 – 6.00 Kg = 2.10 Kg

Sample B:

F_{b1}= Initial weight of soyabeans = 6.00Kg

F_{b2}= Weight of soyabeans after digestion = 8.21 Kg

M_{b1}= Moisture gained by soyabeans =$Fa_2 - Fa_1$

M_{b1}= 8.21 – 6.00 Kg = 2.21Kg

Sample C:

Fc_1= Initial weight of soyabeans = 6.00Kg

Fc_2= Weight of soyabeans after digestion = 8.21 Kg

Mc_1= Moisture gained by soyabeans =$Fc_2 - Fc_1$

Mc_1= 8.18 – 6.00 Kg

Mc_1= 2.18 Kg

4.1.2 Oven

Sample A:

Fa_2= Weight of soyabeans after digestion = 8.10 Kg

Fa_3= Weight of oven-dried soyabeans = 5.60 Kg

Ma_2= moisture removed for the soyabeans = $Fa_2 - Fa_1$

Ma_2= 8.10Kg – 5.60 Kg = 2.50 Kg

Sample B:

F_{b2}= Weight of soyabeans after digestion = 8. 21 Kg

F_{b3}= Weight of oven-dried soyabeans = 5.63 Kg

M_{b2}= moisture removed from soyabeans = $F_{b2} - F_{b1}$

M_{b2}= 8. 21Kg – 5.63 Kg

= 2.58 Kg

Sample C:

Fc_2= Weight of soyabeans after digestion = 8. 18 Kg

Fc_3= Weight of oven-dried soyabeans = 5.62 Kg

Mc_2= moisture removed from soyabeans = $Fc_2 - Fc_1$

Mc_2= 8. 18Kg – 5.62 Kg

= 2.56 Kg

4.1.3 Mill

Sample A:

Fa_3= Weight of oven-dried soyabeans = 5.60 Kg

Fa_4= Weight of milled soyabeans = 5.51 Kg

Ma_3= Weight of soyabeans lost during milling = $Fa_2 - Fa_1$

Ma_3= 5.60 Kg – 5.51 Kg

= 0.09 Kg

Sample B:

F_{b3}= Weight of oven-dried soyabeans = 5.63 Kg

F_{b4}= Weight of milled soyabeans = 5.55 Kg

M_{b3}= Weight of soyabeans lost during milling = $F_{b3} - F_{b4}$

M_{b3}= 5.63 Kg – 5.55 Kg

= 0.08 Kg

Sample C:

Fc_3= Weight of oven-dried soyabeans = 5.62 Kg

Fc_4= Weight of milled soyabeans = 5.55 Kg

Mc_3= Weight of soyabeans lost during milling = $Fc_3 - Fc_4$

Mc_3= 5.62 Kg – 5.55 Kg

Mc_3 = 0.07 Kg

4.1.4 Set of sieves

Sample A:

Fa_4= Weight of milled soyabeans = 5.51 Kg

Ma_4= Weight of soya flour through sieve N° 100 = 5.40 Kg

Fa_5= Weight of soya flour = 5.40 Kg

Sample B:

Fb_4= Weight of milled soyabeans = 5.55 Kg

Mb_4= Weight of soya flour through sieve N° 100 = 5.41 Kg

Fb_5= Weight of soya flour = 5.41 Kg

Sample C:

Fc_4= Weight of milled soyabeans = 5.55 Kg

Mc_4= Weight of soya flour through sieve N° 100 = 5.40 Kg

Fc_5= Weight of soya flour = 5.40 Kg

4.2 Particle size analysis

4.2.1 Fineness modulus

Sieve analysis of the three samples (A; B and C) gave the results tabulated below:

Sample A

Table 4.1 sieve analysis of sample A

A	B	C	D	E	F
Sieve N°	Size of opening (Inch)	Wt of material retained (Kg)	% of material retained	Multiply by	
4	0.185	0	0	6	0
8	0.093	0	0	5	0
14	0.046	0	0	4	0
28	0.0232	0.02	0.365	3	1.095
48	0.0116	0.02	0.365	2	1.095
100	0.0058	0.07	1.17	1	1.270
Pan		5.40	98.8	0	0
			ΣD = 100.00		ΣF=3.46

