DESIGN AND FABRICATION OF A COTTAGE YOGHURT PRODUCTION LINE

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JULY, 2000

DEDICATION

To

ROSELINE ATTI UPAHI
My Love

and

to

MARY AWAWU ALIYU UPAHI
The sweetest of all mothers

CERTIFICATION

This is to certify that this Thesis is an original work undertaken by me (Eneji James UPAHI M.ENG/SEET/121/97) under the supervision of Engr. (Dr.) M.G. Yisa and Engr. (Dr.) E.S.A. AJISEGIRI.; both of the Department of Agricultural Engineering, Federal University of Technology, Minna, Nigeria.

All Authors whose works were used in this thesis have been duly acknowledged.

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Date

APPROVAL PAGE

This Thesis is an orginal work of Mr. Eneji James, UPAHI (M.ENG/SEET/121/97) under the supervision of Engr. (Dr.) M.G. Yisa and Engr. (Dr) E.S.A. Ajisegiri of the Department of Agricultural Engineering, Federal University of Technology, Minna.

This Thesis has been prepared, in accordance with the standards, for the preparation of the Master of Engineering (M.Eng) Thesis in the Federal University of Technology, Minna. It is submitted to the postgraduate school, in partial fulfilment for the award of Master of Engineering (M.Eng) degree in Agricultural Engineering (Food Processing and Storage Option).

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ABSTRACT

This study concentrated on the fabrication and testing of a cottage system for yoghurt production. The machine has two functional units. These are the pasteurising/incubation unit as the primary unit and the cooling/detention tank as the second unit. Raw milk is pasteurised at 65^0C for 30 minutes, cooled in the same unit or transferred to the cooling/detention tank by pumping and transferred back to the primary unit. Starter culture is then added here and incubated at 45°C for 3 hours to produce yoghurt. The machine was then fabricated and tested. The test revealed a positive production of yoghurt with organoleptic quality that is comparable to that produced from an organised Industry in Kaduna. Specific tests on the machine showed that the yoghurt produced has pH values ranging from 4.1 to 5.1. Densities of the sample products are of values 1.00, 1.002, 1.2, 1.3 and 1.8kg/m^3 for pasteurised milk and ranged from 1.3 - 1.9kg/m^3 for produced yoghurt. The tests on pasteurization showed that the system was capable of reducing the microbial colony population to less than 5 per cent for three samples out of five. Organoleptically, yoghurt produced from the system has no significant difference from that produced from an existing Industry. It was however accepted next to it; and more accepted than that produced locally. On the whole, the machine has a production cost of ₦ 24,904.55 and a running cost of ₦18.46 per batch of production.

Recommendations have been made on how to improve on the production efficiency of the machine.

CHAPTER ONE

1.0 INTRODUCTION

Yoghurt is a fermented milk product. It is produced by heating milk (fresh or slurry) to a temperature of 63°C. It is then held for 15 to 30 minutes; cooled to 43°C, inoculated with starter cultures and incubated at the same temperature for a minimum of three (3) hours.

Milk, the major raw material used in yoghurt production, has been identified as a source of nutrients for man. As a food product, it provides animals with new tissues, and energy to do work. Milk can be consumed directly or indirectly. Prior to its consumption, milk is passed through various stages of handling and processing. During these stages, it could be infected by pathogenic agents from the handler, the handling equipment or even the environment in which milk is handled. Milk is usually converted into cheese, ice cream, or yoghurt. In its direct form, milk is pasteurized, skimmed, or condensed.

Perhaps due to awareness that in developing nations, human diets are deficient in animal protein, or simply due to appellation, the consumption of milk (particularly in its converted form) has been on the increase in recent times in Nigeria. This development saw the advent of small scale producers of yoghurt and other allied products of milk. Consequent upon this development, there was an increase in the contamination of milk by the handlers, equipment, and environment because milk has been identified as an ideal medium for bacteria proliferation. To stem the side effects of the contamination on human health, it has become pertinent to develop small-scale machinery to be used in the production of yoghurt. This will reduce the contact between milk, and the handlers. This is the focus of this research study and upon completion, it is envisaged that production of yoghurt on small-scale basis would rather be encouraged than phased out. This will inadvertently increase the utilization of milk resources in Nigeria and ensure proper hygiene in the local production of yoghurt.

1.1 STATEMENT OF PROBLEM

Though a food substance, yoghurt is a substrate for microbial growth. The sharp drop in Nigeria's national economy had brought with it a number of disorientations. One of these disorientations is the unchecked quest for profit maximization at the expense of the quality of goods produced in the country. By this, it is implied that many products are turned out daily in large quantities with little or no quality control. While the side effects of this development may be bearable on some products, the same cannot be said about food products which if contaminated has adverse effects on the consumer.

The low level of personal income of Nigerians forced many to go for goods that are affordable only without consideration for the quality level of the product. Yoghurt production in Nigeria used to be done by the organized industry. The drop in the national economy resulted in the high price of yoghurt which had become an accepted refreshing drink amongst Nigerians. This therefore encouraged the cottage producers of yoghurt. Most of these household producers did not and still do not keep to the recommended hygiene for the processing of milk and milk products. Almost every operation in the production process gives room for contact between the milk and the bare bodies of the producer(s). This, coupled with the fact that the equipment used are far short of the requirements for food processing and the fact that these equipment are not pathogenically free, makes the yoghurt produced from them unsafe for human consumption. There is therefore the need to bring about an improved system of cottage production of yoghurt.

1.2 PREVIOUS RESEARCH ACTIVITIES

There are no available facts in literature indicating that there have been system developments for the production line of yoghurt on a cottage basis. However, there are indications that unit operations have been considered in design for cottage uses. Notable amongst these is the development of a cottage pasteurizer by Ajisegiri (1993). The unit pasteurizer had an efficiency of 95 per cent. The operation cost is one kobo per batch of a 20-litre production within a 30-minute production (pasteurization) time as at that time. The machine was reported to be safe in use and pathogenically free. This development motivates further development into other units of operation for yoghurt production. These units are considered for development in this project.

1.3 PROJECT OBJECTIVES

This project focuses on the following specific objectives:-

(a) To design and fabricate a cottage machine for the production of yoghurt.

(b) To test the fabricated machine for pasteurization, homogenization and capacity

(c) To test the yoghurt produced for palatability

1.4 SCOPE OF THE PROJECT WORK

This project work is intended to cover the followings:-

1) The design of the system.

2) The selection of the components and and fabrication of the equipment.

3) Testing of the system for pasteurization efficiency

4) Palatability tests on the product of the line.

5) Analyse the running cost per unit of production.

1.5 LIMITATIONS

Production of yoghurt is best with fresh cattle milk. But the 'cattle Fulani' move about with the cattle and milk such cows at different stations. This places a limitation on constant supply of fresh milk. There are few organized ranches and many of such ranches do not have pasteurizing equipment to prolong the life of fresh milk. Where fresh milk is obtainable, it has to be processed immediately since milk is a highly perishable product. This therefore, prè-surposes that the cottage system may not have the capacity to process all the milk obtainable from Fulani cattle rearers. Also, as fresh milk production is not ensured all the year round, powdered milk can be used for producing yoghurt. This machine will however be made to be able to produce yoghurt using both fresh milk and powdered milk.

1.6 PROJECT JUSTIFICATION

Milk is a good medium for bacterial proliferation. It has also been known to be a good substrate for some micro-organisms which are responsible for some deadly diseases such as Tuberculosis caused by micro-bacterium Bovis Spp; Leptospirosis caused by Brucella albortus; Q-fever caused by Coxiella burnetti and even the typhoid fever caused by Salmonella typhi etc. (Banwart, 1989). There is therefore no wonder that the period of household production of yoghurt is accompanied by the proliferation of typhoid fever cases and diarrhoea. For this reason, any work focused on minimizing or eliminating the contamination of food that brings about these diseases, will be justified. This is because the value of health as may be preserved is far more than any accruable financial benefits from the production and marketing of yoghurt. In addition, cottage industries are potential sources for economic development owing to their wide spread nature despite their low output.

Recently, the government of Nigeria, in order to protect the health of the citizens, set up an agency; the National Agency for Food and Drug Administration and Control (NAFDAC) to monitor and ensure that food and drug items produced in Nigeria are of health standards. In the bid to realize its mandate, the agency has, in place, modalities for checking and phasing out food items that are not produced at specified sanitary conditions. Most of the local producers of yoghurt may fall into this category. With a project of this nature therefore, such cottage industries will be encouraged to keep on producing and at the same time meeting NAFDAC's standards. This will, in the end, promote the industries. It is a known fact that some of the big industries today started as cottage industries in yester-years.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 MILK AS A DAIRY FOOD PRODUCT

Two key words are found here. These are "Dairy" and "Food".

By the New Lexicon Webster's Encyclopedic Dictionary of English language, "dairy" is defined as a "part of a farm given over" for the production of milk, cream, cheese etc. Similarly, food is defined as "any substance which, by process of metabolism, a living organism can convert into fresh tissue, energy etc.", (Isaac, 1974).

From the foregoing, milk is both a dairy product and food. By definition, milk is a white fluid that is secreted from the mammary glands of female mammals. This secretion is a natural process and the secreted fluid is nature's provision as a complete food for very young animals (Harper, 1976; Ihekoronye and Ngoddy, 1985). Milk is not only an excellent food for young calves, it has become a valuable food for both human children and adults. It is an important source of animal protein and it is because of this importance of milk to human diet, that the Food and Agricultural Organization(FAO) stipulated a minimum per capita consumption per year of 40kg for developing nations. Reports however reveal that this minimum level is not being met according to Ajisegiri (1993).

2.2 CONSTITUENTS OF MILK

The constitution of milk varies according to the source that may be affected by the breed, nature of its food and the season during which lactation is had. The most important constituents of milk are fat, protein (casein), lactose, and the minerals, collectively referred to as ash. Water is a major constituent taking about 88% of milk content. It serves as the solvent for the colloidal system which milk is. Table 2.1 shows the composition of milk from the different sources:-

Table 2.1 Composition of milk according to source (%)*

Source	Total Solid	Fat	Crude Protein	Casein	Lactose	Ash
Cow	12.60	3.80	3.35	2.78	4.75	0.70
Goat	13.18	4.24	3.70	2.80	4.51	0.78
Sheep	17.00	5.30	6.30	4.60	4.60	0.80
Water-Buffalo	16.77	7.45	3.78	4.30	4.78	0.78
Woman	12.57	3.75	1.63	-	6.98	0.21

SOURCE: Jennes and Patton,(1959)

*The difference of the total for a specific source and 100 gives the content of water.

Table 2.2 gives the composition of fresh milk and its contribution to diet.

Table 2.2 Composition of milk and its contribution to diet

		Percent contributions to nutrient Allowances by 1 pint of Milk daily	
Component (Nutrient)	Amount in 100g of Milk	Man with daily expenditure Of 12.6MJ	Girl (3-4yrs) with daily expenditure of 6.2MJ
Energy	272 kJ	3	25
Protein	3.3 g	22	34
Carbohydrate	4.7 g	4	8
Fat	3.8 g	6	12
Water	88 g	-	-
Calcium	103 mg	86	69
Iron	0.1 Mg	1	2
Vitamin A	56 μg	17	29
Thiamine	50 μg	17	33
Niacin	90 μg	4	9
Riboflavin	170 μg	48	95
Ascorbic Acid	1.5 mg	55	75
Vitamin D	0.1 μg	-	3(max)

SOURCE: Delia and Herbert,(1986)

Cow milk, which is the most widely used source of milk, has the following compositions as presented on Table 2.3.

Table 2.3 Composition of cow milk

CONSTITUENT	CONTENT (%)
Water	87.1
Fat	3.9
Protein	3.3
Lactose	5.0
Ash(Mineral)	0.7

SOURCE:- Delia and Herbert (1986).

From the table above, it could be seen that cow milk has a solid (non-fat) content of 9 percent, total solid of 12.9 percent. This is close to the presentation on Table 2.1. Milk, as can be seen from Table 2.2, is a major source of energy. It contains carbohydrate, fat, and protein in the descending order of content.

The major constituents of milk are discussed below.

2.2.1 The Water of Milk

Water is the solvent of the milk colloidal solution. It gives bulk to the milk and holds the solids in solution or suspension, (Artherton and Newlander, 1987).

2.2.2 The Carbohydrate of Milk

This consists of the disaccharide lactose. It is also called milk sugar. Lactose is the only sugar produced by mammals but it lacks sweetness as may be compared to other forms of sugars. Milk contains bacteria called lactic bacilli, which have enzymes that can breakdown lactose into lactic acid according to equation 1

$$\underset{\text{(lactose)}}{C_{12}H_{22}O_{11}} + H_2O + \xrightarrow{\text{lactic bacill}} \underset{\text{(lactic acid.)}}{4CH_3CH(OH)COOH} \quad \ldots 1$$

(Artherton and Newlander, 1987)

2.2.3 The Fat of Milk

The fats in milk are oily droplets of minute sizes ranging from 5μm to 10 μm. Due to this size of the oil droplets, a drop of milk contains millions of fat droplets. The fat of milk is more digestible than other forms of fats. This is because of the emulsified nature of milk substrate. It is higher than the aqueous phase of the milk. Because of this, milk is allowed to stand, so that the fat droplets can rise to the top and coalesce to form larger droplets forming a larger area of cream over the liquid mass of milk. Where it is not desired in the milk solution, the coalesced fat is removed from the top of the milk mass. The fat of milk may be broken down in sizes through a process called homogenization. With or without homogenization, milk is a stable emulsion. The fat-water interface is stabilized by adsorbed natural emulsifiers in the milk (Delia and Herbert, 1986).

2.2.4 The Protein of Milk

Proteins are of high biological value. The proteins contained in milk ,according to Frazier and Westhoff (1978),are:-

(a) Casein (2.6 percent) which is precipitated under acid conditions.

(b) Lactalbumin (0.12 per cent) and

(c) Lactoglobulin (0.3 per cent).

Lactalbumin and Lactoglobulin are called ***whey*** proteins. They remain in solution after acidification. Casein is a family of phosphorus containing proteins. It binds the calcium and other minerals present in the milk.

2.2.5 The Mineral Elements of Milk

These occur in form of salts or as constituents of organic nutrients. Some of the minerals are solutions. Others are colloidally dispersed either as sole particles or combined with protein. The milk from a particular animal specie contains all the mineral elements required by the young ones to grow. Some of the mineral elements present in milk include calcium, phosphorus, chlorine, and iodine. Iron is present but in small quantities. This makes milk a deficient source of iron for the young animals. Some of the elements are found in combined forms such as calcium phosphate. Combined phosphorus is also found in casein and in phospholipid such as lecithin (Banwart, 1989)

2.2.6 The Vitamins of Milk

Vitamins are present in milk either as fat globules or in aqueous solution. Vitamins A and D are found in milk fat. Vitamin A is found in a more appreciable quantity than vitamin D. The quantity of each depends on the season and nature of feed given to the animal. Vitamin A in milk, is partly due to carotene which gives milk its creamy colour.

Other vitamins found in milk are riboflavin, thiamine, ascorbic acid, and a small quantity of niacin. The quantity of these vitamins in milk depends on the treatment given to it before it reaches the consumer (Ihekoronye and Ngoddy, 1985).

2.3 TYPES OF MILK

Milk can be distinguished according to its water or fat content. By this, milk could either be fresh or dried and whether fresh or dried, it could be whole, semi-skimmed, or skimmed.

By fresh milk, it is implied that the water content of the milk is retained, while dried milk implies milk from which the water has been evaporated. Whole milk is a complete milk. It contains all the essential nutrients of milk and by standard, it should contain not less than 3 percent of fat. Semi-skimmed milk is that from which a proportion of the fat has been removed. Semi skimmed milk should contain 1.5 - 1.8 per cent of fat. Skimmed milk is the milk from which the fat is removed to a level that it contains 0.3 per cent or less of fat. In practice, skimmed milk contains 0.1 per cent of fat. The nutritional value of skimmed milk is as good as that of whole milk, except for the loss of fat and fat-soluble vitamins A and D that are lost when the cream is skimmed off (Delia and Herbert, 1986; Atherton and Newlander, 1987).

Table 2.4 shows the average composition of whole and skimmed milk from dairy cattle, according to Delia and Herbert (1986).

Table 2.4 Average composition of whole and skimmed milk from dairy cattle

Nutrient	Whole Milk (%)	Skimmed Milk (%)
Water	87.5	90.2
Protein	3.3	3.2
Fat	3.8	0.2
Carbohydrate	4.8	5.0
Minerals(Ash)	0.5	0.7
Energy Value Per 100 g	65 kcal =272 kJ	33 kcal =142 kJ

SOURCE: Delia and Herbert, (1986).

2.4 PROPERTIES OF MILK

The properties of milk will be discussed under five broad headings namely, physical, electrical and thermal, chemical, rheological and biological properties.

2.4.1 Physical Properties of Milk

Physically, milk is a dilute emulsion, colloidal dispersion and a true solution (Paul and Charley, 1959). The followings are the physical properties of milk:-

(a) Shape

Milk is a fluid and as such deforms continually under shear. It has the ability to flow and as such has no definite shape but has a definite volume. As a fluid, it takes the shape of its container.

(b) Colour

Milk has a bluish-whitish colour. The white or milky appearance is due to the colloidal dispersion of fat globules, calcium caseinate and calcium phosphate and the principal substance that impacts a yellowish colour as carotene and riboflavin. The colour of milk can be affected by the breed of animal and the nature of feed given to the animal that is producing the milk.

(c) Flavour

It is not easy to discern the natural taste of milk. Milk has a pleasant taste and slightly sweet. It derives its sweetness from the lactose contained in it and its saltiness is from the mineral salts such as the presence of chloride. Abnormal flavours in milk are brought about by:-

(i) Contamination of feed of milking animal which is transmitted to the milk (physiological causes).

(ii) Production of rancidity of milk due to the action of lipase i.e. fatty acid and fat content (enzymatic causes).

(iii) The oxidation of fats (chemical causes).

(iv) Bacterial contamination (biological causes).

(v) Absorption of flavours from the surrounding environment (migrational or mechanical causes).

2.4.2 Electrical and Thermal Properties of Milk

Since milk contains some salts that are soluble, they dissociate in solution to form ions, which are electrically charged and can thus conduct electricity. This therefore presupposes that milk can conduct electricity. Whole milk has a lower conductivity than skimmed milk. This, according to Jennes and Patton (1959), implies that milk also has resistance to electric flow.

Artherton and Newlander (1987), reported that milk has a conductivity in the range of 46.1×10^{-4} to 49.2×10^{-4} mhos.

Thermally, milk has a boiling point in the range of 100°C to 100.6°C and a freezing point, which is almost constant at -0.55°C (Artherton and Newlander, 1987; Hall and Davis, 1978). Both the boiling point and freezing point depend on the extent of soluble constituents mainly lactose and chlorides (Jennes and Patton,1959).

Table 2.5 below shows the values of thermal constants for milk and yoghurt after Harper (1976).

