DESIGN AND PROTOTYPE DEVELOPMENT OF A CENTRIFUGAL CREAM/SKIM MILK SEPARATOR

BY

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AUGUST 2003

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PGD PROJECT REPORT

Submitted To The
Department Of Agricultural Engineering, School of Engineering and Engineering Technology,
Federal University of Technology Minna-Niger State
In Partial Fulfillment of The Requirements
For The Award Of Postgraduate Diploma in
Agricultural Engineering (Farm Power & Machinery Option)

AUGUST 2003

APPROVAL PAGE

This is to certify that this project is an original work undertaken by Umar Mohammed Maradun (PGD/AGE/2000/2001/113) and have been prepared in accordance with the regulations governing the preparation and presentation of project in the School of Engineering and Engineering Technology, Federal University of Technology Minna – Niger State.

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DEDICATION

To my late father Mallam Muhammad Maradun

ACKNOWLEDGEMENT

I wish to express my profound gratitude to all those who contributed in one way or the other to the success of this project. I am particularly indebted to my supervisor. Dr. B..A. Alabadan for his unprejudiced Criticism and encouragement.

I equally wish to recognize the encouragement and invaluable assistance accorded by Dr. (Engr) A. Ajisegiri of the Department of Agricultural Engineering FUT Minna, Eng'r E.C. Nwalor, S.E. Umar, and Dahiru Mohammed all of the Dept. of Agricultural Engineering, Kaduna Polytechnic.

Finally, it is extremely necessary to register my heart-felt appreciation to my friends, colleagues, associates and countless individuals who have in one way or the other been instrumental to the actualization of this project.

Umar Mohammed Maradun.

ABSTRACT

A prototype centrifugal cream/skim milk separator was developed to separate the two products from wholemilk. The separation was done under centrifugal action by subjecting the milk contained in a rotating bowl with a speed of 2920 rpm for four minutes.

The difference in density between cream and the skim milk is the key factor in centrifugal separation.

The rotating bowl has a capacity of $0.013m^3$, which revolves for four minutes for the separation to occur.

The bowl is enclosed in a cylinder casing that contained lagging material welded in it so as to aid in preventing heat loss to the surrounding for effective separation.

After separation, the products are then discharged through outlets at the bottom of the bowl which are to be kept closed while the machine is in operation.

After the test with 0.9kg of whole milk repeated four times, the average mass of the cream obtained was 0.018kg and 0.877kg for the skim milk.

The throughput efficiency of the machine was found to be 44%.

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CHAPTER ONE

1.0 INTRODUCTION

Milk and milk products form a most important part of the human dietary. Milk is considered as the nature's most nearly perfect food, being deficient only in iron. As such, it is an excellent food for raising the young of any species.

There is a lack of appropriate technical packages for both milk production and processing in the developing countries. Available technologies are often inappropriate to African conditions as they are capital intensive, import- dependent and do not take account of local constraints. Walshe (1990), stated that undue reliance has been placed on transferring technology rather than generating it within Africa – the extent of adaptive research that is needed in a continent with such a wide range of agro ecological conditions and farming systems has been under estimated. There has been under investment in adaptive research in livestock projects by comparison with other agricultural project.

Cream/skim milk separation is an operation carried out in the dairy industry with the purpose of separating cream and skim milk from whole milk.
Several methods are available for the separation, but the one of concern here is the mechanical method. Efficient separation of the butter fat from milk is an important matter, and a small loss of cream is serious.

Centrifugal separation accomplishes in a few minutes a separation which is more efficient and time saving than can possibly be achieved by any method relying on the force of gravity alone. The whole milk is rotated at a high speed in a steel bowl, and the heavier element (skim milk) pass to the periphery, leaving the lighter cream near the centre.

Milk for direct human consumption and for manufacturing milk products is obtained from many kinds of domestic livestock, but it is estimated that approximately 90% of the world's total supply is produced by various breeds of domestic cattle (Williamson and Payne, 1987)

1.1.0 AIM AND OBJECTIVES OF THE STUDY

1.1.1 AIM

The project is aimed at design and construction of a prototype centrifugal cream/skim milk separator that will help in improving the economic standard of our small scale dairy farmers and the nation as a whole.

1.1.2 OBJECTIVES

- The objective of the study is to design and construct a prototype centrifugal machine to separate whole milk into cream and skim milk and
- To determine the performance efficiency of the machine.

1.2 JUSTIFICATION

Milk is perishable, has a relatively short shelf life and an ideal product for bacterial growth. It must therefore, be carefully handled both during production and while processing.

Milk separation is one of the steps in processing of fluid milk through which skim milk and cream are obtained. Other products like ice-cream, cheese, Whey, Butter and yoghurt are post separation products which increases the shelf life of the milk.

Several attempts have been made to improve on milk separating process. This project has not been left out in such attempts.

There is therefore, the need to design a simple and inexpensive machine that can be afforded by the individual households to carry out the task of separating the products from whole milk.

1.3 SCOPE OF THE STUDY

The scope of this project will involve the design and development of a prototype centrifugal milk separator and testing of the machine to separate cream and skim milk from a whole milk.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 COMPOSITION OF MILK

Buchheim and Dejmek (1990), stated that gross composition of milk varies considerably among different species, and further variation is caused by genetic variants within species, age, nutritional status, lactation stage etc. All milks seem to contain lactose, tryglycerides, and a range of milk typical proteins, including phosphorus and calcium carrying casein. The major proteins of cow milk are categorized into whey protein and caseins. The composition of milk from different animals is given in appendix 'A'.

Another typical analyses of milk of different breeds of cow as given by Barrett (1979), is shown in appendix 'B'.

2.2 PHYSICAL PROPERTIES OF MILK

Milk, of a complex chemical nature due to its various constituents, also has a complicated physical properties. Milk exists in three general states of dispersion (i.e. coarse, colloidal and molecular dispersion) influenced by its particle diameters. (Eckles et al 1993)

2.3 CHEMICAL REACTION OF MILK

Milk when freshly drawn from the cow, shows an amphoteric reaction (i.e it turns red litmus blue). Normal fresh milk has a hydrogen-ion concentration of approximately pH 6.5 to 6.6 (i.e slightly acidic). The acidity of fresh milk is due to certain constituents of milk some of which give an acid reaction and some of which actually combine with the alkali. The acidity of fresh milk is due to the phosphates of milk, the protein and slight degree of carbon dioxide and citrates. (Eckles et al 1993).

SPECIFIC GRAVITY AND FREEZING POINT OF MILK

Eckles et al (1993), referred to milk as a complex colloidal system in which the dispersion medium, water contains salts and sugar in solution making it to be heavier than water. The specific gravity of milk is averagely 1.032 at 15.5^0C. The specific gravity of milk is influenced by the relation of its constituents, each of which has a different specific gravity, approximately as follows: Fat 0.93, Lactose, 1.666, proteins 1.346, casein 1.31, salts, 4.12.

The average specific gravity of the milk solids other than fat as given by various authorities range from 1.6007 to 1.638. Milk reaches its maximum specific gravity at temperature of -0.55^0C, the freezing point. As milk fat (cream) is the lightest constituent of milk, the more it is present, the lower the specific gravity will be. The lactometer is used to determine the specific gravity of milk by measuring the volume of known weight. Determination is done after atleast an hour after milking because of the air and carbon dioxide contained in the fresh milk.