Fineness modulus, FM= ΣF/100

FM= 3.46/100

FM= 0.0346

Average size of particles = $0.135(1.366)^{FM}$, mm

$= 0.135(1.366)^{0.0346}$

= 0.136 mm

Sample B

Table 4.2: sieve analysis of sample B

A	B	C	D	E	F
Sieve N°	Size of opening (Inch)	Wt of material retained (Kg)	% of material retained	Multiply by	
4	0.185	0	0	6	0
8	0.093	0	0	5	0
14	0.046	0	0	4	0
28	0.0232	0.02	0.36	3	1.08
48	0.0116	0.02	0.54	2	1.08
100	0.0058	0.09	1.62	1	1.62
Pan		5.41	97.48	0	0
			ΣD = 100.00		ΣF=3.78

Fineness modulus, FM= ΣF/100

FM= 3.78/100

FM= 0.0378

Average size of particles = $0.135(1.366)^{FM}$, mm

$= 0.135(1.366)^{0.0378}$

= 0.137 mm

Sample C

Table 4.3 sieve analysis of sample C

A	B	C	D	E	F
Sieve N°	Size of opening (Inch)	Wt of material retained (Kg)	% of material retained	Multiply by	
4	0.185	0	0	6	0
8	0.093	0	0	5	0
14	0.046	0	0	4	0
28	0.0232	0.03	0.54	3	1.62
48	0.0116	0.05	0.90	2	1.80
100	0.0058	0.07	1.26	1	1.26
Pan		5.40	97.30	0	0
			ΣD = 100.00		ΣF=4.68

Fineness modulus, FM= $\sum F/100$

$$FM = 4.68/100$$

$$FM = 0.0468$$

Average size of particles = $0.135(1.366)^{FM}$, mm

$$= 0.135(1.366)^{0.0468}$$

$$= 0.137 \text{ mm}$$

4.2.2 Uniformity index

Sample A

Table 4.4: uniformity index of sample A

Sieve N^0	Size of opening (in)	%of material retained	Total / 100	Nearest whole N^0
4	0.185	0		
8	0.093	0	0	0
		Total = 0		
14	0.046	0		
28	0.0232	0. 365	0.0365	0
		Total = 0. 365		
48	0.0116	0. 365		
100	0.0058	1. 270		
Pan		2. 98.00	9. 9635	10
		99. 635		

From the above,

Uniformity index of sample A = 0: 0: 10

Sample B

Table 4.5: uniformity index of sample B

Sieve N^0	Size of opening (in)	%of material retained	Total / 100	Nearest whole N^0
4	0.185	0		
8	0.093	0	0	0
		Total = 0		
14	0.046	0		
28	0.0232	0. 36	0.036	0
		Total = 0. 36		
48	0.0116	0. 54		
100	0.0058	1. 62		
Pan		97. 48	9. 964	10
		Total = 99. 64		

From the above,

Uniformity index of sample B = 0: 0: 10

Sample C

Table 4.6: uniformity index of sample C

Sieve N^0	Size of opening (in)	%of material retained	Total / 100	Nearest whole N^0
4	0.185	0		
8	0.093	0	0	0
		Total = 0		
14	0.046	0		
28	0.0232	0. 54	0.054	0
		Total = 0. 54		
48	0.0116	0. 90		
100	0.0058	1. 26		
Pan		97. 30	9. 946	10
		Total = 99. 46		

From the above,

Uniformity index of sample C = 0: 0: 10

4.3 Moisture content of flour samples (after milling)

Table 4.7: moisture content of milled flour

Sample	Soyagrits	Soyapowder
A	10.8%	11.0%
B	9.1%	10.8%
C	9.1%	10.6%

4.4 Discussion of results

Moisture content after digestion

From the material balance equation, the moisture content of the soyabeans immediately after blanching is given by:

Moisture content, MC

$$= \frac{\text{Wt of soyabeans after digestion} - \text{Wt of soyabeans before digestion}}{\text{Wt of soyabeans before digestion}}$$

For sample A

MC = (8.10-6.0) x100/6.00

=35.0%

For sample B

MC = (8.21-6.00) x100 / 6.00

= 36.83 %

For sample C

MC = (8.18 –6.00) x100 / 6.00

= 36.33 %

The values above show that the soyabean samples absolved appreciable amount of moisture during digestion. this has to be since blanching of soyabeans needs to be done to make it edible and soft in readiness for further processing without need for additional heat treatment.