Table 2.5 Thermal values of milk and yoghurt

Type	Water Content (%)	Freezing Point (° C)	Specific Heat Capacity(kJ/kg°K)		Latent Heat kJ/kg	Thermal Conductivity (W/m ° C)
			Below Freezing Point	Above Freezing Point		
Milk Yoghurt	87.5 4.0-4.5	-1	2.05	3.9	289	0.53 0.53-0.67

SOURCE:: Harper (1976).

Milk, according to Ajisegiri (1993), has a specific heat of 0.93J/kg/°K and a heating value of 143Cal/kg (598.6J/kg). Milk processing involves thermal treatments but care is always taken to ensure that vital nutrients are not destroyed.

2.4.3 Rheological Properties of Milk

Rheologically, milk is a non-Newtonian fluid as it deforms continuously under shear. The main rheological properties of milk are density, surface tension, specific gravity and viscosity; Mohsenin (1970).

(a) Density

At 20°C the solid density of milk is between 1.026 and 1.032g/cm^3 (Borwankar and Shoemaker, 1991). The average of this according to Ajisegiri (1993), is 1.030kg/m^3. The variation in density, according to Ihekoronye and Ngoddy (1985), is due to differences in fat and non-solid contents of milk. According to these authors, an increase in density is brought about by the liberation of gases like Carbon dioxide (CO_2), and Nitrogen (N_2) which are usually present in freshly drawn milk to the extent of 4.5%. Milk has a bulk density of 610kg/m^3.

(b) Surface Tension

Surface tension of milk is 50 dynes/cm at 20°C. This is lower than that of water, which is 72.75 dynes/cm at the same temperature, (Jennes and Patton, 1959). The presence of proteins and lipids in milk depress the surface tension, (Paul and Charley, 1959). In addition , Jennes and Patton (1959) reported that the surface tension values for different types of milk vary in the range of 51 - 52 dynes/cm for ***Rennet Whey***; 52 - 52.5 dynes/cm(0.52 – 0.53 N/m) for skimmed milk and 39-40 dynes/cm(0.39 – 0.4 N/m) for whole milk. All the milk samples were however sourced from cows.

(c) Specific Gravity

The specific gravity of milk is influenced by those of the constituents of the milk. The average value of specific gravity for milk however according to Paul and Charley (1959), is 1.032 for cow milk.

(d) Viscosity

This property is the consumer's appeal. Milk has viscosity between the two extremes of undesirable gelatinous state and that of thinness that permits the rising of the fat in the fluid milk. The state and concentration of protein in milk, the fat content, the period of milk collection and the temperature of milk according to Jennes and Patton (1959) are factors that affect the viscosity of milk. Milk has an average viscosity of 0.001 Ns/m^2 (Hall and Davis, 1978).

Certain treatments affect the viscosity of milk. Such treatments include acidification, salt balancing, heat treatment, homogenization, and the action of various enzymes and bacteria. In particular homogenization has been proved to increase the viscosity of milk. The viscosity of milk can also increase with age when milk is pasteurized, whether it is homogenized or not (Jennes and Patton, 1959).

2.4.4 Chemical Properties of Milk

Milk, chemically, consists mostly of **triglycerides** of fatty acids to about 98-99%. It is generally characterized by a relatively high proportion of short-chain fatty acids that are significant in flavours and off flavour of milk and milk products. Other chemical components of milk are **diglycerides, monoglycerides, phospholipid**, sterol free fatty acids, waxes, fat soluble vitamins such as vitamins A, D and E. These in addition to the presence of mineral salts give milk specific chemical properties. These specific properties are:-

(a) pH

This specifies the acidity level of the milk. Milk is slightly acidic with an approximate pH of 6.6 to 6.7 at 25°C (Shakuntala and Shadaksharaswamy, 1986; Ajisegiri, 1993). The temperature at which pH is measured is important because milk exhibits a great dependence on temperature. At the same temperature, for the pH value to alter, a great deal of bacterial souring must occur.

This, of course, is due to the considerable buffering capacities of the phosphates, citrates, and proteins present in the milk. Mastitis can cause the pH to rise above the specified range. Mastitis is a disease associated with cattle (Ihekoronye and Ngoddy, 1985; Handerson, 1971).

When milk turns sour, the pH drops and when it reaches 5.2, the milk curdles and the casein is precipitated in the form of flocculent curds. This should however not be confused with the clotting of milk, which is the formation of a tough mass of calcium caseinate.

(b) Creaming

Fat globules of milk rise to the upper surface of milk to form a creamy layer. The depth of the layer depends upon the amount of fat, size of fat globules and the extent of heat treatment on milk. Fresh milk that has been cooled to 4°C gives the most distinctive cream line. Milk that has been pasteurized for 15 seconds at 71.7°C has a slightly lower and less defined cream layer. When heated to 75°C, milk looses its creaminess. Homogenization of milk also destroys creaming properties of milk (Artherton and Newlander, 1987)

(c) Oxidation - Reduction

This property is a function by which if the oxygen level is increased, it is oxidation, but when lowered it is a reduction. The reduction of oxygen can be brought about by bacteria which uses up the oxygen contained in the milk. The bacteria also produce some reducing substances into the milk during metabolism and this may affect the level of oxygen contained in the milk (Artherton and Newlander, 1987). Generally, the chemical nature of milk can be altered by the addition of external constituents such as is added during the production of yoghurt from milk.

2.4.5 Biological Properties of Milk

This is an estimation of how milk will behave with respect to the presence of micro-organisms. Milk harbors a number of micro- organisms, each of which has a specific demand for continual existence. Some of these organisms are pathogenic in nature while others seek to bring milk to deterioration.

The main biological properties of milk are:-

(a) Coagulation

Coagulation is clotting or curdling. It is brought about by enzymatic action or by the addition of acid to milk. The milking cow has enzymes rennet produced in the stomach which can find its way to the milk. There are some other **proteolytic** enzymes which are produced by the bacteria present in the milk and which can cause coagulation of milk. These enzymes act in stages:-

(i) the absorption of the enzyme into the casein particles.

(ii) changes in the state of the casein particles.

(iii) precipitation of the modified casein as a calcium salt.

As opposed to enzymatic coagulation, acid coagulation is controlled by pH. According to Shapton and Shapton (1991), the casein particle is at its isoelectric point at pH of 4.6. Where it has its least affinity for water and hence it undergoes precipitation.

(b) Fermentation

This is a process whereby an enzyme acts on carbohydrate food contents to cause or produce reduction in the content of such food material to produce its acidic nature. In milk, the fermentation of lactose to lactic acid and with subsequent decrease in the pH value results in coagulation.

2.5 MICROBIOLOGY OF DAIRY FOOD PRODUCTS

The composition of any food product dictates the type of flora associated with the food.

The study of the microbiology of food product comprises the safety and spoilage of the food. In terms of milk and milk products, it deals with the safety and spoilage of fluid milk and milk products as well as the fermentation of milk into a plethora of cheeses, yoghurts, and fermented milks; (Sanders, 1992). The knowledge of this is to provide means of preserving milk as safe food product.

Foods serve as substrates for microorganisms. They use food as a source of nutrient for their growth and this results in the spoilage of the food product. By increasing their numbers, utilizing nutrients, producing enzymatic changes, contributing off-flavours by breaking down of product or synthesis of new compounds, they can "spoil" a food product. This is a normal consequence of the actions of micro- organisms and since milk is a good medium for microbial proliferation, it is easily susceptible to spoilage (Frazier and Westhoff, 1978; Ajisegiri, 1993). To prevent this, minimum contact is maintained between microorganisms and foods or better still, they are eliminated (where possible) from the foods. Another possible approach is to modify their storage conditions to inhibit the growth of the microorganisms. Some of these microorganisms are pathogenic and are therefore critical to public health (Frazier and Westhoff, 1978; Goji, 1990).

Despite these seemingly harmful natures of microorganisms present in foods, the interactions between microorganisms and food products are sometimes beneficial as exemplified by many cultured products consumed and enjoyed. A good example is yoghurt, which is produced by the inoculation of starter cultures. Some microorganisms may be beneficial in some foods while they are not in others. This is because any food is a substrate and certain characteristics of the food dictate what can grow or not in the food medium. These characteristics are:-

(i) Hydrogen ion concentration (pH)

(ii) Moisture content (i.e. water activity concept)

(iii) Oxidation-Reduction (0-R) potential

(iv) Presence of hibitory substances or barriers (Banwart, 1989)

Every microorganism has a minimal, maximal and optimal pH for it to grow. Yeast and molds are more acid tolerant than bacteria. Though most foods are neutral or acidic, their inherent pH varies (Frazier and Westhoff, 1978). Acidic foods of low pH are not easily spoiled by bacteria but by molds or yeast. Thus, the keeping quality of a food (such as milk) is related to its restrictive pH. The pH does not only affect the growth rate of micro- organisms but also the rates of survival during storage. On the other hand, the level of water content in food promotes the multiplicity of the organism. A microorganism present in a food substance can be **aerobic, anaerobic** or **facultative**. High oxidation-Reduction potential favours anaerobes and permits facultative process (Banwart,1989).

Bacterial activities in foods result in accompanying chemical changes such as:-

(i) hydrolysis of protein to polypeptide amino acids and ammonia or amines.

(ii) hydrolysis of fats to glycerol and fatty acids.

Bacteria also use the O-R reactions to obtain energy from foods yielding such products as organic acids, alcohol, aldehydes, icetones, and gases. A diversity of microbes is associated with dairy products. These include gram-positive and gram-negative bacteria, molds, yeast, and bacteriophages. Spoilage and pathogenic microorganisms are predominantly controlled by pasteurization, refrigeration, fermentation, and limiting post-processes contamination.

2.5.1 Natural Flora of Milk

Milk in its natural state is sterile but when it is infected, the natural state can be changed. Bacteria inhabiting the teat do migrate up into the interior causing even aseptically drawn milk contain some bacteria predominantly micrococci, streptococci and corynebacterium bovis. Milk taken from a mastitic animal (one with a teat or undder infection) will show dramatic levels of microbes including streptococci, staphylococci, coliform, pseudomonas aeruginosa and corynebacterium pyogenes. Sick animals may also shed pathogenic microbes including mycobacterium species, Brucella species, mycoplasma and Coxiella burnetti (Banwart,1989).

2.5.2 Contamination of Milk as a Food Product

Milk that comes from healthy animals has complex flora on milking. Since milk is an animal product, microbes associated with mammals, farms, feeds and green plant material may find their way into the milk. Milk, like other food materials, can be contaminated through any or a combination of the following ways:-

i) animals ii) sewage iii) soil iv) water v) air vi) during handling and processing.

Contact with any of the above and or contact with equipment used in processing can allow pathogenic bacteria to infest milk. The packaging material and the handling personnel can be another source of contamination. Equipment are usually sanitized before use to reduce contamination (Mossel and Ingram, 1955). According to Seligmann and Rosenbuth (1975), human beings shed 10^3 to 10^4 viable organisms per minute. Table 2.6 shows the number of workers with positive cultures involved in different occupation.

Table 2.6 Number of workers engaged in different occupation and positive cultures of coagulase-negative and coagulase- positive staphylococci, faecal coliform and enterococci obtained from their hands

Occupation	No.of workers examined	No. of workers with with positive cultures	
		Number	Percent
Non Food Employment	200	87	43.5
Mechanized Food Industry	127	68	53.5
Catering services	207	151	72.9
Bakeries	27	26	96.3
Ripened Cheese industry	124	114	91.9
Meat Industry	129	125	96.9

SOURCE: Seligman and Rosenbuth, (1975).

2.5.3 Milk Borne Disease carrying Microbes

As a result of poor handling and/or contamination, milk may carry certain disease causing microorganisms. Such diseases and micro-organisms include:-

a) Tuberculosis caused by micro-bacterium Bovis.

b) Brucellosis caused by Brucella albortus.

c) Leptospirosis caused by Leptospira eptospira.

d) Q fever caused by Coxiella burnetti.

Other diseases associated with milk are scarlet fever, septic sore throat, undulant fever, gastroenteritis and diphtheria (Fung, 1992).

Other milk pathogens as given by Shankuntala and Shadaksharaswamy (1986), are:-

i) Bacillus Ceraceous which is associated with diarrhoea and vomiting.

(ii) Clostridium Perfrigens; formed in raw and pasteurized milk and even in powdered milk and causes stomach cramp and prolific diarrhoea.

iii) Listeria Monocytogenes causing meningitis and septicaemia.

Others are:-

iv) Salmonella Spp. v) Yersinia enterocolitica (Shapton and Shapton , 1991).

Apart from Bacillus carecus, all other pathogens can be eliminated through heat treatment. This is why milk must be pasteurized before use. To further minimize the entry of pathogenic bacteria, milking machines are used instead of hand milking.

The thermoduric (pathogens surviving pasteurization) endanger the storage quality of milk and milk products since they grow well in milk. This is why both milking and storage equipment must be sanitized properly to reduce the number of microorganisms that enter the milk. This is because even the aseptically drawn milk contains not less than 500 microorganisms (Frazier and Westhoff, 1978). Care must also be taken during transit and at the processing level so that no further entry of microorganism is allowed.

2.5.4 Spoilage of Milk

When milk sours, it is considered spoiled especially when it curdles. The sour taste, followed by coagulation, is an evidence of acid formation. When this happens, solid jelly like curds or weaker curds that release clear ***whey*** are given out. This type of acid formation accompanies lactic acid formation, which occurs when raw milk is kept at room temperature. Within this temperature range of 10 to 37°C, streptococcus lactic is most likely to cause the souring and there is a possibility of growth of Coliform bacteria, Enterococci, lactobacilli and micrococci. At higher temperatures such as 37°C to 50°C, five thermophilous and five Faecalis may produce about one percent acid followed by lactobacilli such as Lactobacillus bulgaricus.

Accompanying acid formation in milk is the production of gas by Coliform bacteria. Frazier and Westhoff (1978) stated that the above is a spoilage phenomenon in milk and milk products. Other accompanying phenomena are:-

i) **Proteolysis**; which is the hydrolysis of milk proteins by microorganisms. This phenomenon is favoured by low temperature.

ii) **Ropiness**; This is sliminess which occurs in milk, cream or ***whey***. Ropiness may be of bacteria origin or non-bacterial origin. Bacteria causing Ropiness may be formed in water, manure, utensils and feed.

The action of bacteria on milk can cause changes on the milk fat. The common changes on the milk fat are:-

1) Oxidation of the unsaturated fatty acids.
2) Hydrolysis of the butterfat.
3) Combined oxidation and hydrolysis to produce rancidity on the milk (Frazier and Westhoff, 1978; Sanders, 1992; Seligman and Rosenbuth, 1975).

Other changes include:-

(a) alkali production (b) flavour changes (c) colour changes.

Amongst the causes of spoilage to milk, microbes have been identified as the most perturbing. The most outstanding method of eliminating the microbes is through heat treatment. But because thermoduric and thermophiliic microbes can survive pasteurization and to ensure processors that the minimum heating is achieved, processors often use temperatures and times somewhat beyond what is minimally required. The greatest challenge to fluid milk processors, however, is to limit the contamination that occurs after pasteurization during transporting and bottling (packaging) of milk and milk products.

By far, the most significant group of microbes in the spoilage of fluid milk, according to Sanders (1992), is the **psychrotrophs**. Psychrotrophs are microbes that are capable of growing at refrigeration temperatures. Psychrotrophs include at least 27 genera of bacteria, four genera of yeast and four genera of molds, (Sanders, 1992). Proper refrigeration becomes the utmost important means of controlling microbial growth in milk and its products. In fermented milk, however, low pH is a major controller of microbial growth. This is in conjunction with high titratable acidity as well as the dominance of the flora by starter bacteria which ensures continual acidity of the milk under storage.

2.6 MILK HANDLING AND PROCESSING

As can be inferred from the foregoing reviews, milk is a highly perishable food item. It is for this reason that milk is not only desired to be handled hygienically but also processed promptly. Processing of food items involves treatments given to them in order to preserve them and prevent spoilage. Two major things are responsible for the spoilage of milk and these are the content and extent of content of microorganisms and the extent of chemical constituents and nature of the milk. Therefore to process milk is to seek to eliminate the microorganisms in milk or adjust their conditions of presence that will be suitable for safe keeping of the milk. These are aimed at "inactivating the disease causing organisms and to prolong the shelf life of the milk product" (Ajisegiri, 1993).

The four ways of achieving these according to Harper (1976) as cited by Ajisegiri (1993) are through the processes of **Homogenization**, **Sterilization**, **Thermization** and **Pasteurization**. Of these methods, pasteurization has been identified as a very effective means of eliminating microbes without causing considerable damage to the milk nutrient particularly the protein (Isaac, 1971, Handerson, 1971).

The handling and scientific processing of milk involves the followings presented in their order of occurrence.

2.6.1 Clarification of Milk

This involves the straining of milk for the purpose of removing lumps and foreign materials such as particles of dust, dirt and other undesirable substances which may cause changes in the natural state of the milk. Industrially, centrifugal clarifiers are used. The clarifier is usually set at speeds that will ensure that there is little separation of the cream. Clarification also removes cells from udder which have entered the milk. It also removes some microorganisms from the milk. High centrifugation (about 10,000rpm) removes about 99 percent of the spores and more than half the vegetative cells of bacteria plus some protein. There is however a specialised centrifugal procedure for the removal of bacteria called **Bactofugation** (Frazier and Westhoff, 1978). This method is not extensively used commercially. A clarified milk is ready for pasteurization.

2.6.2 Pasteurization of Milk

Pasteurization is mild heat treatment given to milk for its preservation. Historically, milk first received heat treatments to increase its shelf life. When it became evident that milk serves as a source of food borne diseases, pasteurization became a safe guarding treatment. The objectives of pasteurization are:-

1) to kill all the pathogens present in the milk
2) to improve the keeping quality of the milk (Harper, 1976)

Where the milk is being pasteurized for making yoghurt or cheese or cream, a third purpose of pasteurization is to destroy microorganisms that would interfere with the activities of desirable organisms such as the starter culture. The methods used in pasteurization include the followings:-

(a) Holder Method

This method involves heating milk to 62.8°C and holding the temperature for 30 minutes (Frazier and Westhoff, 1978). This eliminates Coxiella burnetti. This method is used in batch processing of milk and the pasteurization is called Vat- pasteurization. The pasteurized milk is cooled fast.

(b) High Temperature Short Time (HTST) Method

This involves the use of heat exchanger in which the milk is heated to 72°C and the temperature is held for 15 seconds (Frazier and Westhoff, 1978; Ajisegiri, 1993; Goji, 1990). This method is a continuous processing method and it is the most widely used method today commercially. Some processors have involved heating temperature higher than the minimum and holding for 5 to 10 seconds longer. This has the ability to reduce micro- organisms by 90 - 99 percent.