TASTE AND ODOUR OF MILK

Normal fresh whole milk tastes slightly sweet and has characteristics although non-pronounced odour. The odour disappears when milk is allowed to stand a few hours or following cooling and aeration immediately after milking. A variety of abnormal tastes and odours may be found. Eckles et al (1993) gave the following as the sources of these abnormal tastes and odours:

i. Due to disturbed physical condition of the cow
ii. From the feed of the cow
iii. From the absorption of pronounced odours to which milk is exposed
iv. From the decomposition of the milk constituents resulting from the growth of bacteria and other microorganisms
v. From foreign material actually present in the milk
vi. From changes due to chemical action

THE COLOUR OF MILK

Milk ranges in colour from a bluish – white to a golden – yellow, depending upon the breed of animal, the kind of feed, and the amount of fat and solids present. In large quantities, milk appears entirely opaque while in thin layers it is slightly transparent. Skim milk, or milk which is low in fat percentage, shows a bluish tint. (Eckles et al 1993)

SPECIFIC HEAT OF MILK

Milk has a specific heat of 0.938 at 15^0C, of 0.920 at 40^0C. Various milk products have different specific heat due to their difference in chemical composition. At 15^0C the specific heat of whey is 0.976, of skim milk, 0.943; 15% cream, 0.923; 20% cream, 0.940; Butter, 0.527; and milk fat, 0.467 (i.e as the fat content increase the specific heat also increase. (Eckles et al, 1993)

The specific heat of milk is important in measuring the cost of heating and cooling milk and milk products.

BOILING POINT OF MILK

Milk is influenced by heating in several different ways. Should milk be slightly high in acid, it will curdle or coagulate when boiled.

Eckles et al (1993), stated that milk is slightly heavier than water and boils at a temperature slightly above that of water. Milk boils averagely at temperature of 100.17^0C. The boiling point of 100.6^0C is given by (Hall, 1979).

Other effect of heat on milk is on its flavour and odour, the viscosity and the fat. When heated to temperatures near the boiling point, milk acquires a pronounced cooked taste and a familiar kitchen odour. The fats globules tend to form in cluster when milk is heated.

VISCOSITY OF MILK

The viscosity of a fluid is its resistance to flow, agitation, or shear. Normal milk is said to have a viscosity of 0.001 Ns/m^2 at 25^0C. All liquids appear more viscous at low than at high temperatures. Milk is no exception to this rule (Hall 1979).

When milk is subjected to temperatures such as those reached under pressure, an increase in the viscosity of milk results. When milk is subjected to prolonged agitation the viscosity is reduced. Aging, souring, and the development of certain types of bacteria in milk are responsible for an increase in viscosity. It is conceded, generally that the increase in viscosity is due to the changes taking place in the proteins of milk, primarily casein, which has hydrophilic properties similar to other proteins (Eckles et al, 1993).

ADHESIVENESS OF MILK

Milk posses adhesive properties due to the casein of milk, which is used in rather large quantities in the manufacture of casein glue, one of the strongest glues made.

EFFECT OF ENZYMES ON MILK

Milk is subject to many changes. The complexity of its composition makes it subject to the action of all types of enzymes which are either present in it at the time of production, or produced by microorganisms which find milk an excellent medium in which they may grow. Eckles et al (1993) stated that the proteins, fat, and sugar of milk may be decomposed completely by the action of enzymes. Many off-flavours, which occur in milk and its products, are linked with the formation of certain enzymes in milk.

2.4 CREAM/SKIM MILK SEPARATION FROM WHOLE MILK

When the milk fat is concentrated into a fraction of the whole milk, that portion is referred to as CREAM. The remaining fraction of the whole milk (less the portion of the cream fraction) is SKIM MILK (or serum). Cream is separated for several purposes. The most important is to obtain a product from which butter may be

churned more economically than from whole milk. Cream also provides a richer product than milk for table use or for certain manufacturing purposes, more especially for ice cream making. (Eckles et al, 1993).

Culpin (1992) added that efficient separation of the butter fat from milk is an important matter, for the total fat is normally around 4%, and a small loss of cream is serious.

2.4.1 BASIC PRINCIPLE OF SEPARATION

As the title suggests, skim milk/cream separation, according to Svarovsky (1999), involves separation of the two phases, from a suspension with the aim of recovering both the cream and the skim milk.

Separation of cream from milk is said to be possible because of a difference in specific gravity between the fat and the liquid portion or serum. (Eckles et al 1993).

Whether separation is accomplished by gravity or centrifugal methods, the result is dependent upon this difference. When milk is allowed to stand, the force of gravity affects both skim milk and cream, exerting a downward pull on each which is proportional to its specific gravity. As the skim milk is heavier, it assumes a position below the cream. When the cream (in the form of globules) rises to the surface, the globules maintain their identity at the temperatures below their melting points preventing the formation of a layer of cream. When milk is revolved swiftly in a device like a separator bowl, where the generated centrifugal force is about one thousand times greater than that of gravity, the milk is thrown to the outside of the arc through which it is traveling. The greater force is exerted on the one of greater specific gravity. The skim milk, therefore, is forced to the outer periphery of the bowl, causing the formation of two layers, skim milk outside and closely crowded fat globules interspersed with some skim milk inside. Leading these two layers out from the bowl through different outlets completes separation. (Eckles et al 1993).

2.4.2 TRADITIONAL METHOD OF CREAM/SKIM MILK SEPARATION

Information gathered through oral interview with some of our local cattle rearers on the method of skim milk/cream separation from whole milk seems to be in conformity with what Eckles et al (1993) referred to as "gravity creaming" which include the shallow-pan and the Deep-setting methods. These methods are still practiced where small quantities of milk are produced or the conditions of butter making still are quite primitive. The only difference between the two is that one uses a shallow pan while the other one uses a deep cans.

The milk is poured into the pans immediately after milking while still warm, and the pans are placed preferable in a moderate temperature environment. The separation is accomplished by gravity. The skimming is done at the end of 24 to 36 hours, at which time the cream will rise on top. The milk below the cream usually is coagulated. The cream is removed with a tin "Skimmer". After skimming, our local farmers will then collect the cream with still some percentage of skim milk in a guard and vigorously shake it. At the end of this the two contents will separate.

2.4.3 THE WATER DILUTION METHOD

This method was found on the supposition that the addition of water to whole milk would lower the viscosity so that the cream could rise more readily. A special tank fitted at the bottom with a drain faucet, above which was a strip of glass giving a view of the contents of the tank, was commonly used. Separation is accomplished after about twelve hours, the skim milk – water mixture was drained through the facet until the cream was seen nearly to reach the drain. The cream then was caught in a separate container. Eckles et al (1993) said that this method failed as separation of fat was not complete and the skim milk watered in this manner was neither so palatable nor so valuable for food as ordinary skim milk.

2.5 CENTRIFUGAL SEPARATION

In centrifugal separation, the components of a mixture (in this case cream and skim milk) are separated mechanically by accelerating the material in a centrifugal field

which operates on the mixture in the same manner as a gravitational field (Othmer 1967). The centrifugal field however, can be varied as required by changes in rotational speed or dimensions of the equipment where as gravity is essential constant. Culpin (1997) added that the centrifugal separation accomplishes in a few minutes a separation which is much more efficient than can possibly be achieved by any method relying on the force of gravity alone.

Leung (1197), categorized centrifuges for the separation of solids from liquids to be of two general types.

(i) Sedimenting centrifuges, which requires a different in density of the two phases as in cream and skim milk (solid-liquid or liquid-liquid) and

(ii) Filtering centrifuges (for solid-liquid separation), in which the solid phase is retrained by the filter medium through which the liquid phase is free to pass.

2.5.1 COMPARISON OF METHODS OF MECHANICAL SEPARATION

Several fundamentally different methods which usually overlap in only certain areas, were given by Othmer (1967) by which mechanical separations may be accomplished. He sighted an example of the methods used in the separation of immiscible liquid mixtures containing only small quantities of solid material. The alternative methods may include gravity or centrifugal settling, electrical coalescence, or coalescing filters.

The one that is more appropriate for separation of liquid-liquid-solid mixtures containing appreciable solids, such as greater than 0.5%, is gravity or centrifugation equipment that accomplish the three phase separation in one step or may just reduce the solid content sufficiently to complete the operation as a subsequent liquid-liquid separation.