From the particle size analysis carried out,the percentage of milled product passing through Sieve No 100 was 98.8%, 97.48%, and 97.30% for samples A, B, and C respectively. Also, the fineness modulus for the three samples A, B, and C were respectively 0.0346, 0.0378, and 0.0468 respectively. These figures confirm that the milling process was carried out according to Soyaflour requirement that at least 97% of the final product should pass through Sieve No 100. Most foods prepared with Soyaflour require it to be in fine powder.

The uniformity index of 0: 0: 10 obtained for each of the three samples confirms the overall particle size distribution as "very fine" as opposed to "coarse" or "medium".

The relatively high moisture content of between 9.1% to 11% gotten after milling as opposed to the required maximum of 6% was as a result of exposure of the product to the atmosphere from where it would have gained moisture.

4.5 Cost analysis

This can be broken down into material cost and labour.cost.

Material cost

Table 4.8: Cost of materials

Material description	Unit price (₦)	Quantity	Amount (₦)
Pressure gauge	1,800	1	1,800
Glue (Abro-gum)	750	1 pair	750
Boltex	700	1 yard	700
Galvanized steel Pipe with stop bolt (20mm diameter)	500	1m	500
Hose	80	2 yards	160
Vacuum pump (1 hp)	10,000	1	10,000
Heater	250	2	500
Insulator (5cm thick foam)	300	$2m^2$	600
Soya beans	100	18 kg	1,800
Total			16,810

The total material cost = ₦16, 810

Labour cost

The labour cost is assumed to be 30% of the total material cost

Labour cost = 30% x ₦16, 810

= ₦ 5, 043

Total cost incurred during the entire project = material cost + labour cost

=₦16,810 + ₦ 5,043

=₦21,953

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The blanching of Soyabeans was achieved by steam heating in a digester and which led to further processing into flour. 6kg per batch of soyabeans were blanched in three batches. Digestion was done at a steam temperature of 85°C, a pressure of 0.58 bar and with a holding time of 2 hours. Moisture content of the seeds for samples A, B and C before digestion was 10.5 % each and after digestion were respectively 35.0%, 36.83% and 36.33%. The digestion of the Soyabeans led to its processing into flour fit for consumption without further serious heat treatment. The moisture content of the milled for samples A, B and C were respectively 10.8%, 9.1% and 9.1% for the Soyagrits; 11.0% and 10.6% for the finer flour samples. The difference in moisture content between the Soyagrits and Soyaflour of each samples arose from the fact that the Soyaflour has a larger surface area than the Soyagrits and thus absorbs moisture from the atmosphere more easily than the grits per unit time.

More than 97% of the milled Soyabeans passed through Sieve No 100 after carrying out sieve analysis. This was a physical requirement for it to be called Soyaflour.

The digester is thus considered appropriate for Soyabean processors.

5.2 Recommendation

To further improve on the digester, the following are recommended.

1. The steam transmission pipe diameter to feed chamber diameter ratio should be increased to effect a more uniform cooking of the Soyabeans as more steam would be introduced per unit time, enhancing the overall blanching process.
2. The capacity of the digester should be increased to meet with the demand and need for Soyaflour production.
3. Soyaflour produced should be dried to at least 6% moisture content before storage to increase the shelf life and eliminate chances of microbial activity.