(c) Ultra High Temperature Very Short Time Method (UHT)

This involves heating milk to 137.8°C for 1 second. This has, however, been modified to either heating milk to 93.4 °C and held for 3 seconds at 149.5°C for 1 second. Milk pasteurized in this way is said to be "ultrapasteurized". Milk used for whipping cream, coffee cream and half-and-half are ultrapasteurized.

The efficiency of pasteurization depends on:-

1) Pasteurization temperature
2) The holding time
3) Total number of bacteria
4) Proportion of total microbe that is thermoduric.

2.6.3 Homogenization of Milk

Homogenization is a process of making milk fat and milk sacrum stable by mechanical application of force, which renders the mixture homogenous. Homogenization of milk is achieved by passing milk through a small aperture under high pressure. The pressure applied, is in the range of 160 - 180kg/cm^2. This applied pressure forces the milk through the small aperture thereby resulting in the reduction of the size of the fat globules from the 0.1 - 20μm to a maximum size of 2μm (Shakuntala and Shadaksharaswamy, 1986).

Homogenized milk has a creamier structure, bland flavour and a whiter appearance. The processing given to milk may be specific depending on the intended use. For instance, if milk is to be evaporated or condensed, it is sterilized instead of being pasteurized. Sterilization involves longer and high temperature treatment. Processing of milk therefore can be in line with the sequence below:-

i) Milk is received and cooled

ii) Milk is sampled and evaluated for bacterial count, sediment, acidity, alcohol, appearance, flavour and odour.

iii) Milk is clarified or filtered.

iv) Milk is stored and fat standardized to solid non-fat (optional).

v) Milk is pasteurized.

vi) Water is removed by evaporation.

vii) Milk is homogenized.

viii) Product is cooled (if making condensed milk, homogenization precedes evaporation and sugar is added immediately after cooling).

ix) Product is re-standardized.

x) Product is placed in cans that are sealed.

xi) Leaking cans are rejected.

xii) Product in cans is heated, sterilized and cooled.

xiii) Cans are cased.

xiv) Cans with product are stored (Shreve and Brink Jr. ,1977).

Each of the steps above are done with specialised equipment and in specifically laid out procedures.

Milk, during processing, can be converted to its allied products. These products are:-
1) Evaporated Milk 2) Condensed milk 3) Ice Cream 4) Yoghurt, etc.

Processing of milk can result in the loss of some nutrients. This is illustrated in Table 2.7.

Table 2.7 Nutrient losses in processing and storage of milk

Process	Nutrient Lost	Comments
Pasteurization	10% of vitaminB; thiamine(BL); pyridoxine(B6);FolicAcid;VitaminB12; and 25% of Vitamin C.	
Boiling	25% of Vitamin B1,slight loss of Riboflavin in open pan	If all Vitamin C is lost, then boiling destroys Folic Acid.
UHT Milk	Same as for Pasteurization	50% of Pyridoxine and Vitamin B12 is lost in 3 months storage
Bottling	20% of Thiamine and Vitamin B12	
Sterilization	30% of Folic Acid &60% of Vitamin C	
Evaporated Milk	80% Vitamin B12,50% Vit.C and B6,20% Vit. A,20% Vitamin B1	Vitamin D is added, but evaporation is the destructive way of preserving milk.
Condensed milk	10% of Vit. B1 and B6;25%of Vit. C and Folic Acid;30% of Vitamin B12.	Less destructive than evaporation; added sugar reduces the need for heat to sterilize cans.
Dried Milk	Same as for Pasteurization	Significant loss is had only when fat-soluble vitamins are removed from skimmed milk.

SOURCE: Handerson, (1971)

2.6.4 Storage of Milk

As stated earlier, milk is a highly perishable product. It is for this reason that milk is promptly processed and stored or stored properly after collection. The care and storage of milk involves the followings:-

1) Milk should be taken indoors immediately after collection to avoid rancidity of fats and loss of vitamin B.
2) An alternative means is to place the milk in a cool place out of direct contact with sunlight and where it cannot be contaminated.
3) Milk should be stored in refrigerators. Milk can be kept at 4.4 °C or less or even near freezing point for many days without appreciable change in quality.
4) Milk containers should be sterilized and properly covered especially when under refrigeration.
5) Old and new milk should not be mixed.
6) Milk should be used in the order it was delivered.

2.7 YOGHURT AS A MILK PRODUCT

Yoghurt is a fermented milk product. It is made from heat-treated, homogenized milk, which is inoculated with a culture containing equal amount of Streptococcus Thermophilous and Lactobacillus Bulgaricus bacteria. The essential change produced by these bacteria is that the lactose in the milk is converted into lactic acid. At the initial stages of fermentation, the streptococci are most active, converting lactose into lactic acid and also producing diacetyl until the acidity increases to pH 5.5. Thereafter, the lactobacilli continue the production of lactic acid until the acidity increases further to pH 3.7 - 4.3. At the same time acetaldehyde is produced and this gives yoghurt its characteristic flavour. The fermentation is continued until acidity reaches 0.8 - 1.8 per cent. At this stage, the product thickens. If desired, flavour can be added and this further exposes the yoghurt to live bacteria.

2.7.1 Types of Yoghurt

There are three(3) basic types of yoghurt. These are:-

(a) Natural Yoghurt:- This type of yoghurt has no added flavour.

(b) Fruit Flavoured Yoghurt:- This type of yoghurt has fruit juice syrup added to it before incubation takes place.

(c) Whole or Real Fruit Yoghurt:- This type has fruit in a sugar syrup stirred in after it has been incubated.

The nutrient content of the types of yoghurt is shown in Table 2.8 below.

Table 2.8 Nutrient content of yoghurt types

Nutrient	Natural Yoghurt (%)	Flavoured Yoghurt (%)	Fruit Yoghurt (%)
Water	85.7	79.0	74.9
Fat	1.0	0.9	1.0
Protein	5.0	5.0	4.8
Carbohydrate	6.2	14.0	17.9
Minerals	0.8	0.8	0.8
Energy Value per 100 g	52 kcal. =215 kJ	81 kcal. =342 kJ	95 kcal. =405kJ

SOURCE: Delia and Herbert, (1986).

2.7.2 Production of Yoghurt

Yoghurt can be produced from fresh milk, dried milk or even milk from other accepted sources; e.g. Soya bean milk. The major raw materials required for the production of yoghurt at any scale include:-

1) Milk, (Fresh or powdered)
2) Water
3) Sugar
4) Starter culture
5) Flavour (optional)

The raw materials are passed through the processes as indicated on Fig.2.1 below:-

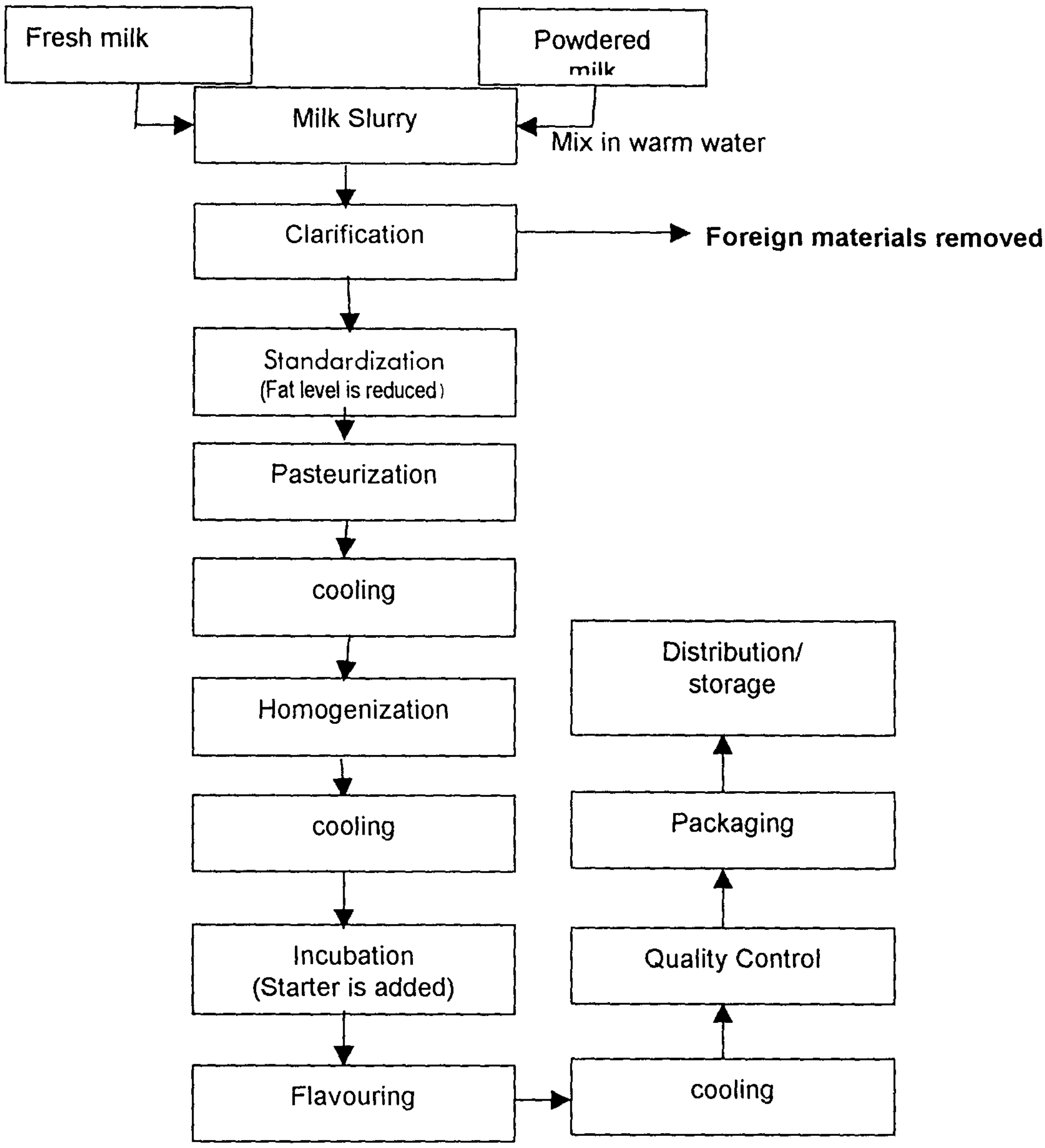


FIG. 2.1 Flow Line for Yoghurt Production

The processes involved are enumerated below:-

i) **Milk Slurry:-** This is the mixing of milk with preheated water. In this, water is heated to 35°C. To this, a quantity of sugar (about 20% of total solid content) is added and stirred for about 1 minute to ensure proper dissolution. Milk is then added and stirred thoroughly for about 20 minutes. Milk content is about 11% of total solid content. This is done industrially and at cottage levels.

ii) **Clarification:-** As explained earlier, this is the removal of foreign materials from the milk or milk slurry by centrifugation or straining. Centrifugation is used in large industries while straining is adopted for cottage production of yoghurt.

iii) **Standardization:-** Fat content level is adjusted here to conform to the type of yoghurt to be produced. This is done industrially but seldomly done by cottage producers of yoghurt.

iv) **Pasteurization:-** This involves heat treating the clarified and standardized milk. In this, milk is heated to the required temperature, depending on the method being used, and held for the specified time intervals. Details of pasteurization have already been discussed.

v) **Homogenization:-** This is a mechanical process on the milk. Here, pasteurized milk is forced through a small aperture under a pressure, of 160 - 180kg/cm^2 (Handerson, 1985). Homogenization is used to reduce the size of the fat globules to ensure stability of the milk slurry (Obafunmi, 1978). This is done locally by using electric blenders.

vi) **Cooling:-** At this stage, the homogenized milk has its temperature reduced to about 42^{o}C to 45^{o}C to make it ready for incubation. Different means of cooling have been adopted ranging from water bath to evaporative cooling methods. Locally, cooling is achieved by dipping the container into a bath of water and keeping it there for a time lag. Alternatively, the content could be cooled in open air.

vii) **Incubation:-** this is the process by which the pasteurized milk is converted into yoghurt. During this process, the cooled homogenized milk is inoculated with a starter culture; which is a mixture of two starter bacteria namely <u>Lactobacillus Bulgaricus</u> and <u>Streptococcus Thermophilous</u>. The mixture is stirred properly and kept at 45^{o}C for a period of three(3) hours. During this period, the combined action of the <u>L. Bulgaricus</u> and <u>S. thermophilous</u> increase the acidity of the product, thus giving it a sour taste. At the expiration of the incubation period, the output is yoghurt. If left in this form it is termed plain yoghurt.

For industrial and cottage productions, the starter culture could either be purchased as packaged commercially or could be extracted from an already incubated milk and kept for the next day's production. In this case about 2% (weight basis) is added as starter culture.

viii) **Flavouring:-** the conversion of lactose into lactic acid produces bye products, which give flavour to the yoghurt. Such bye products are mainly carboxyl compounds, vitalize fatty acids and alcohol. Where additional flavouring is required, commercially available flavour concentrates are added. These give the yoghurt specific aroma and increase its drinking appeal.

In Nigeria, certain fruits are added which introduce pleasant flavour and enhance their organoleptic characteristics. Locally, flavours are seldom added. Some producers add colourising flavours; which result in many colours of yoghurt.

ix) **Cooling:-** A further cooling is allowed here to permit the packaging of the yoghurt.

x) **Quality Control:-** At this stage, the product is assessed to confirm that the properties conform to stipulated standards for food products. This involves ascertaining the bacterial count level, the pH, the palatability etc. Except for the organized industries, cottage manufacturers do not carry out post-production tests on the yoghurt they produce. This therefore implies that taking locally produced yoghurt has a significant level of risk bearing. This is true because locally produced yoghurt does not receive the needed hygiene.

xi) **Packaging:-** Packaging of any product has some purposes. The main purpose is to contain the product. Other subsidiary reasons are:-

a) to preserve the product

b) advertise the product

c) to protect the product from being damaged.

Packaging has some legal notes as the package carries information on the product, its quality level, content, constituents and the dates of manufacture and expiration. Yoghurt is mostly packaged in any of the followings:-

1) Plastic bottles.

2) Collapsible paper packs

3) Polyethene products.

The choice of a package depends upon the cost, the durability, ability to protect the product and local availability.

xii) **Storage:-** Yoghurt is stored at temperatures in the range 5 – 8°C. This is why refrigeration is the best storage for yoghurt, since it contains live and active acid forming bacteria (Delia and Herbert, 1986). Freezing is not desirable for yoghurt during storage.

2.7.3 Effects Of Processing On Yoghurt

Fully processed milk into yoghurt comes with accompanying side effects on the processed milk. For instance, over heating of milk fouls the yoghurt and it is manifested by the leakage of ***whey***. Table 2.9 shows the causes of certain defects on yoghurt.

Table 2.9 Defects and causes in milk

Defects	Causes
Failure to grow.	-Presence of antibiotic in milk. -Weakened cultures. -Inadequate heat treatment -Excessive aeration
Over acidity/ Gas Formation	-Too long incubation -Slow cooling -Growth of yeast
Failure to develope flavour	-Imbalance of cultures due to faulty cultures or use of wrong temperature
Broken co agulum and Syneresis.	-Rough handling -Wrong acidity Abnormal milk.

Adapted from : Banwart, (1989)

If cultures are contaminated, it may account for bitter and other foreign taste.

Processing of milk into yoghurt also has effects on the nutritional and physiological values of yoghurt as enumerated below:-

Lactose: During the manufacture of yoghurt, lactose content is decreased by 20 – 30 percent or more. This reduced content is an important factor for better tolerating yoghurt than ordinary milk by lactose deficient people.

Lactic Acid: As milk is being processed into yoghurt, the lactic acid level rises and this demonstrates a number of physiological and biological advantages which include:-

i) Preservation of the product and considerably improving its keeping quality.

ii) Contribution to a mild sour and refreshing taste of the product.

iii) Antagonistic effect against the growth of harmful organisms.

iv) Improving the digestibility of milk proteins.

v) Improving the utilization of calcium, phosphorus and iron.

vi) Provoking the secretion of gastric juice.

Protein: During the preparation of yoghurt, lactic acid fermentation increases the digestibility of proteins.

Fat: Mild fat hydrolysis takes place resulting in the liberation of fatty acids.

Minerals: These remain unchanged during the production of yoghurt.

Vitamins: During the manufacture of yoghurt, changes in vitamins occur as a result of processing procedures and the biological activity of yoghurt bacteria (Artherton and Newlander, 1978).

2.8 QUALITY ATTRIBUTES OF YOGHURT

The acceptability or non-acceptability of a product depends on its quality level, though the psychology of food acceptance also plays a vital role in the choice of food items. However this psychological effect can be played down by the quality attributes of the product (Frazier and Westhoff, 1978). Quality is a peculiar or essential character or inherent feature, which makes a thing what it is properly. By this, quality can be likened to the degree of excellence, the superiority in kind which defines a social status of a product since it relates to the attribute of an elementary sensation of product that makes it unique. The quality attributes of yoghurt which makes it acceptable or by which it induces acceptability include:-

a) Ingredients b) Flavorc) Colour d) Viscosity e) Durability

For yoghurt, the ingredients that make it acceptable are milk (which could be in varied forms), water, sugar and starter culture. From Public opinion, yoghurt made from fresh milk is most acceptable. This is because of its inherent natural taste. One of the characteristics that make foods acceptable is their organoleptic characteristic. This is measured by the flavour, which is perceived through taste and smell. Upon full blending, yoghurt has a pleasant aroma and a soothing sour taste. Plain yoghurt can be sweetened by the addition of sweetening materials such as sugars. Flavours can be injected into yoghurt to bring out or make the taste more pronounced. In terms of colour, yoghurt maintains the milky colour but may deviate due to the presence of some compounds that may not be harmful to the consumers. The standard viscosity for yoghurt is $0.001 Ns/m^2$. The viscosity can be explained literally, as to how dense the milk is. The "denser" the yoghurt is, the more appealing it is to the consumer. Natural yoghurt that is unsweetened lasts longer. To make yoghurt last longer, preservatives are added. How long natural yoghurt lasts depends on its additives (or ingredients) and consequently its quality level. Yoghurt that is contaminated does not last long enough as to attract the consumers' appealance.

2.9 UNIT OPERATIONS IN COTTAGE PRODUCTION OF YOGHURT

Unit operations, in production, are a small number of basic operations undertaken to achieve a production sequence. They are such that can be isolated and operated independently (Maxwell, 1972). In yoghurt cottage production, the followings are the unit operations:-

Milk Stranining

In this unit operation, the milk that is to be used is strained i.e. the foreign materials are removed by passing the milk through finely knitted clothes to retain the solid materials and allow liquid milk to flow through.

Pasteurization

In this unit operation, milk to be used for yoghurt is thermally treated to eradicate all non-conforming bacteria or disease causing microbes. This unit can be isolated from the production line and done in batches.

Homogenization

This is a unit operation by which the fat globules are reduced in size. Locally, this is achieved by the use of a domestic blender

Incubation

In this operation, the milk is converted to yoghurt. This is done in a unit processing. In this, starter cultures are added to the substrate, then it is maintained at a specified temperature for a specific time and the end product is the natural product.