Othmer (1967) further explained that in application requiring separation of appreciable quantities of solids from liquid, alternative or complimentary methods may include screening, vacuum or pressure or centrifugal filtration, flotation, gravity or centrifugal thickening or separation, as well as more specialized methods such as electrostatic or magnetic separation. One or more of these methods may overlap in many areas of application. Screening gives relatively incomplete separation of the components based on particles size and it is particularly valuable for high tonnages where sizes exceed 40 mesh. Centrifugal filtration is often applied to batch production of fine-slow draining solids, but it is more particularly adapted to handling medium to coarse particles where fair to good washing is required and a very low residual liquid content is necessary. Centrifugal separation by density difference, as opposed to liquid drainage, is adapted to collection and classification of very fine to medium size solid particles in concentrations ranging from very low to medium as well as compressible gelatinous, and amorphous materials that characteristically plug drainage media. Gravity settling is most suitable for relatively large volume flows containing low concentration of solids whose settling rate exceed about 1×10^{-3}cm/sec. Froth flotation can clarify fine dispersions of liquids or solid particles, particularly where the density difference between continuous and dispersed phases is small and the flow volume large. Separation by selective froth flotation and snik-float system is common practice in ore dressing.

2.6 THEORY OF CENTRIFUGAL SEPARATION

Centrifugal separation relies on two physical principles to accomplish its intended purpose, depending upon the type of equipment used. One type, characterized by the solid wall bowl, achieves separation by making use of the difference in density between materials to be separated. The other typified by the perforate basket, follows the principles of drainage of a liquid phase through a packed bed or cake of solid particles (Othmer 1967).

This project utilizes the first principle.

2.7 EARLY DEVELOPMENT OF CENTRIFUGAL SEPARATION

According to Eckles et al (1993), the first application of centrifugal force in removing fat from milk seems to have been made in 1959, when Fuchs, of Germany, whirled milk in test tubes. Fuchs, however, was interested in this method as a means of determining the fat content of milk, not as a means of creaming. His work was followed, in 1860, with a similar study by Fesca of Berlin. The first attempt to substitute centrifugal force for gravity in the creaming of milk was made by Prandtl, of Munich, Germany, in 1864. Prandtl's machine consisted simply of a vertical axis capable of being rotated, on which was mounted a crossbar carrying a bucket at each end. The milk was placed in these buckets and subjected to vigorous rotation, after which the machine was stopped and the cream skimmed off. In 1870, Bond, of Massachusetts, attached two glass jars on a spindle, which could be revolved at 200 r.p.m. By this means, he secured cream from milk within a few minutes. In 1873, Jensen, of Denmark, had a somewhat similar device revolving two buckets at 400 r.p.m.

An advance towards the development of the modern machine was contributed by Moser, of Austria, in 1872, instead of whirling the milk in buckets, his machine used hollow cylinders which were revolved on their own vertical axis. This device was improved and enlarged in 1874 by Lefeldt, of Germany, with a view to adapting it for use in creameries. He used a large drum revolving at 800 r.p.m. With this machine, 100kg of milk were placed in the drum and full speed attained in 5 to 10 minutes. It required 20 or 30 minutes to effect complete separation after full speed was gained and 25 or 30 minutes more for the drum to stop rotating. When the milk has resumed its horizontal position, the cream floated in a heavy layer on top. The skim milk was removed with a siphon and the cream through a valve at the bottom. It was later in 1877 improved by devising a tube, which removed the cream while the machine was in motion. This was accomplished by introducing the tube in such a position that it would remove the cream as it crowded toward the centre of the drum. The skim milk, however, could not be removed while the machine was in motion.

Eckles et al (1993) futher explained that the first continous separator is said to have been invented by Prandtl in 1875, but this device was not adopted for practical use. That of practical importance appeared almost simultaneously in Sweden, Denmark, and Germany in 1879. It is doubtful if any one person may be credited with being the first to invent a continuously operating separator. It is certain that the experiments of Prandtl, Moser, and Lefeldt were important contributions to the invention, and while due credit should be accorded the inventors of the successful machines, it must be recognized that their machines were the result of combining the earlier ideas of pioneers in the same field, and adding certain features necessary to make the machines practical.

The early separators were hollow-bowl machines. The next material advance in construction was made by the De Laval Company, and consisted of adding inside fixtures, or discs, to the bowls. These were known as the "Alpha discs", and the first De Laval machines equipped with these discs were known as the "Alpha Laval". This improvement, coming in 1890 or 1891, increased the efficiency of separation, and, at the same time, permitted reduction in the size of the bowl without interfering with the capacity of the machine. Since that time, various minor improvements have been made, but the present day machines are built to operate on the principles recognized by the early workers already mentioned.

2.8.1 CONSTRUCTION OF THE CENTRIFUGAL SEPARATOR

The modern cream separator consists of a bowl which can be rotated at high speed by means of suitable gears, and arrangements for supplying milk to the bowl and removing the cream and skim milk. The chief parts of the bowl are the shell, the inside fixtures, and the spindle which supports the weight and by means of which the rotation is accomplished. The remainder of the machine is essentially a set of gears so arranged as to make possible the twinning of the spindle on which the bowl is carried at a high speed. When the bowl is supported from the bottom, two bearing are necessary, one to support the weight, and the second to maintain the upright position. The upper bearing is generally fitted inside a spring in order that

the bearing may adjust itself and maintain the bowl in an upright condition even though the frame of the machine is not exactly level. In a few models the bowl is suspended which makes necessary the use of only one bearing and insures the freedom of the bowl at all times to operate in a perpendicular position (Eckles et al 1993).

If the separator has been in operation for some time, separator slime will be found adhering to the wall of the bowl. Next in order comes a layer of skim milk, which at the inner edge of the upright wall of fluid the fat globules are packed closely together forming cream. This gathering of the cream near the centre of the bowl according to Eckles et al (1993) is the first and most important step in centrifugal separation. All that remains is to lead the two layers out of the bowl without remixing. The separate removal of these two layers is accomplished by establishing two outlets at proper distances from the axis of the bowl, one of which connects with the cream layer in the bowl, the other with the outer edge of the bowl where the skim milk with the lowest fat content is found. The connection between the skim-milk layer and the skim milk outlet is made possible by a device called the "dividing disc". Fig. 2.8, shown below illustrates how the discs functions.

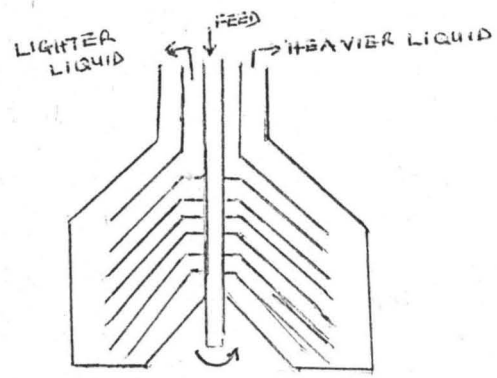


Fig. 2.8 Liquid centrifuges

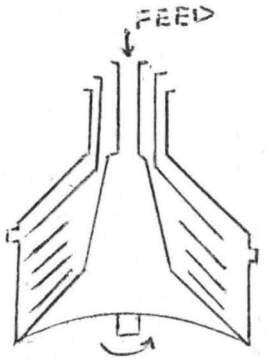


Fig. 2.8b conical bowl nozzle

The skim milk from near the outer edge of the bowl cavity moves between the dividing disc and the inside shell of the bowl. At the top of the disc the space between it and the shell of the bowl connects with a slot in the neck of the bowl. This slot is the skim-milk outlet. The skim-milk which comes from the outlet with

some force is gathered in the "skim-milk pan" from which it flows through the spout provided for that purpose. A second outlet, located on the neck of the bowl above the skim-milk outlet, connects with the inner side of the dividing disc and serves to conduct the cream from the bowl into the cream pan. The skim-milk outlet has a capacity much in excess of that of the cream outlet. The two are so located, however, that when the separator is receiving a normal in flow of milk a portion will discharge from each outlet. The cream outlet opens from a point of removal than is the skim milk. As a result of its location and capacity, the skim-milk outlet removes from 75 to 90 percent of the total in flow, the remainder coming from the cream outlet.