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APPENDIX I

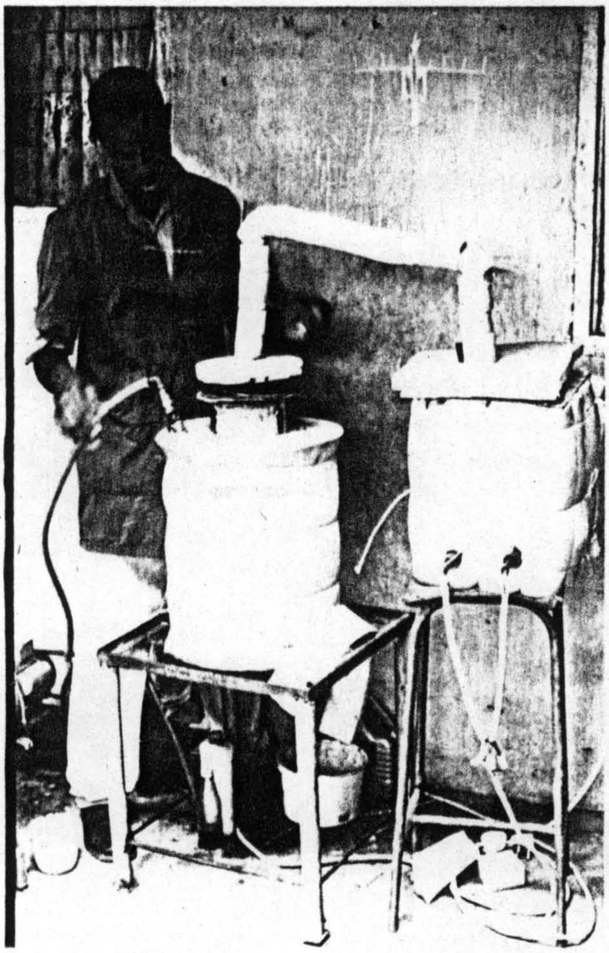

Plate1: Working with the Prototype Digester

APPENDIX II

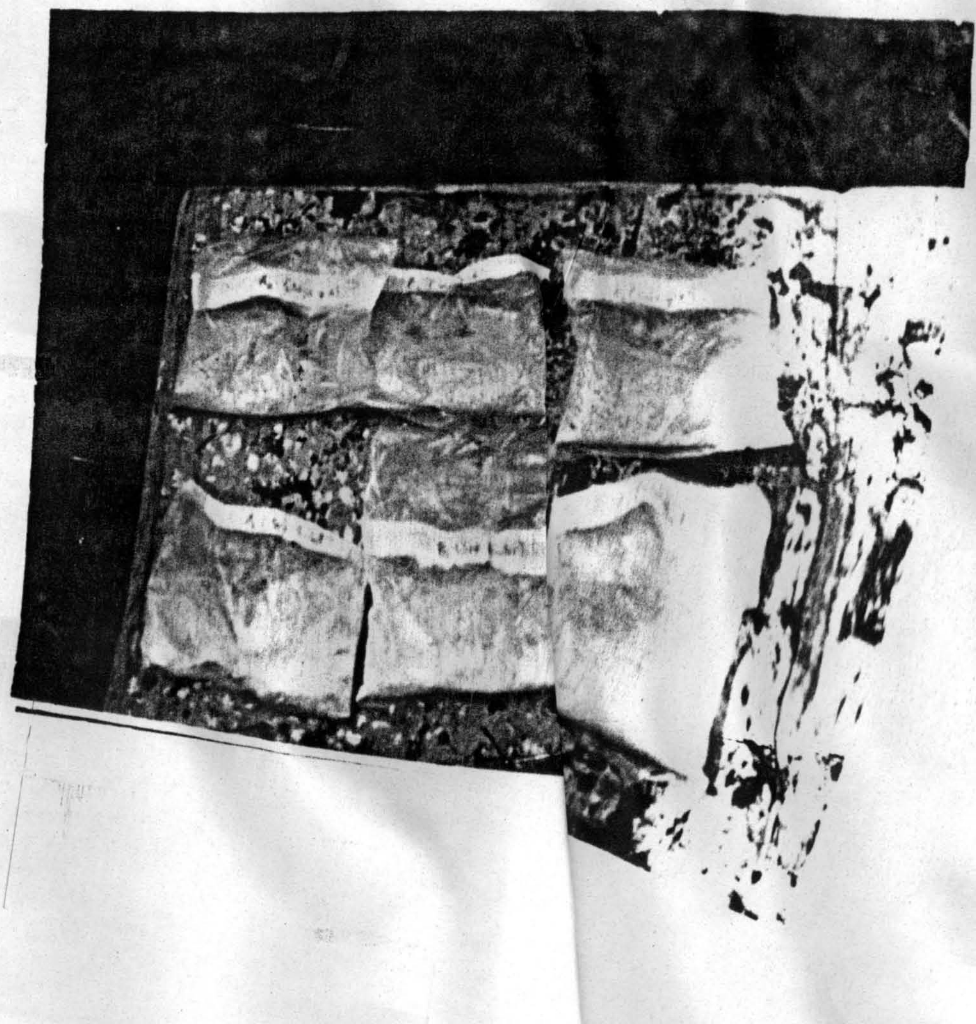

Plate 2: Soya flour samples