Cooling and Flavouring

In this unit operation, the produced yoghurt is cooled to room temperature and flavors can be added. In place of packaged flavors, fruits such as pineapple, mango, orange juices are added to give the yogurt the desired flavor.

Packaging and Storage

This is the trailing unit operation. In this, the cooled yoghurt is filled into retail containers that are, themselves, stored or packaged further into wholesale containers for storage or sale or for consumption.

These unit operations can be executed independently but for a complete production process, the unit operations are fused into a line of production.

CHAPTER THREE

3.0 DESIGN METHODOLOGY

3.1 DESIGN CRITERIA

The focus of any engineering design is to ensure functionality, durability and affordability of the system being designed. The assurance of affordability is based on designing of parts with reference to local availability of materials to be used in construction. For a system as the one to be designed, (with cottage utilization focus), the local availability of constructional materials must be ensured. This will be a major guiding criterion in this design.

For functionality and durability, materials will be selected bearing in mind their response to the conditions under operation. Sizing will be done to agree with computational values and ease of operation. For this design therefore, the followings shall be the guiding criteria:-

1) Calculations will be done to ensure proper sizes of parts and to ensure continuity of flow bearing in mind the likely mechanical effects.

2) Materials will be selected to bear with the chemical nature of the products and the mechanical demands. By this, the strength of the materials to be used will be ascertained to ensure durability under use.

3) Since heat transfer will play a major role in the processing of milk, the thermal properties of the materials to be used will be analysed and the findings will be born in mind during the design.

4) Since milk is a very good medium for the proliferation of bacteria, care will be taken to ensure that minimal contact is allowed between the milk, the handler and the environment.

5) The system will be designed to convert both powdered milk and raw milk into yoghurt.

6) The capacity of the system will be fixed at 25 litres of yoghurt per batch of production.

7) Electricity will be used as the source of energy for all the energy demanding units of the system.

8) In order to reduce drudgery, the operation will be semi automated allowing a few operations to the operator. This will reduce drudgery.

9) During the design, the operational comfort of the operator(s), will be considered.

3.2 FUNCTIONAL PARTS AND UNITS OF THE LINE

The yoghurt production line shall have the following functional parts and units:-

i) The milk tanks

ii) The water jacket

iii) The lagging column

iv) The stirring unit

v) The top cover

vi) The Heating system

vii) The flow lines

viii) The pumping system

ix) The Homogenizer

x) The cooling/detention tank

xi) The frame.

The functions of the parts and compositions are described below.

3.2.1 The Milk Tanks

The milk tanks will contain the milk slurry or raw milk to be processed and the processed milk. The material must be of high thermal conductivity. The tank also holds the pasteurised and homogenized milk during the incubation period.

3.2.2 **The Water Jacket**

This part carries the water that envelopes the milk tank. The water contained in the jacket will be heated by an electric heating source. The heat in the water will be transferred to the milk through the tank walls by conduction until the temperature of the milk is raised to the desired level. The temperature and heating system will be regulated by a thermo-regulator.

3.2.3 The Lagging Column

To prevent the loss of heat generated within the water jacket, the jacket will be further enveloped by a lagging column. The lagging material must be of very low thermal conductivity and will be encased in between the outer wall of the water jacket and the external retaining wall of the lagging column.

3.2.4 The Stirring Unit

The stirring unit consists of a stirring column and a motor. The stirring column will be a shaft which will carry four spikes arranged along a length of the shaft. The stirring unit will be responsible for agitating the content of the milk tank when needed. The milk,while being pasteurised, needs to be agitated or stirred to ensure even heating. Prior to pasteurisation, the milk slurry will be stirred vigorously to ensure proper mixing of constituents. When inoculated with the starter culture, it will be stirred again to ensure uniform distribution of the culture powder. The stirring unit will be responsible for setting water into a swirling motion that will be used in rinsing the milk tank after production is completed.

3.2.5 The Top Covers

The top covers will be the lids to milk tanks, water jacket and lagging column concentrically arranged. It will be a seal to the fluid.

3.2.6 The Heating System

The heating system will be responsible for generating and controlling heat flow in the entire production system. This system will consist of a heating device and a thermal-regulating device. Both of them will be designed.

3.2.7 The Flow Lines

The flow lines consist of pipes, inter-connected to conduct the milk, yoghurt or water (as the case may be) through the production line. The flow lines will also carry milk through the homogenizer to the cooling tank and back to the milk tank for incubation.

3.2.8 The Pumping System

This system is responsible for displacing fluid from a point on the system to another desired point. For the production line to be designed, the pump will perform three major functions. These are:-

a) It will conduct the pasteurised and cooled milk through the homogenizer under a pressure to the detention tank.

b) It will displace milk from the detention tank back into the milk tank through the flow lines.

c) It will circulate water round the system when rinsing the production line after the day's production. The system will consist mainly of a pump, of a capacity to be determined by the design.

3.2.9 The Homogenizer

This unit is used to reduce the size of the fat globules in the milk to ensure stability of fluid milk mass.

3.2.10 The Cooling/Detention Tank

This tank will hold the milk when it is being homogenized. It will also hold the yoghurt produced after incubation for cooling and packaging. The cooling will be by water bath.

3.2.11 The Frame

This supports the entire system, ensures stability of machine while in operation and provides protection for the system from externally undesirable forces or causes. By its design, it could also provide aestesy to the machine.

3.3 THE MACHINE PARTS DESIGN

3.3.1 Design of the Milk Tanks

The milk tanks shall be cylindrical in shape. This shape is chosen because of the circular nature of flow to be developed within the tank while the milk is under stirring. A circular path of flow, if smooth, offers much less resistance to flow than angled paths. This is because the path changes continuously at a steady rate. Fluid flow under a rectangular path changes at an angle of 90°, which suddenly leads to substantial loss in energy. This will require a higher power unit to stir the content than the circular container.

The expected capacity of the milk tank is 25 litres per batch.

i.e. Volume of the cylindrical tank = 25 litres

$$\text{But, } 1 \text{ litre} = 0.001\,m^3,$$

$$\therefore 25 \text{ litres} = 25 \times 0.001\ m^3$$

$$= 0.025\ m^3.$$

For convenience, a diameter d, of the cylinder is fixed at 30cm

$$\text{i.e. } d = 30\text{cm} = 0.3\ m$$

$$\text{But volume of tank, } V = \Pi d^2\, h/4\ ,\ m^3 \qquad 3.1$$

Where, h = the height, m

$$\text{From 3.1, } h = 4\,V/\Pi\, d^2,\ m$$

$$h = 4 \times 0.055/\Pi\ (0.3)^2\ ,\ m$$

$$= 0.354\ m$$

$$\text{The actual volume, } V_a = \Pi d^2\, h/4,\ m^3$$

$$= 0.025\ m^3$$

This volume will be adequate to accommodate the capacity planned for. However to provide for the agitation and for foaming, a 20% allowance is provided for in height

$$\text{New height} = 1.2 \times 0.354\ m$$

$$= 0.425\ m$$

Therefore, the cylindrical tank shall have a diameter of 30cm and a height of 42.5cm.

Flow along a closed curve, such as the horizontal cross section of a cylinder, is called circulation (Duncan, 1970). In this, a fluid rotates about a vertical axis at an angular velocity ω. In Rankine's terminology, the flow could be forced vortex, free vortex or combined vortex. The type of flow that will be developed in this design can be classified as combined vortex. This is because a core cylindrical column of fluid will be put into forced circulation while an outer enveloping column will have a free vortex (Duncan, 1970). See Fig. 3.1

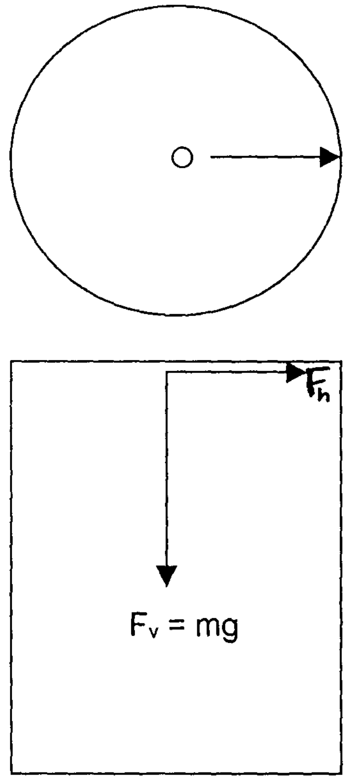


Fig. 3.1 Forces due to circulatory motion

This type of circulation will generate a shell pressure (pressure on the wall due to circulation) given by;

$$\mathbf{P(r) = [P_o + \rho\omega^2 a^2 (1 - a^2) - \rho gh]/2\Pi r^2} \qquad 3.2$$

for $r \geq a$

and

$$\mathbf{P(a) = \rho\omega^2 a^2 - \rho gh + Po} \qquad 3.3$$

for $a \geq r \geq 0$

(Duncan, 1970; Perry and Green, 1997)

where

P(r), P(a) = Pressures at distance ***r*** or ***a*** from the centre of the core , kg/m^2

P_o = Pressure at the origin of the coordinates, kg/m^2

ρ = density of the fluid, kg/m^3

ω = angular velocity of flow, rad/s

a = distance or radius of inner core, m

r = radius of the outer core, m

g = acceleration due to gravity, ms^{-2}

h = depth of fluid , m

It is assumed that the generated flow is in a steady state. Under this condition, the fluid will exert a vertical pressure on the tank. The fluid particles will define a circular path of motion, with constant speed $r\omega$, and a radial acceleration with a component $\omega^2 r$ but exerting an outward pressure having the same component $\omega^2 r$. At any instance, the fluid under circulation exerts two pressures; one due to its thrust on the circular cores given by equation 3.2 or 3.3 and that due vertically given by

$$\mathbf{P_v = \rho gh} \qquad 3.4$$

Where P_v = vertical pressure , kg/m^2 (Duncan, 1970)

During yoghurt production the followings will be added :-

2% by mass of raw milk of starter bacteria

2% by mass of raw milk of sugar

1% by mass of raw milk of flavour

These will increase the mass by 5%.

Mass of milk = density of milk x volume of milk

i.e $m = \rho V$

$= 1.03 \times 0.025$ kg

$= 0.02575$ kg

The S. Thermophilus survives pasteurization temperature but it does not grow in size. However the L. Bulgaricus grows in length. Literature does not however reveal the extent of growth. For this design therefore, a maximum allowance of 5% is allowed for the growth of L. Bulgaricus and other likely contaminants.

$\therefore$ The mass of milk + additives = 1.10×0.02575 kg

$= 0.0283$ kg

Density of combination $= 0.0283/ 0.025\ kg/m^3$

$= 1.13\ kg/m^3$

Using eqn. 3.4, and a density of $1.030 kg/m^3$ for yoghurt; Vertical pressure;

$P_v = (1.130 \times 9.81 \times 0.425)$

$= 4.70\ kg/m^2$

During fermentation, the lactose in the milk is broken into lactic acid carbon dioxide is released. Carbon dioxide is released only if the milk is contaminated by gas releasing bacteria, the absence of which may not be achieved during production. Where it is released, it will add to the mass of the content. Carbon dioxide has a maximum Saturated Vapour Pressure (SVP) of 7.33×10^{-3} Pa (Lewis, 1990).

Steam on the other hand has an SVP of 101.35 kPa (Maxwell, 1972)

$\therefore$ additional pressure $= 101.35 + 7.33 \times 10^{-6}$ kPa

$\cong 101.35$ kPa *(at boiling point of water)*

This additional pressure will be on the top cover; but since it is a closed system, the reaction will be on the base of both the milk tank and that of the water jacket.

$\therefore$ Total pressure, P_T = $(101.35 + 4.7 \times !0^{-3})$ kPa

= 101.36 kPa

This is synonimous with the stress generated on the base of the tank and it is far less than the tensile strenght of both allumunium and mild steel.

Pressure due to circulation is given by equation 3.2 because in this conception, the fluid in the tank is expected to be stirred using a rod carrying a number of spikes. The spikes will be arranged co-axially leaving a clearance between the wall of the tank and the spike end of 3cm.

Radius, r, of the cylindrical tank = 30/2cm

= 15cm

= 0.15m

Radius of inner core, a = (15 - 3)cm

= 12cm

= 0.12m

The origin of the coordinates will be along the vertical central axis where pressure is expected to be zero.

Therefore, P_o = 0

Milk, while under pasteurization, is to be stirred slowly and stirred fast during slurry preparation and rinsing. There are no literature facts on how fast milk or yoghurt should be stirred. There are indications however that any speed above 350 rpm will cause the milk to foam but yoghurt does not. For the purpose of this design, therefore, a speed of 300 rpm shall be adopted but operational speeds shall be specified at lower than 300 rpm.

Thus, the turning speed will be taken as n = 300 rpm

But angular velocity, ω = **$2\Pi n/60$** 3.5;

(Spotts, 1988; Muvdi and McNabb, 1988)

= $2\Pi \times 300/60$ rad/sec

= 31.4 rad/sec

The maximum shell pressure that could be developed on the walls of the cylinder as given by equ.3.2 is

$$P = 0 + 1.030(31.4)^2(0.12)^2\{1-0.12^2/2(0.15)^2\} - 4.30 \text{ kg/m}^2$$

$$= (9.94 - 4.30) \text{ kg/m}^2$$

$$= 5.64 \text{ kg/m}^2$$

This translates to 55.27 N/m^2 of stress; which is $\cong$ 55 Pa. This stress will be tensile and the wall of the cylinder will constantly be put under tension.

This tensile stress acts on the wall of thickness **t.**

But $\mathbf{t = PD/20\sigma}$ 3.6 (Riley and Zachary, 1989)

Where,

P = Shell pressure, kg/m^2

D = Internal diameter, m

σ = Allowable shell stress, N/m^2

but σ = Ultimate stress (σ_u) $\div$ factor of safety (F_s)

Using a factor of safety of 1.5 (dynamic load)

$\sigma = 55/1.5$ N/m^2

$= 36.67$ N/m^2

$\therefore$ $t = (5.64 \times 0.3) \div (20 \times 36.67)$ m

$= 2.31 \times 10^{-3}$ m

$= 2.31$ mm

A thickness of 3mm is therefore chosen for this design.

Aluminium has been chosen as the material for the milk tank. This choice was made considering properties of aluminium. According to Budinski (1992), *"aluminium is widely used in handling food products. It resists attacks by many types of foods but more importantly, it is non toxic."* Aluminium , depending on its degree of alloy, is corrosion resistant.

Mechanically, aluminium has a tensile strength ranging from 90MPa for pure aluminium to 676 MPa for alloyed aluminium (Budinski, 1992; John, 1983). This therefore indicates that aluminium will be able to withstand the stress to be generated by the operation within the cylinder.

HEATING REQUIREMENTS OF THE MILK TANKS

The milk inside the milk tank will be heated to a maximum temperature of 65°C during pasteurization. Heat will be transferred from the boiling water enveloping the milk tank through the walls of the milk tank into the milk. Heat will flow radially inward towards the center. Fig. 3.2. below illustrates the heat flow configuration.

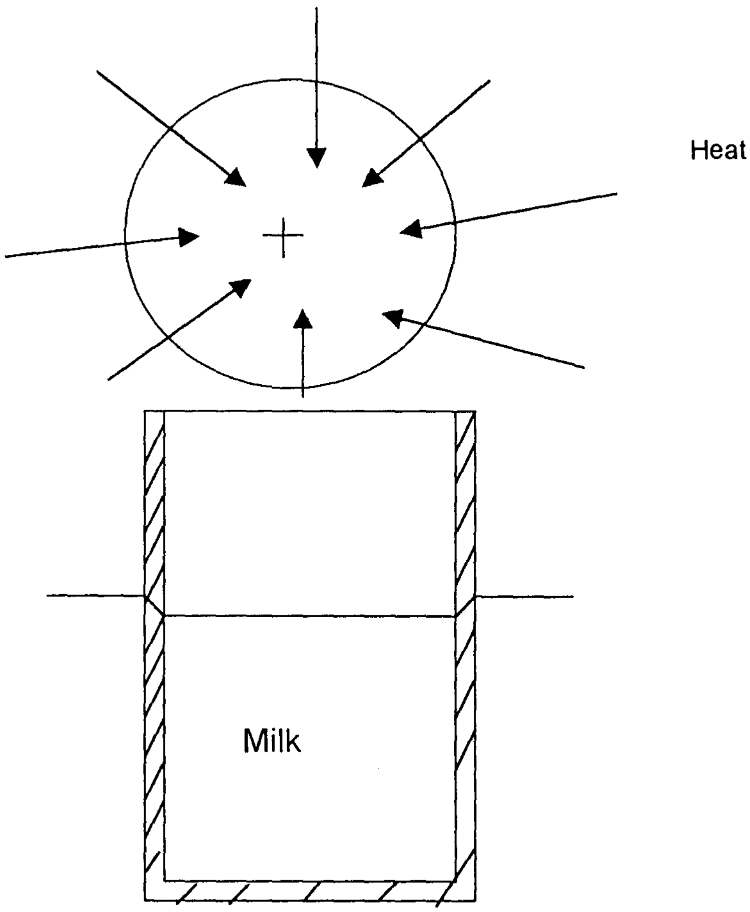


Fig. 3.2 Heat flow configuration

Flow by conduction obeys Fourier's law. This is stated mathematically as;

$$\mathbf{Q = - kA\ dT/dx} \qquad 3.7$$ (Welty, 1978; Incropera and DeWitt, 1981)

Where, Q = Heat flow rate, W

K = Thermal conductivity of conducting material, W/m°C

A = Cross sectional area normal to flow of heat, m^2

dT = change in temperature, °C

dx = distance over which heat is transferred in m.

Heat transferred across curved surfaces such as for a cylinder is governed by the relation:-

$$\mathbf{Q} = \frac{\mathbf{2\Pi kh(T_1 - T_2)}}{\mathbf{ln(D_o/D_i),}} \text{ W} \qquad 3.8$$ (Faires and Sammang, 1978; Welty, 1978; Haberman and John, 1989)

Where

h = height ,m

D_o = outer diameter, m

D_i = inner diameter, m

T_1 = Outside temperature °C

T_2 = Internal Temperature °C

For aluminum $k = 1.2 W/m^oC$ (Eastop and McConkey,1978)

The compartment within which heat is generated and distributed is the compartment comprising of the milk tank, the water jacket and the lagging column. The assembly of the compartment is as shown on Fig. 3.4.