But according to Eckles et al (1993), various arrangements are used to accomplish the effective collection and with minimum of disturbance to the flow pattern in the machine. In liquid separation centrifuges, they indicated that conical plates are arranged which gives smoother flow and better separation .

Solids phases removal present much more of a problem from a centrifuge. Stationary ploughs cannot be used as these create too much disturbance of the flow pattern on which the centrifuge depends for its separation. One method of handling solids is to provide nozzles on the circumference of the centrifuge bowl which may be opened at intervals or continuously to discharge accumulated solids together with some of the heavier liquid.

2.9 CONTROL OF RICHNESS OF THE CREAM

Eckles et al (1993) explained that every separator is equipped with a device for regulating the fat content of the cream. This consists of a means for moving either the cream or the skim-milk outlet toward or further from the axis of the bowl, or for closing off a part of the opening at the same time that it is moved nearer the centre. This device, when attached to the cream opening is known as a "cream screw", and when attached to the skim-milk opening, is known as "skim-milk screw". When the cream screw is moved nearer to the centre of the bowl, the centrifugal force

Temperature of the milk: When all other factors are kept constant, an increase in the temperature of the milk to be separated causes a decrease in the fat percentage and vice-versa. Eckles et al (1993). They further added that with certain machines, the separation of milk at extremely low temperatures results in a decrease of fat percentage in the cream rather than the increase that might be expected normally. This is due to the clogging of the bowl with the cold cream which adheres to the inside fixtures of the bowl. Cold cream does not flow so readily as warm cream, and therefore, less liquid is permitted to pass through the cream opening when cold. Culpin, (1992), indicated that separation should commenced while the milk is still warm, as it is then easier and more efficient than at temperatures below 30^0C otherwise it should be heated to 32^0C. But Scott (1989), wrote that, modern methods of cream production involve preheating milk to about 50^0C followed by centrifugal separation to the desired fat content.

Richness of Milk: In the case of most separators the richness of the milk exercises a direct influence upon the fat percentage of cream skimmed form it. The effect is more pronounced with some separators than with others, due to the difference in bowl construction. The effect of the fat percentage of the milk upon the richness of the cream is explained by the fact that the separator bowl is so constructed as to deliver from the cream outlet a rather definite proportion of the inflow regardless of the richness of the milk. If the same quantity of cream is secured from two lots of milk having the same weight but different fat contents, it is clear that the cream from the richer milk will contain the more fat.

Rate of inflow: If the rate of inflow of milk into a separator bowl is markedly altered, a change in the fat content of the resulting cream is to be expected. When other conditions remain constant, a reduction of inflow causes an increase in the percentage of fat in the resulting cream Eckles et al (1993).

operating at this outlet is decreased, due to a reduction in the circle through which it whirls. At the same time, the opening is moved nearer to the inside of the wall of liquid being centrifuged.

Michael and Ojha (1992), added that if more and a thinner cream is required, the cream screw should be screwed out; if less and thicker cream is desired, it should be screwed in a little. A quarter of a turn will increase or reduce the separated cream quantity to the extent of two percent (2%).

2.10 FACTORS GOVERNING THE FAT PERCENTAGE

The percentage of machine-skimmed cream can be varied by changing the position of the cream screw. Other factors which cause variations in fat content of cream that are not commonly known are given by Eckles et al (1993) as follows:

1. The speed of the machine
2. Temperature of milk when separated
3. Richness of milk
4. Rate of inflow
5. Amount of water or skim milk used for flushing, and
6. Amount of separator slime in the bowl.

Other conditions remaining the same, the higher the speed of the bowl rotation the richer the cream. As the speed of the bowl is increased, the centrifugal force applied to both the cream and skim milk within the bowl is necessarily increased. Centrifugal force varies not with the velocity, however, but as the square of the velocity. The skim milk, being further from the centre of the bowl, revolves through a greater arc or at a greater velocity than does the cream. This increased speed results in a greater total quantity passing out of the skim-milk opening. This inevitably decreases the amount of cream, which means a higher fat percentage. Culpin, (1992), gave the range of speed of rotation of the bowl as 6000 – 9000 rpm, while Michael and Ojha (1992), gave the range of speed to be between 3000 to 3500 rpm.

Amount of Flushing: It is customary to flush the separator bowl just after the milk has all passed through the machine by allowing water or skim-milk to flow into the milk intake. This is done to remove cream lodged within the various parts of the bowl and the cream spout. Addition of water or skim milk to the cream resulting during flushing, will lower the percentage of fat in the product. (Eckles et al, 1993).

Formation of Separator Slime: When farm separators are washed properly after each separation, it is rarely a factor in altering the fat content of cream. A slight reduction in the fat percentage of cream may result if large amounts of milk are separated and the machine is cleaned only after each second operation. The effect is more often noticed with power separators than with hand machines, because power machines often are operated continuously for 4 to 5 hours so that a very thick layer of slime forms on the inside of the bowl shell. When this takes place, the space where the skim-milk passes between the dividing disc and shell of the bowl is reduced so that more and more milk is diverted to the cream outlet. One of the first indications of this condition is an increase in the size of the stream flowing from the cream spout. The increased flow is, therefore, a signal to stop and clean the bowl. (Eckles and Combs, 1993).

2.11 EFFICIENCY OF THE CREAM SEPARATOR AND THE FACTORS GOVERNING THE EFFICIENCY.

The efficiency of any separator in removing the fat from the skim-milk portion of milk can be measured by the fat content of the skim milk. Eckles and Combs (1993), indicated that a good separator, properly operated, leaves practically no fat in the skim milk. A fat content of more than 0.03 percent is said to means that the machine is either mechanically imperfect or is incorrectly operated, while Culpin, (1992), explained that with a separator that is properly adjusted it is possible to reduce the loss of fat to 0.02%.

The factors that are known to affect the efficiency of separation as given by Eckles and Combs (1993).

1. Mechanical conditions of the machine
2. Low temperature of milk
3. Low speed of bowl
4. High rate of inflow
5. Clogging of bowl
6. Production of Excessively rich cream
7. Separation of high acid milk

Mechanical conditions of the machine. Occasionally, the spindle supports the bowl at such a level that the stream of cream from the cream outlet is split between the cream and the skim-milk pans, thus remixing some of the cream with the skim milk from which it was just separated. This difficulty is corrected by readjusting the height of the spindle, which usually can be done by means of an adjustment at the lower end of the spindle. It is important also, that the separator be set level; otherwise, a vibration of the bowl occurs. This results in incomplete separation. (Eckles et al 1993).

DAIRY HYGIENE

Milk is a excellent medium for the multiplication of bacteria of many kinds, and the warmer the milk, the more rapidly will bacteria multiply. These two factors make milk vulnerable to heavy bacterial contamination. Therefore, strict dairy hygiene must be observed (Barrett and Larkin 1979).

In gravity creaming, it has been found that certain types of pathogenic bacteria concentrate in the cream layer. In centrifugal separation some of these disease bacteria but not all of them are cast off in the slime accumulating in the bowl. A considerable proportion of them is distributed in both cream and skim milk, especially the former. Consequently, separation is not a process for increasing the

safety of milk from the standpoint of disease – producing types of bacteria. (Eckles et al 1993).

Scott (1989), indicated that in order to make a safe product with good keeping quality, milk is normally heat processed. A number of manufacturing processes require 'preheating' of the milk. However, the exact time and temperature vary in relation to the requirement and may vary form fairly to quite intense heating.

Thermization: This is a lower intensity of heat treatment than pasterization, and the main purpose is to destroy psychrotrophic bacteria, which produce heat resistant enzymes that cause deterioration of the milk product prior to further processing. The milk is heated to 63 – 65^{0}C for about 15s.

Pasteurization: This eliminates pathogens from milk and cream. The process of pasteurization is applied to eliminate all important pathogens and at the same time to kill the majority of other microorganisms in the raw milk. Milk may be treated either at a relatively low temperature (62-65^{0}C) for an extended period of time (30 min) or at a higher temperature (72^{0}C) for a brief period (15s). (Longree 1972).

Other preheating processes of milk include utra-heat treatment or ultra high temperature, and sterilization. (Scott 1989).

CHAPTER THREE

3.0 DESIGN METHODOLOGY

The centrifugal milk separator will consist of the following components:

i. A cylindrical bowl in which the milk to be processed is centrifugally accelerated.

ii. A 'feed' to introduce the milk to be separated.

iii. A drive shaft.

iv. Two drive shaft bearings.

v A drive mechanism (electric motor) to rotate the shaft and the bowl.

vi. A casing with another inner cylinder to house the lagging material.

vii. A frame to support and align these elements

3.1 DESIGN CONSIDERATION

- To rotate the separator bowl at speed of 2920 rpm for effective separation.
- To separate $0.194m^3$ of whole milk into cream and skim milk per hour at the rate of $0.013m^2$ per batch.
- To process the milk under hygienic conditions.
- Use material of adequate strength and do not contaminate the products.

3.2 MACHINE DESCRIPTION AND OPERATIONAL PROCEDURE

3.2.1 MACHINE DESCRIPTION

The machine consists of a short, wide cylindrical bowl of 0.28m diameters, 0.026 height with 0.015m small cylinder head of 0.02m diameters. The bowl has a flat bottom and it turns on a vertical axis.

The capacity of the main bowl is $0.013m^3$. Feed (milk) enters from above through the cylindrical head while the bowl is stationary. Inside the bowl and rotating with it are closely spaced cones of sheet metal set one above the other. They serve as baffles operating as accelerators or decelerators ensuring that the milk within the bowl maintains the same angular velocity as the bowl. (Othmer 1967).

2 No. 0.01m inner diameter of 0.05m length galvanized pipes were positioned and welded on holes on the bottom of the bowl one placed at a distance of 0.03m away from the axis and the other at 0.11m away from the axis (i.e close to the bowl wall) to provide outlets for the cream and skim milk respectively. The two outlets are closed with a cork while filling the bowl and when in operation. They are only opened after processing the milk when the machine is stationary in order to discharge the processed products. The discharge pipes rotates freely within 0.04m groove beneath the casing.

Enclosing the bowl is another cylinder of diameter 0.34m and a height of 0.34m (giving a clearance of 0.03m for the rotating bowl). The casing is of same height with the outer cylinder but a diameter of 0.38m. The clearance between the outer cylinder and the casing is 0.02m and that is where the lagging material (cotton wool) is placed in order to maintain the milk temperature (30^0C – 35^0C) for effective separation (Michael and Ojha 1992).

Strongly welded at the bottom centre of the bowl is a 0.23m length shaft of diameter 0.02m which passes through two sealed ball bearings (size 6304). Each bearing having an external diameter of 0.05m and 0.02m internal diameter for the shaft to pass through. The bearings housing are brazed to a four legged frame that is carrying the machine components. At the tail end of the shaft, a pulley of outer diameter 0.08m, 0.009 groove depth, 0.013m groove width and groove angle of 60^0 to accommodate v-belt is fixed in order to receive power from the source. For more details see the working drawings.

3.2.2 MACHINE OPERATIONAL PROCEDURE

The bowl is where the milk to be processed is placed and rotated by the help of a an electric motor of 2.0 horse power capacity (1.5kw) through a v-belt drive at a speed of 2920 rpm.

As the bowl rotates, due to density difference between the cream and the skim milk, the heavier liquid (skim milk) will be thrown to the periphery of the bowl where it is collected after operating the machine for about four minutes through a discharge pipe that is located at the bottom of the bowl close to its wall. The cream collected through the discharge pipe that is located close to the bottom centre of the bowl.

While in operation, the two discharge pipes remain closed using cork material which are removed at the end of the operation while the machine is stationary for the processed products to be released by gravity.

3.3 MACHINE COMPONENTS DESIGN CALCULATION

3.3.1 FLOW RATE

To calculate the amount of whole milk to be processed for hour.

$$\rho_m = \frac{M_m}{V_m} \text{ kg/m}^3 \quad \ldots\ldots\ldots \quad 3.1$$

where: ρ_m = Density of whole milk kg/m^3 = 1033kg/m^3

M_m = Mass of whole milk in kg

V_m = volume of whole milk to be processed in an hour m^3

= 0.194m^3

M_m = $\rho_m x V_m$ 3.2

= 1033kg/m^3 x 0.0194m^3 = 200kg

Mass flow rate for an hour = $\frac{200kg}{60\text{min}}$ = 3.33kg/min

Volume of whole milk per batch = $\frac{M_m}{\rho_m}$

$$\frac{13.33kg}{1033kg/m^3}$$

= 0.0129m^3

$\cong$ 0.013m^3

Mass per batch = $V_m \times \rho_m$

= $0.013m^3 \times 1033kg/m^3$

= 13.33kg

No. of loading/hour = $\frac{200kg}{13.33kg}$ = 15

3.3.2 SHAPE AND DIMENSIONS OF MILK SEPARATOR BOWL

To enhance efficiency of the centrifugal separator, it is known that a cylindrical shape gives more positive result. (Leung, 1997). Therefore, a cylindrical shape is adopted for the separator bowl.

With a cylindrical shape

$$V = \frac{\pi Dh}{4} \quad \ldots\ldots\ldots \quad 3.3$$

Where D = Diameter of the cylindrical bowl, m

h = height of the bowl, m

V = volume of whole milk per batch, m^3

$$\therefore \quad 0.013m^3 = \frac{\pi Dh}{4}$$

for the machine to be stable even under the high speed of the rotating bowl, the height of the bowl has to be designed to be smaller than its diameter. (McCabe et al 1993).

By taking an arbitrary values

h = 0.75D

$$V = \frac{\pi Dh}{4} = \pi D^2 \times 0.75D \quad \ldots\ldots\ldots \quad 3.4$$

$$\text{Hence } 0.013m^3 = \frac{\frac{3}{4}\pi D^3}{4}$$

$$D^3 = \frac{0.013x4x4}{\pi x3}$$

$$D^3 = 0.022m$$

$\therefore$ D $= \sqrt[3]{0.022m} =$ 0.28m

Radius, r $= \frac{D}{2} = \frac{0.28}{2} =$ 0.14m and

$\therefore$ h $=$ 0.75 x 0.28m $=$ 0.21m

but there has to be a clearance to take care of the increase in the milk height in the bowl as a result of centrifugal action while in operation.

$H = \frac{5}{4}h$ 3.5

$= \frac{5x0.21}{4} =$ 0.263

freeboard $=$ H – h $=$ 0.263 – 0.21

$=$ 0.052m

A small cylindrical head of height 0.015m and 0.20m diameter is chose to further minimize spillage during operation. The overall dimensions of the complete separator bowl is as shown in fig. 3.1

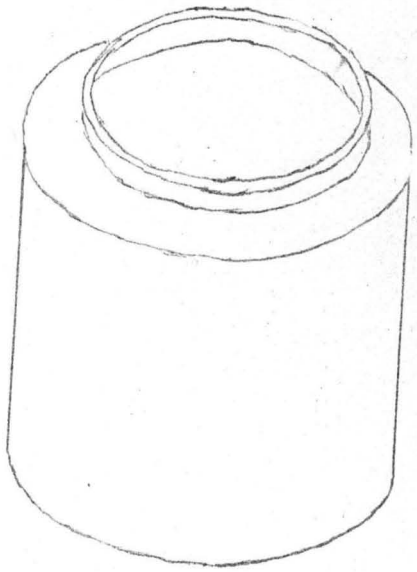


Fig. 3.1: The cylindrical bowl dimensions.