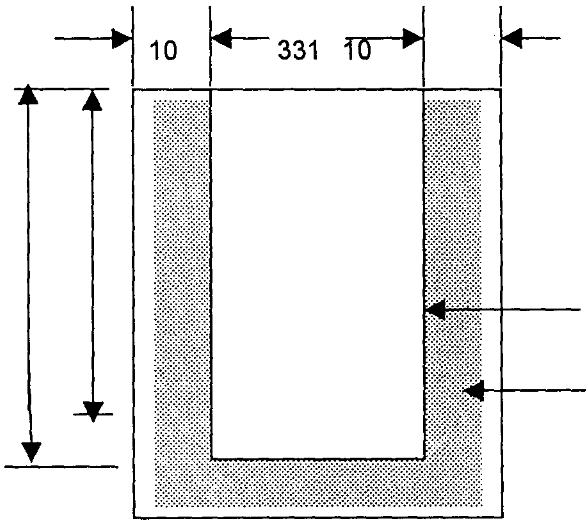


Fig. 3.3 Lagging Column configuration

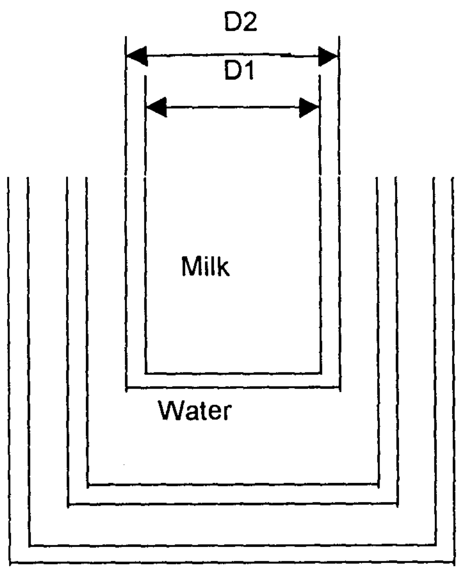


Fig. 3.4 Compartment Assembly

From the above and the foregoing:-

D_i = 300mm = 0.3m, D_2 = 306mm = 0.306m

D_3 = 326mm = 0.326m, D_4 = 329mm = 0.329m

D_5 = 349mm = 0.349m, D6 = 352mm = 0.352m

Volume of water in the water jacket, Vs is given by:-

$V = (\pi D_3^2h/4 + \pi D_3^2H_1/4 - \pi D_2^2H_1/4)\ m^3$; ($h = H_2 - H_1$

$= \pi/4(D_3^2h + D_3^2H_1 - D_2^2H_1)$

$= 0.00916\ m^3$

Density of water = $1000 kg/m^3$

But Density (ρ) = mass (m)/Volume(v) 3.9

Therefore, mass of water, m = ρV = 1000kg/m^3 x 0.00916 m^3

= 9.16 kg

The milk during pasteurization will be heated to a temperature of 65°C. (Ajisegiri, 1993 adopted this temperature as against the 62.8°C specified by literature). At this temperature since both the milk and water will be expected to be at thermal equilibrium. Therefore, temperature of water is taken to be 65°C. Estimated room temperature is 26°C.

Quantity of heat required to raise the temperature of water to 65°C is given as:-

Q = MCdT 3.10

where C = specific heat capacity of water

= 4.19 x 10^3 J/kg °C^{-1}

dT = temperature gradient

= (65 - 26)°C

$\therefore$dT = 39°C and,

Q = 9.16 kg x 4.19 x 10^{3}J/g °C x 39°C

= 1,496,835.6 J

This is also the enthalpy of water i.e ΔH_w = 1,496,835.6 J

The working principle of the arrangement above involves conductive heat transfer from the hot water to the milk through the separating wall; and the heat lost to the environment through the lagging material and the walls. The thermal illustration of the figure 3.4 can be as in Fig. 3.5.

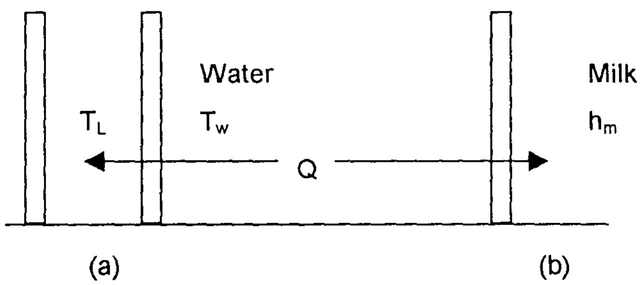


Fig. 3.5 Heat Flow Across Walls

Convective heat transfer coefficients for this temperature range are given as:-

h_o = 41.47

h_w = 0.055

h_m = 6.20 ; Ajisegiri (1993)

Therefore, the overall heat transfer coefficients are calculated as thus:-

$$1/U_a = 1/h_o + 2(L_s/K_{ms}) + L_l/K_l + 1/h_w \quad 3.11$$

Where L_s = Thickness of steel = 1.5mm = 0.0015m

L_l = Thickness of lagging = 10mm = 0.01m

K_l, K_{ms} = Thermal conductivities of lagging and mild steel = 0.027 W/m°k;45 W/°C respectively

$1/U_a$ = 1/41.47 +2(0.0015/45) + 0.01/0.027 +1/0.055

= 18.58

$\therefore U_a$ = 0.054

U_a = 0.054 (for heat loss to environment).

Similarly, for heat transferred to the milk,

$$\mathbf{1/U_b = L_A/K_A + 1/h_m} \qquad 3.12$$

Where L_A = thickness of alluminium

K_A = thermal conductivity of alluminium

h_m = convective heat transfer coefficient for milk

$1/U_b$ = 0.003/1.2 +1/6.2

= 0.164

$\therefore U_b$ = 6.11

From Fourier's equation, heat flux

$$\mathbf{q = UA\Delta T} \; ; \qquad 3.13$$ (Incropera and Dewitt ,1981)

Where q = heat flux

U = overall heat transfer coefficient

A = conducting surface area, m^2

ΔT = change in temperature, °C

q_a = 0.054 x [$\prod(0.352)^2/4 + \prod(0.352 \text{ x}0.493)$](65 -26) W/m^2 °C

= 1.35 W/m^2 °C

Similarly,

q_b = 6.11 x [$\prod(0.306)^2/4 + \prod(0.306\text{x}0.4)$]x25 x 39 W/m^2 °C

= 47.32 W/m^2 °C.

To know the quantity of heat that will be required to raise the temperature of milk to the desired level, the enthalpy for milk will be calculated:-

i.e $$\mathbf{\Delta H_m = \rho V C_p \Delta T} \qquad 3.14$$

where, ρ = Density of milk = 1.03kg/m^3

V = Volume of milk = 0.025 m^3

C_p = Specific heat capacity for milk

= 3.9 kJ/kg °C, (Maxwell, 1972)

ΔT = (65°C - 26°C) = 39°C

$\therefore \Delta H_m = (1.03 \times 0.025 \times 3.9 \times 10^3 \times 39)$ J

$= 3916.58$ J

Heat lost to the environment is given as;

ΔH_e = Heat flux x surface area 3.15

$= 1.35 \times [\Pi(0.352)^2/4 + \Pi(0.352)^2\ 0.493$ J/S

$= 0.867$ J/s

For a total time of 40 minutes holding time,

Heat lost = 0.867 J/s x 40 x 60s

= 2080.8 J

Therefore, Total heat required,

$\Delta H = (1,496,835.6 + 3,916.58 + 2080.8)$ J

= 1,502,833 J.

Using a 2000-watt heater and assuming an efficiency of 70% with a further 10% for other losses, gives an overall efficiency of 60%.

Actual heating wattage = 2000 x 0.6 W.

= 1200W

Theoretical take off time for the temperature to reach the desired level

t = 1,502,833 /1200 s

=1252.4sec.

= 20.9mins.

3.3.2 DESIGN OF THE WATER JACKET

The water jacket will also be cylindrical since the milk tank is cylindrical and it carries the water that envelopes the milk tank.

The space round the milk tank will be filled with water and it will be heated by the heating element to provide an indirect heating to the milk.

The major requirement here is to specify the size of the space surrounding the tank and the thickness of the material to be used.

A clearance of 10mm will be allowed between the milk tank and the inner wall of the jacket. This will contain the water. There will be one port on top of size 7mm to accommodate a pipe to serve as a water inlet. At the base, a compartment of 50mm will be provided to accommodate the heating element.

Volume of water in the jacket,

$V_w = \Sigma\ (\Pi d^2 h) / 4$

$V_w = \Pi(0.329)^2 (0.05) /4 + \Pi/4[(0.329)^2 - (0.306)^2]\ 0.428\ m^3$

$= \Pi/4[(0.329)^2 (0.05) + \{(0.329)^2 - (0.306)^2\}0.428]\ m^3$

$= 0.00916\ m^3$

$= 9.16$ litres

Density of water $= 1000\ kg/m^3$

$\therefore$ Mass of water $= 1000\ kg/m^3\ X 0.00916\ m^3$

$= 9.16$ kg

add mass of milk = 4.3 kg

add mass of milk tank $= \{[\Pi(0.33)^2 \times 0.425] - [\Pi(0.3)^2 \times 0.410]\} \times 2640$ kg

$= 77.88$ kg

Total mass = 91.34 kg

Total weight $= (91.34\ X 9.81)\ kgms^{-2}$

$= 896\ kgms^{-2}$ (N)

This weight acts on the base of the tank exerting a compressive stress

$= 896/(0.35)^2\ N/m^2$

$= 7{,}314\ N/m^2$

$= 7.3$ kPa

Mild steel will be used as the material for its malleability, availability and strength in use. The internal surface will be coated with pure aluminum to prevent corrosion of the milk steel surface. The thickness of the coating shall be 1mm. Mild steel has thermal conductivity of $45 Js^{-1} {}^{o}C^{-1}$ (Maxwell, 1972) and a compressive strength of 562 MPa (John, 1983). Mild steel sheets are commercially available in thickness 1mm, 2mm, 3mm and higher values. To ensure the ease of workability and still ensure structural stability, 3mm thickness shall be adopted. See Fig. 3.6

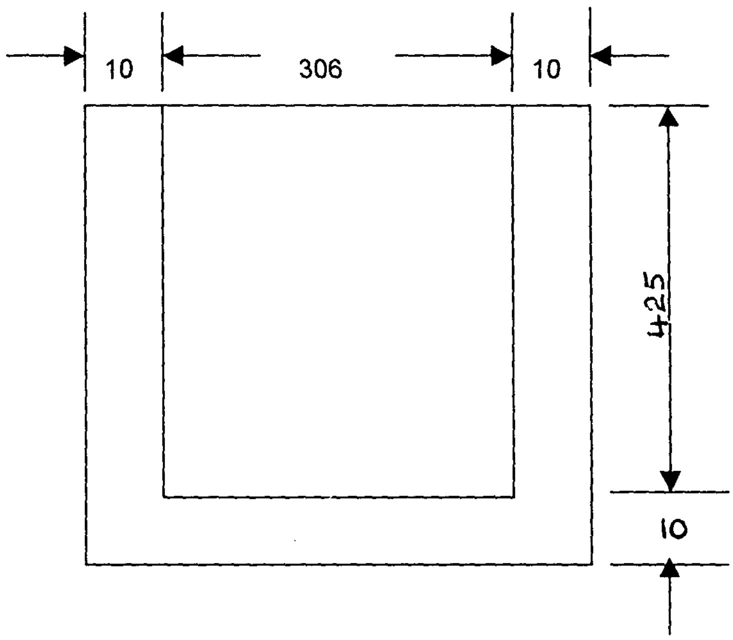


Fig. 3.6 Water Jacket-Milk tank configuration

From Fig 3.6, therefore

$h_i = (428 + 50)\text{mm}$

$= 478\text{mm}$

$= 0.478\text{m}$

$h_o = 478 + 1.5 \text{ mm} = 479.5\text{mm}$

The internal diameter $d_i = (306 + 20)$

$= 326\text{mm}$

The outer diameter $d_o = (326+6)\text{mm}$

$= 329\text{mm}$

3.3.3 DESIGN OF THE LAGGING COLUMN

The lagging column envelopes the water jacket. It is cylindrical in shape and has a top that flushes with the top of the milk tank and that of the water jacket. The outer wall of the water jacket forms the inner retaining wall for the lagging material.

From an earlier heat analysis expected heat loss rate is 867 J/s

For a circular path; using equation 3.8,

$Q = 867 \text{ W}$

$K = 0.027 \text{ w/m } ^oK$ (for sand)

$T_1 = 100\ ^oC$ (temperature of boiling water)

$T2 = 32\ ^oC$ (Expected external temperature)

$D_i = 310 \text{ mm}$

$= 0.310 \text{ m}$

$\therefore \quad \ln (D_o/D_i) = \{(2\Pi \times 0.027 \times 0.425)(100 - 32)\} / 867$

$= 0.287$

$D_o/D_i = e^{0.287}$

$= 1.33$

$\therefore \quad D_o = 1.33 \times 0.3 \text{ m}$

$= 0.3097 \text{ m}$

$= 309.7 \text{ mm}$

Thickness of lagging $= (D_o - D_i) / 2$

$= (309.7 - 300) /2 \text{ mm}$

$= 4.8 \text{ mm}$

$\cong 5\text{mm}$

A thickness of 10mm is adopted for the lagging (bottom and sides). Inferring from Fig. 3.4;

Volume of sand $V_s = [\Pi/4(0.351)^2 \times 0.01] + \Pi/4[(0.351)^2-(0.331)^2] \times 0.48$

$= 0.00611\ m^3$

Density of sand = 1,515 kg/m^3

Mass of sand = Density x Volume

= 1,515 x 0.00611 kg

= 9.25665 kg

Weight of sand = 9.25665 x9.81 kgm/s^2

= 90.8077365 kgm/s^2

The weight will be acting over an effective area, $A_{eff} = \Pi(0.351)2\ m^2 = 0.387\ m^2$

$\therefore$ Generated stress = 90.8077365/0.387 N/m^2

= 234.65N/m^2

$\cong$ 235Pa

This is below the compressive strength of mild steel that is adopted for this design.

Fine- grained sand has been chosen as the lagging material. Fine sand has thermal conductivity of $0.027JS^{-1o}C^{-1}$ (Incropera and Dewitt,1981).

3.3.4 DESIGN OF THE STIRRING UNIT

The stirring unit will consist of the stirring shaft, which shall carry spikes, and a driving motor.

(a) The Stirring Shaft

The stirring shaft shall be cylindrical in shape and shall have the configuration as on appendix C1 (No. 4).

To design the shaft, the diameter ***d*** of the shaft will be determined. The spikes will be arranged at right angles on the horizontal plane to ensure continuous stirring and they will be placed at a distance ***h*** from each other.

As stated earlier, number of turns n = 300rpm

$\therefore$ Angular speed, ω = 31.4rad/s

= 32 rad/s

For optimum condition, it is assumed that the cylinder will be filled to the brim at a particular instance.

Volume of milk = internal volume of milk tank

$= \Pi\ d^2\ h\ /4\ \ m^3$

$= \Pi\ (0.3)^2\ (0.425)\ /4\ m^3$

$= 0.03m^3$

Density of milk, ρ_m = 1.03kg/m^3

Mass of milk, $m_m = (1.03 \times 0.03)$ kg

$= 0.031$ Kg

Angular acceleration of milk in rotation

$$d\omega/dt = r\omega^2 \ ms^{-2}, \qquad 3.16, \text{ (Hannah \& Stephens,1972)}$$

where $r = 0.15$m

$\omega = 32$ rad/s

$\therefore d\omega/dt = (0.15)(32)^2 \ m^{-2}$

$= 153.6 \ ms^{-2}$

But Force = mass x acceleration

$$\text{i.e } \mathbf{F} = \mathbf{m \, d\omega/dt} \qquad 3.17$$

$= 0.031 \times 153.6$ N

$= 4.76$ N

This is the force that the rotating fluid will impact on the walls of cylinder. This also implies that the force to be impacted on the fluid must be a minimum of the above. Since two rotors (spikes) will be used, this force is assumed equally impacted by them. But for the purpose of computation, it is assumed that the force is applied by one rotor.

Length of rotor from central shaft, = 0.12m

Torque generated $T_c = 4.76 \times 0.12$ Nm

$= 0.57$ Nm

$$\text{Inertia torque on rotor 1, } \mathbf{T_{R1} = I_1\omega^2}\, \theta_1 \qquad 3.18$$

(Hannah and Stephens,1972)

where I_1 = moment of inertia of rotor 1, m^4

ω = angular speed in rad/s

θ_1 = twist on Rotor 1.

For an initial computation, it is advised to assume $\theta = 1$ rad. (Hannah and Stephens, 1972)

$$\text{and } \mathbf{I = \Pi d^4/ 64} \ m^4 \qquad 3.19 \text{ (Khurmi, 1981)}$$

Where d = diameter of the rotor.

Starting with a diameter,d = 8mm = 0.008m

$T_{R1} = (\Pi \times d_1^4 \times \omega^2 \times 1)/64$ N-m

$= (\Pi \times (0.008)^4 \times (32)^2/64$ N-m

$= 0.0021$N-m

Torque on Rotor 2, $\mathbf{T_{R2}} = \mathbf{T_1}\, \omega^2\, \theta_2$

$$\text{Here, } \theta_2 = [\theta_1 - (\omega^2 L_{1\text{-}2} /GJ)]\, I_1\theta_1, \qquad 3.20$$

(Hannah and Stephens, 1972)

Where,

θ_2 = twist on rotor 2

L_{1-2} = distance between Rotors 1 and 2, m

G = modulus of rigidity for rotor material, N/m^2

J = Polar moment for rotor material

Equation 3.22 can be reduced to

$$\theta_2 = \theta_1 - (\omega^2 L_{1-2} / 16G) \qquad 3.21$$

Alluminium will be used for both the rotors and the shaft due to their earlier stated suitability for use in food materials.

For aluminum, $G = 27 \times 10^9$ N/m^2

L_{1-2} = 20 cm (chosen)

= 0.2m

θ_2 = $1-[(32)^2(0.2)]/[16 \times 27 \times 10^9]$

= $1 - 4.74 \times 10^{-10}$

= 0.999999999

$T_{R2} = \prod d^4 / 64 \times \omega^2 \times 0.999999999$ N-m

$= \prod \times (0.008)^4 \times (32)^2 \times 0.999999999/64$ N-m

= 0.0021 Nm

These computations reveal that the inertia torque on the rotors, are insignificant.

Effective torque on central shaft T_c = 0.57 Nm.

Power transmitted by this torque,

$$\mathbf{P = T\omega} \qquad 3.22 \text{ (Hannah and Stephens,1972)}$$

P = 0.57 x 32 watts

= 18.24 watts

= 18.24 x 0.001341 hp

= 0.025 hp.

The diameter, D, of the central shaft is given by

$$\mathbf{D^3 = 16/S_s \sqrt{[(K_b M_b)^2 + (K_t M_t)^2]}} \qquad 3.23$$

(Hall et al,1961).

Where S_s = Shear stress, Pa

K_b = combined and fatigue factor applied to bending moment.

M_b = Bending moment, Nm

K_t = Combined shock and fatigue factor applied to torsional moment

M_t = Torsional moment, Nm

Since the shaft in this case will be rotating about the vertical axis, there will be no bending.