Area (A) of the bowl 'a' $= 2\pi rh$ 3.6

$=$ 2 x π x 0.14 x 0.26

$=$ 0.229m^2

3.3.3 SECOND CYLINDER AND CASING

The separating bowl has to be enclosed by a second and a third cylinder (casing), which are stationary. Lagging material to prevent the milk required temperature from falling so as to achieve effective separation (Hall and Davis 1979) is placed in between the two stationary cylinders. The spacing between the rotating bowl and the second cylinder is 0.03m while the lagging space is 0.02m. The set-up is as shown in fig. 3.2

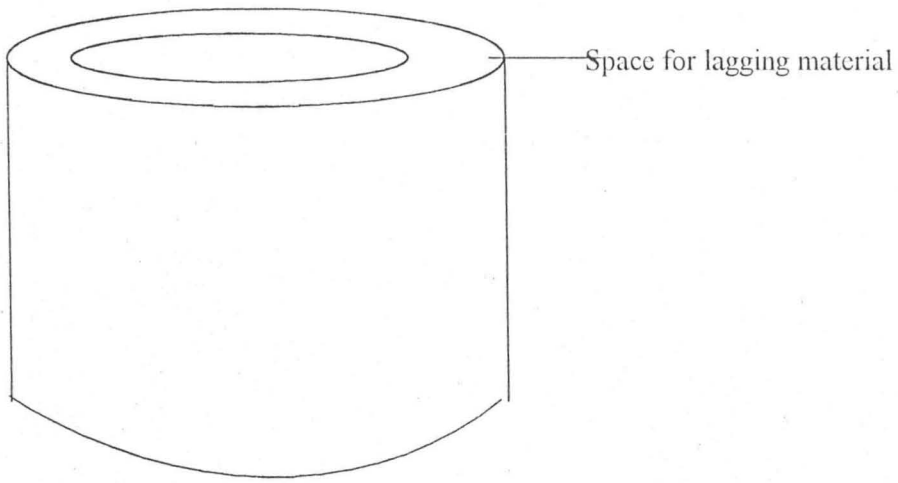


Fig. 3.2 showing space for lagging material within the casing.

3.3.4 DETERMINATION OF THE BOWL WALL PRESSURE

The static pressure (Ps) exerted by the milk on the separator bowl is given by

$$Ps = F/A = \frac{\rho v g}{A} \quad \ldots\ldots \quad 3.7$$

Where

Ps = Static pressure, Pa or N/m^2

A = Bowl area = $0.229m^2$

F = Force, N

ρ = Density of milk, = $1033kg/m^3$

V = Volume of milk = $0.013m^3$

g = $9.81m/s^2$

Since pressure acts in all directions

Area of the bowl bottom = πr^2 ..... 3.8

$$= \pi (0.14)^2$$

$$= 0.062 m^2$$

Total area = $0.229m^2 + 0.062m^2$

= $0.291m^2$

$$Ps = \frac{1033x0.013x9.81}{0.291}$$

= $442.71N/m^2$ = 0.45Kpa

3.3.5 PRESSURE EXERTED ON BOWL WALL DUE TO CENTRIFUGAL FORCE

Apart from static pressure from the milk, the rotating bowl wall experiences additional pressure due to centrifugal acceleration. Centrifugal acceleration G, is measured in multiples of earth gravity. According to Leung (1997), G is given by

$$G/g = 0.0005559\ \Omega^2 D \quad \ldots\ldots 3.9$$

Where Ω = speed of the centrifuge, rpm

D = diameter of the bowl, m

Culpin (1993) gave the speed range of 6000 – 9000 rpm, but in this design been a prototype a speed of 2920 rpm is chosen.

Taking Ω = 2920 rpm and

D = 0.28m

G/g = $0.00059 \times (2920)^2 \times 0.28$

= 1334.6

G = 1334.6g

Hence pressure on bowl wall due centrifugal acceleration is given

$$Pc = \frac{Fc}{A} = \frac{MG}{A} \quad \ldots\ldots 3.10$$

Where Pc = wall pressure due to centrifugal force N/m^2

Fc = centrifugal force

M = mass of whole milk per batch, kg = 13.33kg

Area of cylinder bowl = $0.229m^2$

$$Pc = \frac{13.33x1334.6x9.81}{0.229}$$

$= 762104.97N/m^2$

$= 762.1Kpa$

Total wall pressure = Ps + Pc. 3.11

$= 452.71 + 762104.97$

$= 762557.68N/m^2$

$= 762.6Kpa$

3.3.6 ADEQUACY OF BOWL WALL THICKNESS

For a thin wall cylinder as in this design stainless steel (18-8) cold rolled with elastic strength and ultimate strength of 1140 and 1310Mpa respectively, a thickness of 0.001m is adequate in terms of its ability to withstand the circumferential and axial stresses.

3.4 CENTRIFUGAL SHAFT DESIGN

Data

Power of the electric motor	=	2H.P = 1.5KW
Speed of the electric motor	=	1460 rpm
Diameter of the driving pulley	=	0.16m
Mass of bowl	=	1.5kg
Mass of milk per batch	=	13.33kg
Density of Galvanized steel	=	$7800kg/m^3$

3.4.1 The forces acting on the shaft are as a result of:

(a) Axial load (Fa) due to the weight of the bowl, the weight of milk contained in the bowl and the weight of the driven pulley.

(b) Torsional force as a result of the drive from the pulley

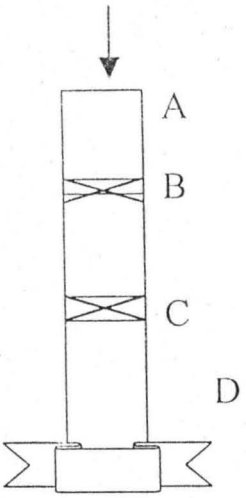


Fig. 3.3: Sketch of the shaft loading

Where

A	=	machine load
B and C	=	Bearings
D	=	is the driven pulley

3.4.2 Calculation of the Components Weight

Weight of B and C are negligible

To calculate the axial load (Fa)

- Mass of milk per batch = 13.33kg

  Weight of milk per batch = 13.33 x 9.81 = 130.8N

- Weight of bowl = Area x Thickness x ρgs x g

  = 0.229 x 0.001 x 7800 x 9.81

  = 17.5N

- Weight of pulley = 2π r x width x thickness x ρgci x g

  = 2π (0.04)x 0.020 x 0.025 x 7200 x 9.81

  = 9.3N

  Fa = 130.8 + 17.5 + 9.3 = 157.6N

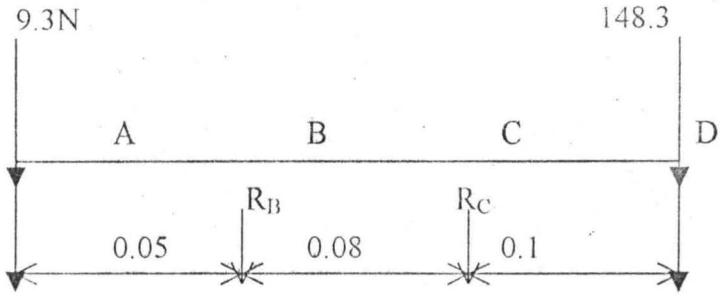


Fig. 3.4: Free body diagram of the shaft

The combine effect of these forces (fig. 3.4) will cause:

i. Bending moment

ii. Torsional moment

3.4.3 To Calculate torsional moment Mt

Speed of the driven pulley is given by the relationship

$N_1D_1 = N_2D_2$ (Hall et al 1980)

$$\therefore \quad \frac{N1}{N2} = \frac{D2}{D1} \qquad \ldots \quad 3.12$$

where

N_1 = speed of driving pulley, rpm

N_2 = speed of the driven pulley, rpm

D_1 = diameter of the driving pulley

D_2 = Diameter of the driven pulley

$$N_1 = \frac{1460}{N2} = \frac{0.08}{0.16}$$

$$N_2 = \frac{1460X0.16}{0.08} = 2920\text{RPM}$$

$$Mt = \frac{KWx1000}{2\pi rev/\min} = \frac{9550xKW}{N2}(N_M) \qquad \ldots\ldots \quad 3.13$$