Therefore, Eqn. 3.25 reduces to

$$\mathbf{D^3 = 16/ S_s \sqrt{(K_t M_t)^2}} \qquad 3.24$$

S_s = 8000 psi for shaft without keyway (ASME Code Specification)

$S_s = 8000 \times 1/2.2 \times 1/(25.4)^2\ N/m^2$

$= 5.63\ N/m^2$

$= 5.63 \times 10^6\ N/m^2$

=5.63MPa

Similarly by ASME Code,

K_t = 1.5 to 3.0 for load suddenly applied with heavy shock.

K_t = 2.0 is chosen for this design

Similarly:

$$\mathbf{M_t = (hp \times 33{,}000 \times 12 \times 25.4)/(2\Pi \times rpm \times 1000)}\ N\text{-}m \qquad 3.25,\ \text{(Hall et al ,1981)}$$

$= (0.072 \times 33{,}000 \times 12 \times 25.4)/(2\Pi \times 300 \times 1000)$ Nm

= 0.33 N-m

Substituting into eqn. 3.23

$D^3 = (16/ \Pi \times 5.63 \times 10^6)\ [(2 \times 0.33)^2]^{1/2}$

$= 5.97 \times 10^{-7}\ m^3$

$D = (3\ \ 5.97 \times 10^{-7})^{1/3}$ m

= 0.008m

= 8mm

Diameter of main shaft = 8mm

This is the required minimum diameter of the central shaft. For this design therefore, a shaft diameter of 10mm shall be adopted. The power rating of the driving motor shall be above 0.025 hp.

A 0.1hp motor will be adopted for use. Under this condition, the expected twist on the main shaft shall be;

$$\theta = \mathbf{TL/JG} \qquad 3.26\ \text{(Spotts, 1963)}$$

Where, T = total torque on shaft

= 0.57Nm

L = total length of shaft

= 0.425 m

$J = \Pi d^4/32\ m^4 = (0.010)^4 /32\ \ m^4$

$= 9.82 \times 10^{-10}\ m^4$

$\theta = (0.57 \times 0.425)/(9.82 \times 10^{-10} \times 27 \times 10^9)$ rad.

= 0.009 rad

$= 0.52^\circ$

This is within acceptable limit.

For configuration, see Appendix C1

3.3.5 DESIGN OF THE TOP COVER

The top cover will be a circular disc with internal diameter slightly higher than the external diameter of the external casing. The clearance between the internal diameter and the external diameter of the outer casing will carry rubber band to serve as seal to both vapour leakage and heat. It will serve as a means of tight fitting of the cover. The top cover consists of a wider disc and a smaller disc, which will cover the milk tank and the water jacket. This will be replaceable. The two circular plates will sand-witch the lagging material of an earlier design thickness. For this, the discs will be made of mild steel of thickness 1.5mm. It will carry ports to allow refill of water to the water jacket, refill of milk and inoculation, and for the passage of the stirring shaft. The ports will be made to accommodate a ½" (=13mm) pipe piece. It will carry a thermal insulator.

Diameter of the external discs dc = 352 mm. For configuration, see Appendix C1.

A small hole of diameter 7mm is provided, for the entry of thermometer. A central hole of diameter 13mm will be provided to allow passage of stirring shaft. The stirring shaft will be held tight as it passes through a ¾" roller bearing which will be placed directly above the central hole.

3.3.6 DESIGN OF THE HEAT CONTROL SYSTEM

During incubation, the heat is expected to be kept at 45°C and held for three(3) hours. But as heat is a continuous flow process, a system is being devised that will trigger the heating device on when the temperature inside the yoghurt falls below 45°C and off when it rises above 45°C.

The system whose electronic diagram is shown on Fig. 3.8 will be used. The schematic diagram shows a temperature controller based on an integrated circuit (IC, LM335A) sensing element, a device whose output voltage changes with change in temperature. An operational amplifier LM741 configured as a comparator, compares the voltage of the adjustable reference divider R_i - V_{R2} - R_s with the output of the sensor, V_{out}. The reference voltage is set slightly below the sensor's output voltage at the desired temperature. i.e. $V_{ref} < V_{out}$ (desired temperature). At this jucture, the comparator, acting as an electronic switch is off. When the desired temperature is reached, $V_{out} > V_{ref}$, the Comparator is turned off. This in turn switches on the NPN power transistor TIP41 that drives the relay. The heating element will be connected to the normally closed terminal of the relay. Power is then supplied to the heating element when the relay is off, at $V_{out} < V_{ref}$. Power is cut off at $V_{out} > V_{ref}$.

The LM335 is a convenient 2-terminal temperature sensor that behaves like a Zener diode with a voltage of + 10m V/°K; e.g. at 25°C (298.2°K) it acts like a 2.982 Volt zener. It comes with an initial accuracy as good as 1°C and it can be externally trimmed. A single point calibration can typically improve its accuracy to 0.5°C maximum over a -55°C to + 125°C range. After trimming, the output could be accurate to 0.1°C at the test temperature with accuracy budget increasing to 0.5°C at the temperature extremes. Since at 25° C, V_{out} = 2.982V.

A 10mV-rise per °K will yield table 3.1 below:-

TABLE 3.1 Voltage Values On Thermal Changes

Temperature °C	°K	V_{out}	
25	298.2	2.982	
26	299.2	2.992	
27	300.2	3.002	
28	301.2	3.012	
29	302.2	3.022	
43	316.2	3.162	
44	317.2	3.172	
45	318.2	3.182	Desired.
|	|	|	
65	338.2	3.382	

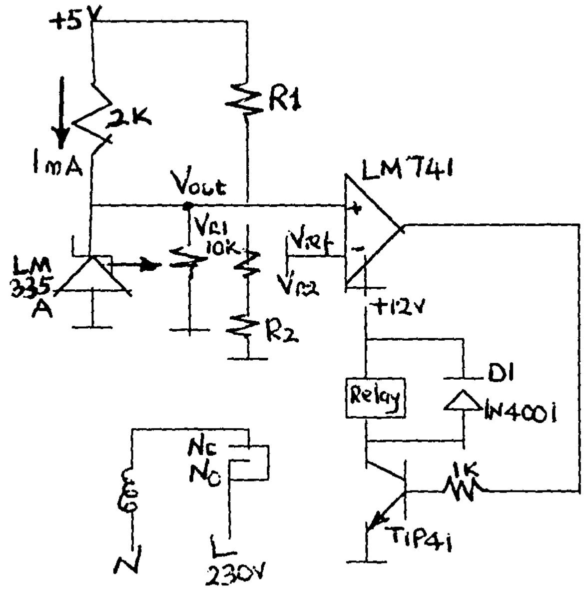


Fig 3.7 Circuit diagram for thermal regulator

3.3.7 DESIGN OF FLOW LINES

To conform with the already existing standard, aluminum pipes shall be used. The most critical variable here is to specify the diameter of the pipe.

Using Colebrook-White equation

$$\mathbf{V = -2\sqrt{2gDS_f}\ \log\{K_s/3.7D + 2.51\vartheta / D\sqrt{2gDS_f}\}} \qquad 3.27$$

A maximum distance l between tanks of 0.5m is chosen

g = 9.81, m/s^2

S_f = head slope

= (0.425 +0.05) / 0.5

= 0.95

K_s = roughness size

= 1.5×10^{-4} for galvanised iron

ϑ = Kinematic Viscosity of fluid

= dynamic Viscosity ÷ density

= 0.001 / 1.03 m^2/s

= 9.71×10^{-4} m^2/s

$\therefore V = -2\sqrt{18.64D}\ \log\{1.5 \times 10^{-4}/3.7D + (2.51 \times 9.71 \times 10^{-4}/D\sqrt{18.64D})\}$

By trial and error, starting with V = 0.2 m/s and increasing or decreasing by 0.01m/s and D = 0.01 m and increasing or decreasing by 0.001m, the values were computed to give the RHS ≅ LHS for the values of V and D as

V = 0.28 m/s

D = 0.011 m

= 11mm

From the above the nearest pipe size is of diameter 12.7 mm (i.e. ½"). So the diameter of the pipe is chosen as 12.7mm.

From continuity equation, the discharge

$$\mathbf{Q} = \mathbf{AV}\ m^3/s \qquad 3.28$$

Where

A = cross sectional area, m^2

V = Flow velocity, m/s

But $A = \prod D^2/4$, m^2

$$\therefore \mathbf{Q} = \mathbf{\prod D^2 V/4} \qquad 3.29$$

$= [\prod(12.7 \times 10^{-3})^2 \times 0.28] / 2\ m^3/s$

$= 7.1 \times 10^{-5}\ m^3/s$

The time it will take to empty the content of the tank = volume / discharge

= $0.025 / 7.1 \times 10^{-5}$ seconds

= 352 seconds

= 5.87 mins.

≅ 6 mins.

The line will be inter-connected using standard ½" elbows, Tees, and valves.

The outlay shall be as in Appendix C2

From this layout, the following flows will generate:-

First Flow:- Valves 1 and 4 will be opened while others are locked. Flow is through homogenizer to cooling tank.

Second Flow:- Valves 2 and 3 are opened while others are closed. Flow will be from cooling tank back into the pasteurizer.

Third Flow:- Valves 1, 4, and 5 will be opened while others are closed. Flow is from the pasteurizer to the cooling tank for final cooling.

Pump Selection

The critical issue here is to determine the power rating and head of the pump to be used. Estimated pressure head H = 1.13m.

Estimated longest run of pipe is in the second run (flow),

Length, L = 3.1m.

Table 3.2 below presents the number of appurtenances that will be used in each flow.

Table 3.2 Flow Appurtenances

Flow	Elbows	Tees	Valves	Entrants
1	5	4	2	1
2	4	2	2	-
3	7	2	4	-

Since the pump will pump in one line at a time, the ones with the highest number of appurtenances will be used in computing the inner losses

Therefore, 7Nos. of elbows will be used in computation, 4 nos. of Tees and 4 nos. of valves.

Minor losses are calculated in terms of equivalent lengths, Le, and

$$L_e = KD/f \qquad 3.30; \text{(Streeter \& Wylie, 1979)}$$

Where K = the head loss coefficients for the fittings

D = diameter of the pipe, m

f = roughness factor.

Since ½" pipe will be used, D = 12.7mm

$= 12.7 \times 10^{-3}$m

f = 0.005 for new pipes (Michael, 1978)

$$K = \sum K_i \qquad 3..31$$

$= K_{elbow} + K_{tee} + K_{valves} + K_{entrant}$

$= 8(0.9) + 4(1.8) + 4(0.19) + 1$

$= 16.16$

$L_e = (16.16 \times 12.7 \times 10^{-3})/0.005$ m

$= 41.05$ m

A factor of safety of 0.6m according to Michael (1978) will be adopted.

$\therefore L_e = (41.05 + 0.6)$ m

$= 41.65$ m

Head loss due to friction in pipe,

$$h_f = f\,(L/D)(V^2/2g) \qquad 3.32$$

But since $V = 4Q/\Pi D^2$ m/s

$V^2 = 16\ Q^4/\Pi^2 D^4$ m/s

$h_f = f(L/D)(16\ Q^2/\Pi^2 D^4 2g)$

$= 8f\,L\,Q^2/\Pi^2 D^5 g$ m

$= [8 \times 0.005 \times 3.1 \times (5.56 \times 10^{-4})^2\,]/[\Pi^2(12.5 \times 10^{-3})^5 \times 9.81]$ m

$= 1.20$ m

Total Head, $H_T = H + L_e + h_f$

$= (1.13 + 41.65 + 1.20)$ m

$= 43.98\text{ m} \cong 44$ m

Ideal head, H_i = Total head $\div$ Loss efficiency. With a loss efficiency of 80 %,

Ideal Head, $H_i = 44/0.8$ m $= 55$ m

But H_i = power/$\rho g Q$, m 3.33,(Chardwick & Morfett,1986)

Power $= H_i \times \rho g Q$

$= (55 \times 1.03 \times 9.81 \times 5.56 \times 10^{-4})$ hp

$= 0.31$ hp

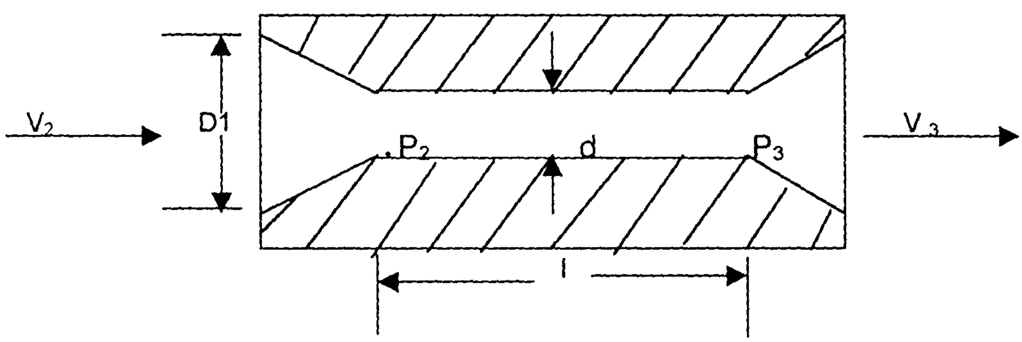
This is the power requirement for the pump.

A 0.5 hp pump will therefore be chosen for this design.

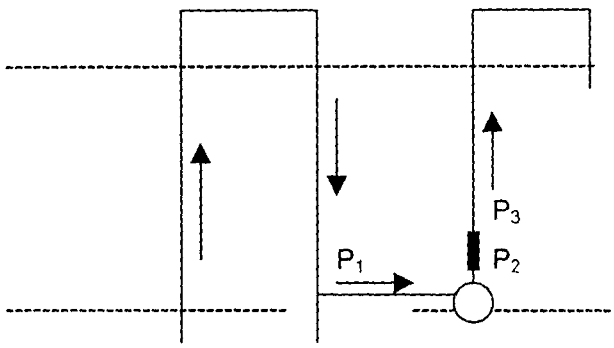
3.3.8 DESIGN OF THE HOMOGENIZER

The homogenizer shall be a circular duct in the form of an orifice whose diameter will be small enough as to allow the breaking down of the milk globules. A recommended pressure range of 160-180 kg/cm^2.

For this project, a pressure of 170kg/cm^2 will be used. This pressure will be provided by the pump. To generate the required pressure, two variables are responsible, the force impacted on the fluid and the cross sectional area of the bore through which it passes. The configuration will be as below.



The critical issue here is to determine the diameter ***d***. The length ***l*** is not significant in the homogenization of milk and as such it can be specified according to the designer's discretion. P_2 is the pressure after the pump and before the homogenizer. P_3 is the pressure after the homogenizer. From the concieved design, the pipe orientation will be as below:-



The suction level of the pump will be at the same level as the suction point of the pipe. Therefore P_1 = suction pressure = 0.

Needed pressure after pump; i,e, pump pressure = 170 kg/cm^2 (specified)

Reynold's number, $\mathbf{Re = VD\rho_m/\mu_g}$ 3.34

Where V = Velocity of flow m/s

= 0.28 m/s

D = diameter of conducting pipe, m

= 0.11 m

ρ_m = density of milk

= 1.03 kg/m^3

μ_g= viscosity

= 0.001 Ns/m^2

$\therefore$ Re = (0.28 x 0.11 x 1.03) / 0.001

= 31.7

Flow is laminar.

The basic friction factor Φ = $\mathbf{0.0396Re^{-0.25}}$ 3.35 (Lewis, 1990)

= 0.0167

Pressure head to be developed by the pump = height of elevation of discharge level from pump level.

$\therefore$ H = External height of milk tank + clearance between milk tank and inner base of water jacket + height of pipe above the tanks.

= (0.425 + 0.05 + 0.05) m

= 0.525 m

But $H = (P_3 - P_2) / \rho g$, m

$\therefore P_3 - P_2 = H\rho g$

$= (0.525 \times 1.03 \times 9.81)\ kgms^{-2}$

$= 5.31\ kgms^{-2}$

$= 5.31$ Pa

but $P_2 = 170\ kg/cm^2$

$= (170 \times 981) / 100\ kgms^{-2}$

$= 1667.7\ kgms^{-2}$

$P_3 = (1667.7 + 5.31)$ Pa

$= 1673.01$ Pa

Using Bernouli's equation

$$\mathbf{Z_1 + P_1/\rho g + V_1^2/2g = Z_2 + P_2/\rho g + V_2^2/2g} \qquad 3.36$$

From the above

$Z_2 - Z_1 + (P_2 - P_1)/\rho g = (V_2^2 - V_1^2)/2g$

But $(P_2 - P_1)/\rho g = 0.525$ m

i.e $0.525 = (V_2^2 - V_1^2)/2g$

$\therefore V_2 = \sqrt{(2 \times 9.81 \times 0.525) + 0.28^2}$ m/s

$= 3.2$ m/s

Similarly applying Bernouli's equation between 2 and 3

$Z_3 - Z_2 = 0.02$ m (chosen)

$P_3 - P_2 = 5.31$ Pa

$(P_3 - P_2)/\rho g = 0.525$ m

$\therefore (V_3^2 - V_2^2)/2g = 0.02 + 0.525 = 0.545$ m

$V_3 = \sqrt{2g(0.545) + 3.2^2}$

$= 4.6$ m/s

Shear stress developed $\mathbf{R_w = \Phi\rho V_2^2}$ 3.37

$= 0.0167 \times 1.03 \times 3.2^2$

$= 0.68$ Pa

Change in pressure across the homogenizer is related by

$$\mathbf{\Delta P = R_w l/d} \qquad 3.38 \text{ (Lewis, 1990)}$$

$\therefore d = 4R_w l/\Delta P$

$= (4 \times 0.68 \times 0.02)/5.31$ m

$= 0.010$ m

$=10$ mm

Diameter of the duct is chosen as 10 mm.

Alluminium shall be used as the material for the homogenizer. See Appendix C1

3.3.9 DESIGN OF THE COOLING TANK

The cooling tank shall have the same configuration as that of the milk tank and water jacket combined less the heating element.

All dimensions shall be as already calculated in 3.3.1 and 3.3.2. (See Appendix C1)

3.3.10 THE FRAME

The frame shall be made of 50mm x 50mm angle iron to carry the assembled components of the production line and the motor and the pump.

To keep the frame stable under vibration, the legs will be provided with means of fastening the frame to the ground.

CHAPTER FOUR

4.0 CONSTRUCTION, ASSEMBLY AND TESTING METHODOLOGIES

4.1 CONSTRUCTION METHODOLOGY

The construction of the parts and the assembly were done in a Central Mechanical Workshop. The parts drawings in appendix C were used for the construction. Materials and equipment used for the construction are as stated in Tables 4.1 and 4.2 respectively.