$$\therefore \quad Mt = \frac{9550x1.5}{2920} = 4.9\text{Nm}$$

3.4.4 Determination of tight side (T_1) and slack side (T_2) belt tension.

For a belt drive

$$Mt = (T_1 - T_2)R \quad \ldots \quad 3.14$$

Where

Mt = torsional moment

R = Radius of the driven pulley

T_1 = Tight side belt tension

T_2 = Slack side belt tension

For a V – belt

$$T_1/T_2 = 5$$

$$T_1 = 5T_2$$

By substituting into the equation

$$Mt = (5T_2 - T_2)R$$

$$Mt = (4T_2)R$$

$$5T_2 = Mt/R = \frac{4.9}{0.04} = 122.5$$

$$T_2 = \frac{122.5}{4} = 30.63N$$

$$T_1 = 5T_2 = 30.63 \times 5 = 153.2N$$

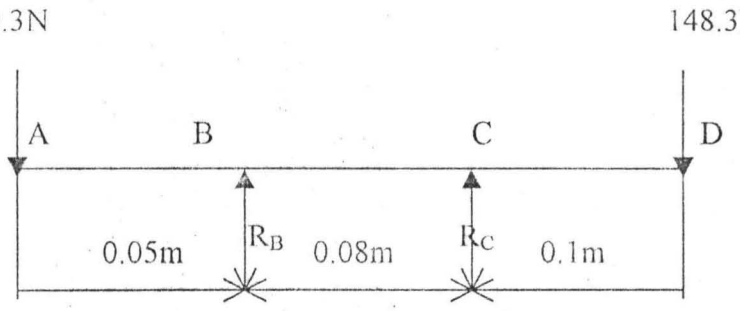
$$\therefore \quad Mt = (153.2 - 30.6) \times 0.04$$

$$= 1226. \times 0.04$$

$$= 4.9Nm$$

3.4.5 Determination of reaction (R_B and R_C)

From fig 3.4: Considering vertical forces



Considering vertical forces

$+\uparrow \sum fy = 0$

$R_B + R_C - 9.3 - 148.3 = 0$

$R_B + R_C - 157.6 = 0$

$R_B = 157.6 - R_C$

Taking moment about point B

$+\circlearrowleft \sum M_B = 0$

$-R_C(0.08) + 148.3(0.18) - 9.3(0.05)$

$-9.3(0.05) - R_B(0) - R_C + 26.694 = 0$

$R_C(0.08) = 26.694 - 0.465$

$$R_C = \frac{26.23}{0.08} = 327.86\text{N}$$

$\therefore \quad R_B = 157.6 - 327.86$

$= -170.56\text{N}$

BENDING MOMENT AT HORIZONTAL LOADING

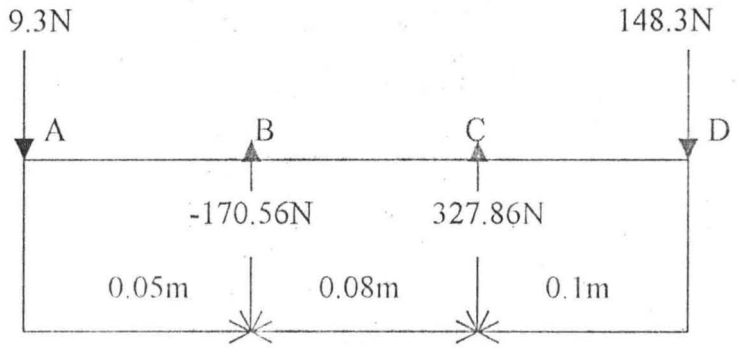


Fig. 3.5:

$+ \sum M_A = 0$

$+ \sum M_B$ when x = 0.05

$-9.3(0.05) = 0.465\text{Nm}$

$+ \quad \sum MC$ when x = (0.05 + 0.08) = 0.13

170.56(0.08) - 9.3(0.13)

13.65 - 1.21 = 12.42Nm

$+ \quad \sum MD$ when x = (0.05 + 0.08 + 0.01) = 0.23

-327.86(0.1)+170.56(0.18)-9.3(0.23)

-32.386+30.7-2.139

= -3.825 ≅ 3.83Nm

3.5 DETERMINATION OF SHAFT DIAMETER

Hall, et al (1980) gave the ASME code equationfor determining the diameter of a solid shaft having axial loading as

$$d^3 = \frac{16}{\pi Ss}\sqrt{(KbMb)^2 + (KtMt)^2} \quad \ldots \quad 3.15$$

where

d = shaft diameter, m

Ss = (allowable) for shaft without keyway = 55MN/m^2

K_b = combined shock and fatigue factor applied to beading moment (load gradually applied) = 1.5

M_b = Bending moment, Nm

K_t = Combined shock and fatigue factor applied to torsional moment for rotating shaft and gradually applied = 1.0

Mt = Torsional moment, Nm = 4.9Nm (3.4.2) and maximum bending moment M_b = 12.42Nm

Substituting the values into the equation:

$$d^3 = \frac{16}{\pi(55x10^6)}\sqrt{(1.5x12.42)^2 + (1.0x4.9)^2}$$

$$= 9.2 \times 10^{-8}\sqrt{350.44 + 24.01}$$

$$= 9.2 \times 10^{-8}\sqrt{374.45}$$

$$d^3 = 9.2 \times 10^{-8} \times 19.351$$

d = $\sqrt[3]{1.79x10^{-6}}$

= 0.012m

factor of safety 0.012 x 1.5 = 0.018m

A 0.02m standard shaft is chosen for the design.

3.6 POWER REQUIREMENT TO OPERATE THE MACHINE

To determine the power required to operate the machine at the expected speed of 2920 rpm .

= 48.666 rev/sec

$\cong$ 49 rev/sec.

Power (P) = 2π NT

Where:

N = shaft revolution per second

T = machine torque, Nm = 4.9Nm

P = 2 x π x 49 x 4.9

= 1508.6 watts

= 1.5 KW = 2H.P

An electric motor of 2.0 H.P capacity is required in the design of the machine

3.7 HEAT INSULATION LOAD

Data

Ambient operating temperature = 30^0C

Required whole milk temperature = 35^0C

Retention time per batch = 4 min (240 sec.)

Thermal conductivity of stainless steel = $21Jm^{-1}s^{-1}{}^0C^{-1}$

Density of cotton wool = $80kg/m^3$

Thermal conductivity of whole milk = $0.56Jm^{-1}s^{-1}$

Specific heat of cotton wool = $1.26Jkg^{-1}$.

Heat conducted by stainless steel bowl with a cylindrical shape of the milk bowl.

Circumference of bowl = 2π (0.14) = 0.88m

Heat conducted away from the milk to surrounding air

$= \quad 21 \times 0.88 \times 0.36 \times (35 - 30)$

$= \quad 33.26$

$\cong \quad 33.3KJ$

Heat released by whole milk

$= \quad 0.56 \times 0.88 \times 0.36 \times (35 - 30)$

$= \quad 0.89KJ$

Total Heat loss $= \quad (33.3 + 0.89)KJ$

$= \quad 34.2KJ$

To prevent this heat loss, cotton wool is selected to serve as lagging material because of its availability low cost, lower weight and high insulating capacity.

Using the expression

$\theta = McDt \quad \ldots \quad 3.16$

Mass of cotton wool needed, m $= \quad \theta / ct$

$M = \quad 34.2 / 1.26x(35 - 30) = \frac{34.2}{6.3}$

$= \quad 5.4kg$

Volume of cotton wool required

$= \quad mass / density \quad = \quad 5.4 / 80 \quad = \quad 0.068m^3$

circumferential thickness of cotton wool required

$t_1 = \quad t \quad = \quad V / A \quad \ldots \quad 3.17$

$t = \quad 0.068 / 0.142 \quad = \quad 0.48$

The insulating load will be stationary while the bowl rotates inside it.

3.8 SELECTION OF BEARINGS

Deep groove ball bearing type is selected based on its wide application in carrying considerable thrust load apart from radial load at high speed.