Table 4.1 Materials Used For The Construction

S/NO.	MATERIAL	SIZE SPECIFICATION	QUANTITY
1.	Alluminium moulds	-	2
2.	2mm mild steel sheets	1828 x 1219mm	1
3.	Alluminium rods	20mm Diameter	2
4.	Alluminium rods	10mm Diameter	8
5.	Angle iron	1 Inch	Item
6.	Sand	medium grained	Item
7.	Pipe (galvanised)	½" dia (internal)	1.2m
8.	Welding Electrodes	Gauge 12	2 pkts
9.	Brazing Rods		6

Table 4.2 Equipment Used For Construction

S/no	Equipment Specification	Rating (kW)
1	Grinding Machine	1.80
2	Centre Drill	2.24
3	Lathe Machine	7.90
4	Hand Drilling Machine	1.80
5	Welding Machine	3.00

4.1.1 Construction Of The Milk Tanks

These tanks were designed to have equal dimensions. The specified material (aluminum) could not be got in commercial sizes. Thus, the tanks were cast out. Prior to the casting, the pattern was prepared, to the specified sizes and the moulding was done after the aluminum materials were melted on a local furnace. The two cylinders were later surfaced on the lathe machine to give the internal surface smooth finishing which is required for milk processing. The final thickness of the cylinder walls was 3mm as specified in the design.

4.1.2 Construction of the Water Jackets and Lagging Column

Two pieces of mild steel plates of sizes 1022 x 440mm (for the water jacket), and 1 piece of size 1103 x 456mm (for the lagging casing), were cut out. They were then folded into a cylindrical shape using the mechanical folder and metal folding aids. The cylinders were welded along the lines of closure to form the complete cylinders.

Similarly, two circular plates of diameters 329mm were cut out of a large plate. Metal scribers were used to mark out the circles from punched centres. A third plate of diameter 352mm was cut out in the same manner. The plates were welded to the base of the cylinders to close one end on each. Six pieces of metal bars of sizes 20 x 20 x 10mm were cut out and welded to predetermined positions on the two similar cylinders to form the bottom rests for the cylinders. The inner positions were coated with aluminum to prevent rusting due to water presence. A circular ring plate was cut out as in Appendix C1 to form the top flange for the milk pasteurizing/incubating unit.

The Milk tank covers were fabricated from mild steel sheets of thickness 2mm. The plates were cut into two discs of diameter 306 mm and two of diameters 326mm. Two plates were used to cover each tank. The two plates sand-witched the lagging material. Drilling through the steel plates as indicated on the design drawing, provided other provisions for the suction pipes and the stirring rods. Two rods of diameter 10mm, with internal holes of diameter 6mm, were welded to provide a through-fare for the thermometer and to fortify the plates. The plates were guided by mild- steel- plate- strips of lengths 943mm and width of 2mm to hold the two plates into a piece. The inner parts of the tank covers were coated with aluminium paint.

4.1.3 Construction of the Agitators

Galvanized steel rods of diameter 10mm were used for these. The shafts were faced on the lathe to give a smooth surface. The spikes were also made from the same galvanized steel rods. They were cut to the required lengths of 120mm each and welded to the shafts. To provide room for proper coupling of the motor to the shafts, a circular disc plate of diameter 15mm was welded to the top of the shaft and the coupler. A hole was made on the coupler to provide means of coupling the shaft.

4.1.4 **Construction of the Pipeline**

The pipe used for the pipeline and networks were cut into the required sizes. Both ends of each piece were diced using the pipe- dicing machine. This is to enable the pieces to be coupled along the line. Bends were maintained at 90° by using the 90° elbows.

4.1.5 **Construction of the Homogenizer**

The homogenizer was fabricated from an aluminium rod of diameter 200mm. The lathe machine was used to bring out the required shape as indicated on the parts drawing.

4.1.6 **Construction of the Frame**

Mild steel 1inch angle iron and square pipes were used for the frame. The component pieces were cut to length using the hacksaw, and the pieces were welded to each other at the appropriate positions to give the skeletal frame for the system. The drawing in Appendix C1 was used as a guide for all measurements.

4.1.7 **Construction of the Heating Control Device**

The circuit diagram on Fig.3.8 was used. The various components were soldered to the appropriate positions on the Printed Circuit Board (PCB) to give a 'Mother Board' for the control system.

4.2 ASSEMBLY OF THE MACHINE

The constructed component parts of the machine were assembled into units together with the used non-fabricated parts. The non-fabricated parts are the commercially available standard parts. These are:-

i) 1No. 2000W heating element
ii) 1No. 0.5hp centrifugal pump
iii) 1No. 100W-240V, a.c. Motor
iv) 5Nos. ½" Tee couplers
v) 6Nos. ½" one way gate valves
vi) 1No. Dimming Switch
vii) 1No. Control Switch
viii) 5 Nos. Sockets
ix) 6 Nos. 90° elbows
x) 5 Nos. ½" Union Connectors
xi) 10 Nos. ½" nipples

The heating element was mounted on a ring plate and the plate was glued to the water tank in such a way that it is below the milk tank. The "∩" shape created at the base of the water jacket - lagging column assembly provides the port for plugging on the heating element to the source.

The various components; milk tank, water jacket, lagging column, heating element, and top covers, formed the unit called the "Primary Unit". In this Unit, pasteurization, inoculation and incubation of the milk takes place. The other milk tank was mounted in the water jacket with the top covers and the discharge outlet to form the "Secondary Unit". The pipe network was mounted in the place. This network incorporates the pump and the homogenizer. The pipes were connected serially incorporating the appurtenances in position. These three segments were mounted on the frame and fastened to position. The motors were fastened to the top flange on the frame. This makes it easy to couple with the stirring shafts. The temperature sensor was fixed and passed through to the milk tank. It was connected to the control panel at the appropriate port. All the wiring for current flow were done by using a single 2.5mm core flexible cables. With all the components fixed, the entire machine was anchored to the ground ready for testing. For assembly drawings, see appendix C2. The pictorial drawing of the assembled machine is as on appendix C3.

4.3 TESTING METHODOLOGY

The assembled machine was passed through both subjective and objective tests. Subjectively, the machine was tested by dry running it. This was to ensure that all the connections made were correct. The machine was plugged to the mains and the a.c. source was put on, after water had been passed through to the water jacket. The temperature was set at 38°C.

The control system, the heating system, the pump and the motors were confirmed to be operational. The machine was further subjected to an objective test to ascertain the degree of functionality and performance of the units and the system as a whole. The objective test was carried as reported below:-

<u>Materials</u>

1. 25 liters of fresh milk
2. 3 packets of powdered milk
3. Water (varied volume)
4. Starter culture
5. 3.5kg of sugar

<u>Equipment</u>

The fabricated yoghurt production system.

Procedure

The test was carried out as follows:-

i) The machine was washed thoroughly to remove dirt and stains.

ii) A sample of the milk to be used was collected in sterilized bottles for bacterial count analysis.

iii) A measured volume of fresh milk (or of milk slurry), V_m, was poured into the milk tank and the top cover placed and the coupling to motor was done.

iv) Six liters of water was passed through the port to the jacket.

v) The thermal regulator was set to 65°C and a thermometer was inserted to record temperatures, T_a.

vi) The machine was plugged to the mains, the source switched on, and the heater button was pressed on.

vii) The motor switch was put on and turned to rotate the stirrer slowly. This was left until the control switched off. At this point, the temperature reading on the thermometer, T_a and the time it takes to reach that temperature, t_x were recorded.

viii) The system was left for 30 minutes; the heater switch was still on. After this time the heater was turned off and the motor turned to increase the speed of rotation for 2 minutes.

ix) The water in the water jacket was drained out and cold water was passed through, to cool the milk. At the end, another sample "B" of the pasteurized milk was taken in a sterilized bottle for bacterial count analysis.

x) The conducting valves through the homogenizer were opened while the others were left closed and the pump switch was put on. Milk flowed through the homogenizer to the detention tank.

xi) The conducting valves from the detention tank through the pump to the primary unit were opened while the others were locked and the pump was put on to transfer the homogenized milk back to the primary milk tank for incubation.

xii) 2mg of starter culture and 20g of sugar were mixed in warm water and introduced to the milk through the port to the milk tank. The heater switch was put on and the motor was turned on to stir slowly for one minute only to evenly distribute the starter culture in the milk substrate. The mixture was left for 3 hours (incubation period).

xiii) After 3 hours, the heater was put off, the valves conducting flow to the cooling tank were opened, while the others were closed and the pump was powered on to transfer the yoghurt to the cooling tank.

xiv) Cold water was passed through the water jacket of the cooling tank for 15 minutes while stirring instantaneously to allow it to cool.

xv) A sample "C" was further collected for physical chemical and biological analyses on the produced yoghurt.

xvi) The samples A, B and C were analysed in the Laboratory for the followings:-

a) pH

b) Density

c) Colour

d) Bacterial count

e) Quality characteristics

xvii) i - xvi above were repeated for two other samples of fresh milk and two samples of prepared slurry from powdered milk on subsequent days. The results are as on Table 5.1.

At the end of each production, the top covers to the milk tanks were removed and the milk tanks were washed and rinsed to prepare it for the next production.

4.4 SPECIFIC TESTS

Samples A, B, C were tested specifically as follows, but each sample was tested for the variables at a time.

4.4.1 pH Determination

i) A quantity of each sample was placed in a container

ii) The pH meter was dipped into a buffer solution and left for 5 minutes to cleanse the nipples.

iii) The terminal nipple was placed in a separate sample of the substrate to be tested and left for five minutes.

iv) The meter was then place on the solution; and it was allowed to stabilize and the pH was measured.

v) This was repeated for the other samples and the subsequent tests. See Table 5.2 for results.

4.4.2 Density Determination

This was determined using the fundamental measuring approach as follows:-

i) An empty measuring cylindrical glass was washed, rinsed and dried.

ii) The cylinder was measured for mass, m_1.

iii) 100ml of each sample was poured into the glass and measured again (sample & glass) as M_2.

iv) This was repeated for other samples.

See Table 5.3 for results.

4.4.3 Colour Evaluation

These tests were subjectively carried out. See Table 5.5 for observations.

4.4.4 Quality Evaluation

These tests were carried out for sample C only (yoghurt produced) for taste and smell in the following manner:-

i) A scoring questionnaire as on Appendix 'A' was prepared for use.

ii) 120ml of three samples were prepared as follows:-

Sample 'A' - yoghurt produced by an organized factory

Sample 'B' - yoghurt produced by a local producer

Sample 'C' - yoghurt produced by the fabricated machine.

iii) 100 ml of each sample was placed in 12 small clean glass containers.

iv) The three samples were served to twelve Judges to taste and smell and score according to the prepared questionnaire.

v) The samples were presented in the following order to allow a particular pair to be served twice (for two sets of six Judges)

ABC, ACB, BAC, BCA, CAB, CBA.

By this, two Judges will test a pair.

vi) This was repeated for the other productions. Sample A was collected from a specific factory (Northern Dairy, Kaduna while samples B were collected from five different local producers. These results are as on Table 5.6.

4.4.5 Bacterial Count Test

This test was carried out for two samples each.

Sample 'A' - Raw Milk or slurry

Sample 'B' - Pasteurized milk using the fabricated machine

Representative samples were collected for each analysis. The following procedure was followed:-

i) The sterile plate agar (tryptone glucose extract agar) was melted and cooled to 43°C.

ii) The agar was poured into the sterile petri plates and allowed to solidify.

iii) The plates were then incubated at 27°C and left overnight (this was done on the eve of the anticipated test date).

iv) 10ml aliquot of the sample was taken and mixed thoroughly.

v) The sample was passed over the stylus on the spiral platter and was switched on to distribute the sample over the surface of the agar and the plates were further incubated for 24 hours at 27°.

vi) On the following day, the plates were removed from the incubators, cooled in a desicator and placed on the platter

vii) The laser colony counter was switched on to count the number of Colony Forming Units (CFU) per gram. This was recorded for the sample.

viii) The plates were rinsed and cleaned.

ix) Steps i - vii were repeated for three specimens each, of both samples A and B for five productions. See Table 5.9 for results.

CHAPTER FIVE

5.0 RESULTS and DISCUSSIONS

5.1 RESULTS

5.1.1 Production Tests

Having finished the assembly it was necessary to carry out test to determine if the machine could produce yoghurt or not. Results of the Production Tests is presented on Table 5.1

Table 5.1 Result of production tests

Test Number	Type of Slurry	Volume Treated (l)	Heating Time (t) mins	Thermometer Reading (oC)	Total Production Time (hrs)
1	Raw milk	12.5	20.0	68.0	4.6
2	"	12.5	21.0	66.0	4.5
3	"	25.0	43.0	66.0	5.3
4	Powdered Milk	12.5	21.5	67.5	4.8
5	"	12.5	20.5	67.0	4.8

Calculation

Average heating time = [2(20+21+21.5+20.5)+43]/5 mins.

= 209/5 min

= 41.8 mins

Average thermometer reading = (68.0+66.0+66.0+67.5+67)/5 ^{o}C

= 66.9^{o}C.

From the calculations, proceeding Table 5.1, it was seen that the system took an average of 41.8 minutes to raise the temperature of the milk to the desired value of 65 ^{o}C. This is against a theoretical time of 20.9 minutes. This higher time taken to heat is an indication of the level of heat loss through the materials and the openings. According to Incropera and DeWitt (1981); under the effect of temperature rise, there sets in the tendency for thermal equilibrium. To achieve this, heat is lost from a region of higher concentration to a region of lower concentration provided there is a port of escape. In this system, perfect closure was not achieved due to constructional errors. This was brought about by the use of equipment and tools that have either lost their use or are no longer preferred in the practice of modern technology.

Thermometer readings were higher than the anticipated pasteurising temperature of 65°C. This is still save for pasteurisation since temperatures up to 90°C are allowed for pasteurisation.

The higher temperature however indicates the level of sensitivity of the temperature control device. The temperature control efficiency of the control device. The difference between the thermometer reading and that of the thermal-regulator can be attributed to:-

i) deterioration of the material used for temperature sensing.

ii) error in the calibration of the equipment.

iii) reduction in thermal sensitivity of the nipples.

iv) errors in rating during the design.

These collectively, could allow more temperature to be taken in before the gauge temperature is reached. This is a property of heat sensing materials, (Haberman and John, 1989; Welty,1978)

$E_{TC} = \{1 - [66.9 - 64]/64.0\} \times 100$

$= 1 - 0.045] \times 100$

$= 0.955 \times 100$

$= 95.5\%$

This reduction in accuracy could be due to the sizing of the components used in the design of the device and it is due to expected losses in the thermal conductivity of conducting material.

5.12.1 pH Determination

The purpose of determining the pH is to confirm that yoghurt has been produced; since for yoghurt pH values are expected to be below 5.1. Table 5.2 presents the result of the tests.

TABLE 5.2 Results of pH determination

Production/ Test No. *	Raw Milk(A) (untreated)		Pasteurised Milk (B)		Produced Yoghurt (C)	
	PH	Temp (°C)	PH	Temp (°C)	pH	Temp (°C)
1	6.2	25	6.5	29	4.1	20
2	5.9	30	7.3	30	4.5	18
3	6.3	28	6.5	31	4.8	22
4	6.6	27	6.8	32	4.4	15
5	6.8	25	6.8	31	5.1	18

*1-3 are raw milk slurry, while 4 & 5 are from powdered milk slurry.

Milk, in its natural state is expected to have pH of 6.6 to 6.7, (Artherton and Newlander, 1987). It could be seen that only one of the samples has pH within this range. This could be explained as due to the time between collection and analysis which could result in the decrease in the pH i.e. it makes it more acidic. The temperature variation between the point of collection and point of analysis could affect the pH of the milk, since the pH of milk is largely dependent on temperature (Shankuntala and Shadaksharaswamy, 1986).

The pH of the produced yoghurt conforms with what is expected. In addition, the processing time and the introduction of biological and chemical agents such as the starter and sugar could alter the pH levels as indicated. The third and fifth productions however may not be able to check the growth of bacteria as much as others. In other words they will deteriorate faster (under natural conditions) than the others. In the production of yoghurt, the temperature variation must be watched. This is because as a result of the phosphates, citrates and proteins in milk, it becomes sour (i.e. acidic) when allowed to change temperature for a wide range of time.

5.1.3 Density Determination

Table 5.3 Results of density determination

No Production.	Raw Milk (A)		Pasteurised Milk (B)		Produced Yoghurt (C)	
	M1 (g)	M2 (g)	M1 (g)	M2 (g)	M1 (g)	M2 (g)
1	5.5	5.60	5.5	5.60	5.5	5.63
2	5.5	5.59	5.5	5.60	5.5	5.64
3	5.5	5.66	5.5	5.68	5.5	5.69
4	5.5	5.61	5.5	5.62	5.5	5.65
5	5.5	5.56	5.5	5.60	5.5	5.67

Calculations

Volume, V = 100ml

$= 100/1000$ liters $= 0.1$ liters

$= 1 \times 10^{-4} m^3$

Mass of liquid in container = $M_2 - M_1$

and density, ρ = Mass/Volume

Therefore:- for the first values

$\rho_A = [\ (M_2 - M_1) \times 1000]/1 \times 10^{-4}\ kg/m^3$

$= M_2 - M_1/0.1\ kg/m^3$

$= 5.60 - 5.5/0.1\ = 1.00 kg/m^3$

This was repeated for all the other values and the calculated values are as presented on Table 5.4.

Table 5.4 Calculated densities

Production No.	DENSITIES kg/m^3		
	Raw Milk (A)	Pasteurised Milk (B)	Produced yoghurt (C)
1	1.00	1.30	1.30
2	0.90	1.02	1.40
3	1.60	1.80	1.90
4	1.10	1.20	1.50
5	0.60	1.00	1.70

The densities of the raw samples were close in value to the theoretical value of 1.03kg/m^3. The change in density due to processing could be linked with partial coagulation during incubation. More so, since the added starter culture is a collection of bacteria, they will grow in a substrate such as milk; especially under the incubating temperatures of 45°C. The growth in bacteria and the resultant massive growth in milk solid constituent will increase the mass per unit volume. As could be seen from table 5.4, the densities of processed milk were higher than the densities for raw milk. This, according to Ihekoronye and Ngoddy (1985), Mohsenin (1970), and many other commentators personally interviewed, could be attributed to liberation of gases that are originally present in the milk, but which, as a result of temperature change, escape from milk thereby leaving more mass of solid material per unit volume. These values however remain to be verified and validated.

5.1.4 Colour Test

Table 5.5 presents the subjective evaluation of the Products.

Table 5.5 Colour evaluation

Production No.	COLOUR		
	Raw Milk (A)	Pasteurised Milk (B)	Produced Yoghurt (C)
1	Egg white	Dirty White	Dirty White
2	"	"	"
3	"	"	"
4	Dirty White	"	"
5	"	"	"

Not much can be said about the observed colour since these were subjectively evaluated. However, the change in colour from its expected bluish-white could, like other changes, be attributed to temperature change. As a result of temperature change, certain contents of milk are broken down chemically. This could alter the colour in milk that is being processed. The whitish colour in yoghurt is due to homogenization effects

5.1.5 Quality Evaluation

The scoring given by the 12 Judges are as in Table 5.6

Table 5.6 Result of scoring on quality evaluations.

JUDGE NUMBER	SCORES		
	A	B	C
1	4	2	4
2	3	3	3
3	3	1	4
4	4	1	3
5	4	2	2
6	4	0	4
7	2	2	3
8	3	2	2
9	1	0	3
10	3	2	3
11	3	4	3
12	3	2	2

Analysis of Variance

To perform the ANOVA, the scoring (using the Duncan multiple range test) is totaled as shown in Table 5.7.

Table 5.7 Scoring summation

JUDGE NUMBER	SCORES Sample A	Sample B	Sample C	TOTAL (T)
1	3	2	4	9
2	3	3	3	9
3	3	0	4	7
4	4	1	4	9
5	4	2	2	8
6	4	0	4	8
7	2	2	3	7
8	3	2	2	7
9	1	0	3	4
10	3	2	3	8
11	3	4	3	10
12	3	2	2	7
TOTAL=	36	23	34	93
MEAN=	3.00	1.92	2.83	

Correction factor, CF= T^2 / Number of Judgements

$= (93)^2/36$

$= 240.25$

Sum of squares, samples, SS_s $= (36^2 + 23^2 + 24^2)/12 - CF$

$= 2981/12 - 240.25$

$= 8.17$

Sum of squares, judges, SS_j $= (9^2 + 7^2 + 9^2 + \ldots\ldots + 10^2 + 7^2)3 - CF$

$= 747/3 - 240.25$

$= 249 - 240.25$

$= 8.75$

Sum of squares, totals, SS_t $= (4^2+3^2+3^2+4^2+\ldots\ldots+3^2+2^2) - CF$

$= 286 - 240.25$

$= 27.75$

Table 5.8 ANOVA table

Sources of Variation	df	ss	ms	F
Samples	2	8.17	4.09	8.35**
Judges	11	8.75	0.80	1.63
Error	22	10.83	0.49	
Total	35	27.75		

Variance ratio, F = Ms(samples)/Ms(Error)

Therefore:- F_{sample} = 4.09/0.49

= 8.35

F_{judges} = 0.80/0.48 = 1.63

From Appendix B1, any value of **F** in excess of 3.44 has significant difference at 5% level and if it exceeds 5.72, it has significant difference at 1% level for degrees of freedom 22 against 2. The **F** value for Judges therefore, has no significant difference. To find which of the samples is significantly different, the standard error is determined

$SE = \sqrt{MS_{Error}}$/No. of Judges

$= \sqrt{[0.49/12]}$

= 0.20

From Appendix B2, the significant studentised value for three treatments against 22 degree of freedom is 3.56.

	A	B	C
Sample scores are			
	36	23	34
The mean values are	3.00	1.92	2.83

Arranging the means according to magnitudes, we have

A	C	B
3.0	2.83	1.92

Least Significant Difference (LSD) = 3.56 x 0.2

= 0.71

If the difference between any two samples is greater than the LSD, then they are significantly different. Comparing;

A to C = 3.0 - 2.83 = 0.17 < 0.71

A to B = 3.0 - 1.92 = 1.08 > 0.71

C to B = 2.83 - 1.92 = 0.91 > 0.71

A	C	B
3.0a	2.83 a	1.92 b

From the ANOVA carried out above, it could be seen that sample A is not significantly different from sample C, but both samples A and C are significantly different from sample B. This implies that though sample A is industrially produced and rated better than sample C, they could be interchangeably used. Thus, the yoghurt produced by this machine is acceptable to the consumers.

5.1.6 Bacterial Count Test

Table 5.9 presents the viable counts as read by the spiral platter for the samples

Table 5.9 Plate counts

Production Number	CFU Per gramme					
	A1	A2	A3	B1	B2	B3
1	16756	16762	16754	922	920	920
2	20050	19870	19990	834	836	832
3	12335	12338	12334	605	600	600
4	14440	14442	14400	862	868	866
5	18012	18006	18006	784	784	783

Calculation

Average count for A, A_v = (A1+A2+A3)/3

B_{av} = (B1 + B2 + B3)/3

From the table above, for the first production

A_{av} = (16,756 + 16,762 + 16,754)/3 = 16,757

B_{av} = (722 + 720 + 720)/3 = 721

This was repeated for the other counts. The average counts are as presented on Table 5.10.

Table 5.10 Average plate counts

Production No.	CFU PER GRAMME		Per cent in sample B
	Sample A	Sample B	
1	16757	921	5.5
2	19970	834	4.2
3	12336	602	4.9
4	14428	866	6.0
5	18008	784	4.4

The standard limit set for milk products is that not more than 5 per cent of the original population should be present after pasteurisation (Handerson, 1971). From Table 5.10 above, it could be seen that three of the productions had less than 5 percent. For the other two having above 5 percent, they could possibly have been contaminated during sampling. Contact between milk and the handler and the handling material gives room for contamination. Contamination of the yoghurt could also be achieved during testing. On the average, the machine could be said to have pasteurised effectively.

5.2 Project Costing

The costing of the system can be broken down into:-

a) Material cost b) Energy cost c) Labour cost d) Logistic costs

e) Operational cost.

5.2.1 Material Cost

The costs of the materials used are as tabulated on Table 5.11.

Table 5.11 Material costing

S/no	Material Specification	Size	Qty	Unit Cost(₦)	Total Cost(₦)
1	Pattern Materials	-	Item	1,200	1,200
2	Aluminium Chips	-	6Kg	400	2,400
3	Mild Steel Sheet	G16	1	1,700	1,700
4	Angle Iron	1¼"	3m	120	360
5	Square Pipe	1"	7.5m	50	375
6	Galvanized Pipe	½"	2m	150	300
7	Gate Valve	"	6	120	720
8	Tee Couplers	"	6	20	120
9	Bolts and Nuts	M10	12	15	180
10	Pipe bushing	1"x½"	2	90	180
11	Electric Motor	100W	2	800	1,600
12	Pump	0.5hp	1	3,500	3,500
13	Heating Element	2kW	1	200	200
14	Core Cable	2.5mm	2m	40	80
15	13 A Plug		1	50	50
16	Thermo-detector		1m	75	75
17	Thermostat Knob		1	50	50
18	Electronic Components		item	230	230
19	Body Filler		item	200	200
20	Aluminium Paint		4 tins	130	520
21	Welding Electrodes	G12	4 pkts.	180	720
22	Tap Head	½"	1	120	120
23	Grinding Stone		2	250	500
24	Hacksaw Blades	1"	2	60	120
25	Dimming Switch		1	200	200
26	1" Bearings		2	75	150
27	Bearing Housing		2	45	90
28	Starter Switch		1	250	250
29	90° Elbows	½"	6	25	150
30	Sockets	½"	6	20	120
31	Galvanized steel rods	10mm	2	250	500
32	Union Connectors	½"	5	50	250
TOTAL=					17,310

5.2.2 Energy Cost

The energy consuming equipment used are listed on Table 5.12 below.

Table 5.12 Equipment and Energy Usage

S/ No	Equipment	Rating (kW)	Hours Used	Total Energy Consumed(kWh)
1	Lathe Machine	7.90	2	15.80
2	Center Drill	2.24	¾	1.68
3	Welding M/c	3.00	6	18.00
4	Grinding M/c	1.80	1	1.80
5	Hand Drill	1.80	½	0.90
			TOTAL=	38.18

Average electricity charge = ₦2.37/kW(NEPA)

Therefore energy charge = 38.18 x ₦2.37

= ₦90.50

5.2.3 Labour Cost

Labour charge per artisan per day = ₦250.00

Number of artisans hired = 3

Number of days worked = 6

Total Labour cost = ₦250 x 3 x 6

= ₦4,500.00

5.2.4 Logistic Cost

A total of ₦740 was spent on local running during the fabrication of the machine.

Therefore, the cost of fabricating the machine = material cost (a) + Energy cost(b) + Labour cost(c) + Logistic cost(d)

= ₦ 22,640.50

Add 10% miscellaneous cost =₦ 2,264.05

Grant total cost = ₦ 24,904.55

5.2.5 Operational Cost

The cost of running the machine can be estimated using the Power consumption estimates as on Table 5.13 below:-

Table 5.13 Running energy consumption

S/ No.	Equipment	Rating (W)	Time of Use(hrs)	Power Consumption(Wh)
1	Pump(0.5hp)	373	0.25	93.25
2	Motor	100	1.00	100.00
3	Heating Element	2000	2.50	5000.00
TOTAL=				5,193.25

Add 50% for delayed running, fluctuation in equipment rating etc.

Therefore, total power consumption estimate = (1.5 x 5,193.25)/1000 kWh

= 7.79kWh

Charge per kWh = ₦2.37 (NEPA, 1999)

Maximum running cost = 7.79 x ₦2.37/ kWh

= ₦18.46

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

A cottage yoghurt production equipment has been designed, fabricated and tested. The equipment produced yoghurt. The capacity was 25 liters of yoghurt per batch. The equipment could pasteurise raw milk at 66.9 ^{o} C resulting in yoghurt with pH value between 4.1 and 5.1; densities ranging from 1.30 to 1.90 kg/m^3. The yoghurt production line is an improvement over the existing local method of producing yoghurt. The tests have revealed that the machine works successfully. The yoghurt from the machine was favourably compared with that from an established Industry.

The running cost is less than ₦20 per batch of production. It is believed that subsequent modifications on this system will increase its production efficiency and reduce the cost of production. The human contact with raw milk during processing is reduced. With further modifications, it could be eliminated. From the tests carried out, the followings were discovered:-

6.1.1 Production Capability

It was ascertained that yoghurt could be produced, using the fabricated system. Higher heating time and pasteurising temperature than expected were however observed.

6.1.2 Yoghurt pH

While the pH values for the raw milk, in agreement with literature provisions, show slightly acidic state, those for yoghurt were highly acidic. This also is as expected. It was discovered that, since absolute control of temperature changes could not be achieved; the acidity of yoghurt may go beyond expected values. It is therefore pertinent to have absolute control over temperature.

6.1.3 Density of milk and yoghurt

This test revealed that within pasteurising temperatures of 63 – 90 ^{o}C, gases such as carbon-dioxide are given off thus reducing de-oxygenation of the milk and blood. This loss results in higher mass, which invariably results in higher densities after milk is processed.

6.1.4 Pasteurisation and Incubation

The system was found to be able to reduce bacterial content to less than the 5 percent recommended limit. Due to high rate of heat loss however, perfect incubation will be achieved at the expense of energy consumption.

6.1.5 Cost of the System

Relatively, the estimated production cost of the system is within average reach. Further modifications could reduce the cost of the system. If the milk tanks, pipes, and appurtenances are to be of stainless steel material, then a higher should be expected.

6.2 RECOMMENDATIONS

To further improve this system, the followings are recommended:-

i) Cast iron should be used as the enveloping cylinder

ii) All the parts having contact with the milk should be replaced with stainless steel materials

iii) The fabrication of the temperature detecting and control system should be

iv) Placement and removal of the milk tanks should be made easier. This can be achieved by repositioning the suction pipes, drop pipes, and thermal regulator.

v) Fibre glass should be used as the insulating material.

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Appendix A

QUALITY ASSESMENT OF PRODUCED YOGHURT
QUESTIONAIRE FOR SCORING

Judge's Number _______

Judge's name ___________________________ Date______________

a) Evaluate the three samples presented to you for taste and smell.
b) Score each sample according to your perception of acceptability based on the taste and smell as below:-

0 - Objectionable taste
1 - Tracely accepted
2 - Slightly acceptable
3 - Acceptable
4 - Very much accepted
5 - Extremely sweet taste

A = B = C =

General comments

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Appendix B1

Variance ratio – 5 per cent points for distribution of F

n_1 – degrees of freedom for numerator
n_2 – degrees of freedom for denominator

n_2 \ n_1	1	2	3	4	5	6	8	12	24	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	249.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.45	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.84	8.74	8.64	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.77	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.53	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.84	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.41	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.12	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.90	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.74	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.61	2.40
12	4.75	3.88	3.49	3.26	3.11	3.00	2.85	2.69	2.50	2.30
13	4.67	3.80	3.41	3.18	3.02	2.92	2.77	2.60	2.42	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.35	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.29	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.24	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.19	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.15	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.11	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.45	2.28	2.08	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.42	2.25	2.05	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.03	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.38	2.20	2.00	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	1.98	1.73
25	4.24	3.38	2.99	2.76	2.60	2.49	2.34	2.16	1.96	1.71
26	4.22	3.37	2.98	2.74	2.59	2.47	2.32	2.15	1.95	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.30	2.13	1.93	1.67
28	4.20	3.34	2.95	2.71	2.56	2.44	2.29	2.12	1.91	1.65
29	4.18	3.33	2.93	2.70	2.54	2.43	2.28	2.10	1.90	1.64
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.89	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.79	1.51
60	4.00	3.15	2.76	2.52	2.37	2.25	2.10	1.92	1.70	1.39
120	3.92	3.07	2.68	2.45	2.29	2.17	2.02	1.83	1.61	1.25
∞	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.52	1.00

Variance ratio – 1 per cent point for distribution of F

n_1 – degrees of freedom for numerator
n_2 – degrees of freedom for denominator

n_2 \ n_1	1	2	3	4	5	6	8	12	24	∞
1	4052	4999	5403	5625	5764	5859	5981	6106	6234	6366
2	98.49	99.00	99.17	99.25	99.30	99.33	99.36	99.42	99.46	99.50
3	34.12	30.81	29.46	28.71	28.24	27.91	27.49	27.05	26.60	26.12
4	21.20	18.00	16.69	15.98	15.52	15.21	14.80	14.37	13.93	13.46
5	16.26	13.27	12.06	11.39	10.97	10.67	10.29	9.89	9.47	9.02
6	13.74	10.92	9.78	9.15	8.75	8.47	8.10	7.72	7.31	6.88
7	12.25	9.55	8.45	7.85	7.46	7.19	6.84	6.47	6.07	5.65
8	11.26	8.65	7.59	7.01	6.63	6.37	6.03	5.67	5.28	4.86
9	10.56	8.02	6.99	6.42	6.06	5.80	5.47	5.11	4.73	4.31
10	10.04	7.56	6.55	5.99	5.64	5.39	5.06	4.71	4.33	3.91
11	9.65	7.20	6.22	5.67	5.32	5.07	4.74	4.40	4.02	3.60
12	9.33	6.93	5.95	5.41	5.06	4.82	4.50	4.16	3.78	3.36
13	9.07	6.70	5.74	5.20	4.86	4.62	4.30	3.96	3.59	3.16
14	8.86	6.51	5.56	5.03	4.69	4.46	4.14	3.80	3.43	3.00
15	8.68	6.36	5.42	4.89	4.56	4.32	4.00	3.67	3.29	2.87
16	8.53	6.23	5.29	4.77	4.44	4.20	3.89	3.55	3.18	2.75
17	8.40	6.11	5.18	4.67	4.34	4.10	3.79	3.45	3.08	2.65
18	8.28	6.01	5.09	4.58	4.25	4.01	3.71	3.37	3.00	2.57
19	8.18	5.93	5.01	4.50	4.17	3.94	3.63	3.30	2.92	2.49
20	8.10	5.85	4.94	4.43	4.10	3.87	3.56	3.23	2.86	2.42
21	8.02	5.78	4.87	4.37	4.04	3.81	3.51	3.17	2.80	2.36
22	7.94	5.72	4.82	4.31	3.99	3.76	3.45	3.12	2.75	2.31
23	7.88	5.66	4.76	4.26	3.94	3.71	3.41	3.07	2.70	2.26
24	7.82	5.61	4.72	4.22	3.90	3.67	3.36	3.03	2.66	2.21
25	7.77	5.57	4.68	4.18	3.86	3.63	3.32	2.99	2.62	2.17
26	7.72	5.53	4.64	4.14	3.82	3.59	3.29	2.96	2.58	2.13
27	7.68	5.49	4.60	4.11	3.78	3.56	3.26	2.93	2.55	2.10
28	7.64	5.45	4.57	4.07	3.75	3.53	3.23	2.90	2.52	2.06
29	7.60	5.42	4.54	4.04	3.73	3.50	3.20	2.87	2.49	2.03
30	7.56	5.39	4.51	4.02	3.70	3.47	3.17	2.84	2.47	2.01
40	7.31	5.18	4.31	3.83	3.51	3.29	2.99	2.66	2.29	1.80
60	7.08	4.98	4.13	3.65	3.34	3.12	2.82	2.50	2.12	1.60
120	6.85	4.79	3.95	3.48	3.17	2.96	2.66	2.34	1.95	1.38
∞	6.64	4.60	3.78	3.32	3.02	2.80	2.51	2.18	1.79	1.00

Appendix B2

Triangle test, difference analysis

Number of tasters	Number of correct answers necessary to establish level of significance			Number of tasters	Number of correct answers necessary to establish level of significance		
	* 5%	** 1%	*** 0.1%		* 5%	** 1%	*** 0.1%
7	5	6	7	57	27	29	31
8	6	7	8	58	27	29	32
9	6	7	8	59	27	30	32
10	7	8	9	60	28	30	33
11	7	8	9	61	28	30	33
12	8	9	10	62	28	31	33
13	8	9	10	63	29	31	34
14	9	10	11	64	29	32	34
15	9	10	12	65	30	32	35
16	10	11	12	66	30	32	35
17	10	11	13	67	30	33	36
18	10	12	13	68	31	33	36
19	11	12	14	69	31	34	36
20	11	13	14	70	32	34	37
21	12	13	15	71	32	34	37
22	12	14	15	72	32	35	38
23	13	14	16	73	33	35	38
24	13	14	16	74	33	36	39
25	13	15	17	75	34	36	39
26	14	15	17	76	34	36	39
27	14	16	18	77	34	37	40
28	15	16	18	78	35	37	40
29	15	17	19	79	35	38	41
30	16	17	19	80	35	38	41
31	16	18	19	81	36	38	41
32	16	18	20	82	36	39	42
33	17	19	20	83	37	39	42
34	17	19	21	84	37	40	43
35	18	19	21	85	37	40	43
36	18	20	22	86	38	40	44
37	18	20	22	87	38	41	44
38	19	21	23	88	39	41	44
39	19	21	23	89	39	42	45
40	20	22	24	90	39	42	45
41	20	22	24	91	40	42	46
42	21	22	25	92	40	43	46
43	21	23	25	93	40	43	46
44	21	23	25	94	41	44	47
45	22	24	26	95	41	44	47
46	22	24	26	96	42	44	48
47	23	25	27	97	42	45	48
48	23	25	27	98	42	45	49
49	23	25	28	99	43	46	49
50	24	26	28	100	43	46	49
51	24	26	29	200	80	84	89
52	25	27	29	300	117	122	127
53	25	27	29	400	152	158	165
54	25	27	30	500	188	194	202
55	26	28	30	1000	363	372	383
56	26	28	31	2000	709	722	737

Source: Laboratory Methods for Sensory Evaluation of Foods 'Agriculture' Canada, Ottawa. Publication 1937