Bearing with the following dimension is chosen in this design:

i. Dynamic capacity of 330kgf

ii. Maximum permissible speed of 10,000 rpm which is greater than the designed speed of 2920 rpm

iii. No. of bearing required is two

For agricultural processing machine operating life range between 400 – 800 working hours. The selected bearing has working life of 4000 hrs and bore diameter of 0.02m to match the shaft diameter.

3.9 BELT SELECTION

A 'B' v-belt type is chosen which is adequate for (2-15kw) machine (Design data, 1982). The dimensions of the chosen v-belt are top width 0.017m, 0.011m thickness and sheave groove angle of 60^0.

3.10 THE SUPPORT

A four legged frame mode of 40mm angle iron is to be constructed. The dimension is 0.5m x 0.5m x 0.2m.

The support made of this angle iron should be strong enough to carry the weight of the machine components and maintain stability when fixed to the ground.

3.11 MACHINE MAINTENANCE

Proper care and maintenance of the separator ensures quality separation under hygienic condition and increases its service life.

Basic maintenance include, lubricating the bearings from time to time, proper washing of the components especially the bowl, regular inspection of the belt and its tension etc.

CHAPTER FOUR

4.0 TESTING, RESULT AND DISCUSSION

4.1 TEST PARAMETERS

The test parameters taken into consideration are:

i. To ascertain efficiency of the machine

ii. To ascertain the machine capacity is achieved

iii. To determine the stability of the machine under operation

4.1.1 TEST PROCEDURE

Before putting the whole milk sample, the cylindrical bowl was initially washed thoroughly to ensure hygiene, and the two outlets at its bottom closed with cork. The sample of whole milk to be processed was then steamed to a temperature of about 35^0C before been introduced into the bowl through the 0.02m diameter cylindrical head of the bowl and then covered.

The bowl was enclosed by the casing that contained the lagging material that help in minimizing the effect of heat loss to the surrounding that will affect the efficiency of separation.

With a V-belt connecting the machine to a power source, which is an electric motor the machine was switched on and after attaining full speed rotating the bowl for four minutes, it was then switched off.

While the machine bowl was stationary, the skim milk that is denser than the cream has already moved to the periphery of the bowl and was allowed to be discharged through its outlet to a container.

After drawing the skim milk, the cream outlet that is closer to the centre of the bowl was then opened to discharge the cream from the bowl.

The process was repeated four times the result obtained is as shown in table 4.2

4.2 RESULT

The four sample of wholes milk labeled A ,B ,C and D each having a mass of 0.9kg that was used in testing the throughput efficiency of the machine yielded the result as show in table 4.2 below.

TABLE 4.2: CREAM/SKIM MILK RESULT

S/N	Sample	Mass of Sample (Whole milk) before Operation (kg)	After processing for 4 minutes	
			Mass of skim milk (kg)	Mass of cream (kg)
1	A	0.9	0.863	1.7×10^{-2}
2	B	0.9	0.882	1.8×10^{-2}
3	C	0.9	0.88	2.0×10^{-2}
4	D	0.9	0.881	1.9×10^{-2}

Table 4.2: Shows the result of cream/skim milk after separation

4.3 THROUGHPUT EFFICIENCY OF THE MACHINE

Average mass of whole milk (sample)= 0.9kg

Average mass of skim milk $= \dfrac{0.863 + 0.883 + 0.880 + 0881}{4}$

$= \dfrac{3.506}{4}$

$= 0.877\text{kg}$

Average mass of cream removed $= \dfrac{(1.7 + 1.8 + 2.0 + 1.9)X10^{-2}}{4}$

$= \dfrac{0.074}{4}$

$= 0.018\text{kg}$

According to Barrett, and Larkin (1979) an average of 4.5% cream is contained in cow whole milk.

Cream content of 0.9kg whole milk is

$$\frac{4.5}{100} \times 0.9 = 0.041\text{kg}$$

$$\text{Efficiency of separation} = \frac{cream\ removed}{cream\ content\ of\ wholemilk} x100$$

$$= \frac{0.018}{0.041} x100$$

$$= 44.4\% \text{ efficiency}$$

4.4 DISCUSSION OF RESULT

In the first sample (A) the mass of the cream was found to be 1.7×10^{-2}kg, which is less than the result obtained in the remaining samples. This was as a result of the quantity retained on the bowl surface. There was an increase in the mass of cream obtained in the subsequent samples of B,C and D.

The initial result of the skim milk was equally less than the subsequent results of the remaining samples due to same reason as in that of the cream.

At the end of the experiment, a total of 44% of the total cream content was realized. Therefore, the throughput efficiency of the separator is 44%.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Centrifugal cream/skim milk separator as analyzed in this project can be used for the quick separation of the products from whole milk without getting spoiled at the end of the operation when compared with the traditional method of allowing the milk to settled by gravity alone.

The separation enhance fast production of other products like, yoghurt, cheese etc.

The design was carried out with due considerations to stability and efficiency of the machine.

Finally, locally available materials were used in the construction

5.2 RECOMMENDATIONS

- This project work should serve as a spring board for more research towards improving its efficiency
- A better way of discharging or removing the cream should be considered due to its stickly nature.
- Large scale production of the machine is highly recommended in other to alleviate the problem of separation as faced by our local farmers
- Government should give more assistance to the farmers so as to improve upon the milk yield of their livestock.

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APPENDIX 'A'

THE COMPOSITION OF MILK FROM DIFFERENT ANIMALS AS GIVEN BY PYKE (1982)

CLASS OF ANIMALS	CARBOHYDRATE %	PROTEIN %	FAT %
HUMAN	6.2-7.6	0.6-2.0	2.0-6.2
COW	4.2-6.8	2.5-4.0	3.0-6.0
BUFFALO	4.5	4.3	7.5
GOAT	4.5	3.7	4.8
SHEEP	4.9	6.5	6.9
MARE	5.7	1.3	1.2

APPENDIX 'B'

A TYPICAL ANALYSIS OF MILK FOR DIFFERENT BREEDS OF COWS AS GIVEN BY BARRRET (1979) IS SHOWN BELOW

MINERAL COMPOSITION IN MILK	ZEBU (%)	FRIESIAN (%)	JERSEY (%)	COLASTRUM FRIESIAN (%)
FAT	6.05	3.50	5.24	3.37
CASEIN	3.32	2.90	3.25	4.83
ALBUMIN AND GLOBULIN				
LACTORSE	4.92	4.90	4.92	2.48
ASH	0.78	0.72	0.76	1.78
WATER	84.37	87.45	85.28	72.72

APPENDIX C

COSTING

Below is the table showing the cost of material and cost of non-machine job and their specification used for the construction of the cream/skim milk separator.

COST OF COMPONENTS AND NON-MACHINE JOB

S/No	Component	Specification	Qty	Unit cost (₦)	Total Price (₦)
1.	Galvanized steel	0.001m thickness 1.0m length 0.5m breath	¼	4500	1125
2.	Bigger Pulley	ϕ =0.016m 0.02m thickness No. of groove = 1	1	450	450
3.	Smaller Pulley	ϕ = 0.08m 0.02 thickness No. of groove = 1	1	300	300
4.	Sealed Bearings	Outer ϕ = 0.025m Bore = 0.02m	1	150	300
5.	Bolts and Nuts	M12 length = 0.03m Top ϕ = 0.01m Nut ϕ = 0.012m	2	10	20
6.	Shaft	Length = 0.23m ϕ = 0.02m	1	100	100
7.	V-Belt	Length = 0.6m	1	350	350
8.	Electrode	Gauge 12	40 P	4	160
9.	Angle iron	Length = 2.5m 0.025 x 0.025mm	2	500	1000
10.	Paint	Gloss black Gloss Gray	2	150	300
11	Galvanized pipe	ϕ = 0.01m length = 0.01m	1	50	50
12.	Emery cloth	Length x breath 0.01 x 0.01m	-	40	80
13.	Bench work	-	-	-	500
14.	Arc welding workmanship	-	-	-	500
15.	Gas welding workmanship	-	-	-	500
16.	Cotton wool	-	100	-	500
17.	Transportation	-	-	-	500
	Total cost				300 **6,535**