DETERMINATION OF SOLIDS CONTENT OF MILK BY SPECIFIC GRAVITY LACTOMETER

BY

BABU MATHEW

THESIS

Submitted in partial fulfilment of the

requirement for the degree

MASTER OF VETERINARY SCIENCE

Faculty of Veterinary and Animal Sciences

Kerala Agricultural University

Department of Dairy Science

COLLEGE OF VETERINARY AND ANIMAL SCIENCES

Mannuthy - Trichur.

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DECLARATION

I hereby declare that this thesis entitled "DETERMINATION OF SOLIDS CONTENT OF MILK BY SPECIFIC GRAVITY LACTOMETER" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy,
11-7-1980.

Babu Mathew

CERTIFICATE

Certified that this thesis entited "DETERMINATION OF SOLIDS CONTENT OF MILK BY SPECIFIC GRAVITY LACTOMETER" is a record of research work done independently by Sri. Babu Mathew under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Mannuthy,
11-7-1980.

Dr. M. Subrahmanyam,
Professor of Dairy Science
(Chairman, Advisory Committe

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude to -

Dr. M. Subrahmanyam, B.V.Sc., M.S. (Tennessee), Chairman of the Advisory Committee, for his inspiring guidance and constant encouragement throughout the study and for the preparation of the thesis.

Dr. K. Pavithran, Associate Professor of Dairy Science, Dr. C.R. Ananthasubramaniam, Professor (Project Co-ordinator, Cattle & Buffaloes), Dr. B.R. Krishnan Nair, Associate Professor of Animal Breeding and Genetics, the members of the Advisory Committee for their constructive criticism and valuable suggestions given from time to time.

Dr. C.P. Anantakrishnan, Professor Emeritus, N.D.R.I., Bangalore and Dairy Adviser to the Kerala Agricultural University for his valuable advices at various stages of the study.

Dr. P.U. Surendran, Professor of Statistics and Sri. K.L. Sunny, Junior Assistant Professor of the Department of Statistics for their services rendered in the planning of the experiment and the statistical analysis of the data.

Dr. P.G. Nair, former Dean for his suggestions and advices.

the Dean, College of Veterinary and Animal Sciences, Mannuthy for providing me all the facilities for the research work.

the staff members of the Department of Dairy Science for their esteemed help.

the Faculty members of the University Livestock Farm, Mannuthy and the Secretary, Ollukara Co-operative Milk Society, in providing the milk samples for the study.

Sri. K.J. Lonan, for getting the manuscript neatly typed.

the Kerala Agricultural University for granting the Merit Scholarship.

Babu Mathew

DEDICATED TO MY BELOVED PARENTS

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INTRODUCTION

INTRODUCTION

Milk is described as nature's most perfect food. It is the sole source of food of most newborn mammals. For infants, milk is the only source of nutrients for the first two or three months of life and plays an important role in the diet of growing child. For adults, it is one of the major protective supplement to normal diet.

Campbell and Marshall (1975) are of opinion that milk is complex not only because it contains some two hundred and fifty individual components but also because of the variation in ratio of its constituents. In buying, selling and processing of milk it is important to know its composition. Although milk is a liquid and often considered a drink it contains an average of 13 per cent solid an amount comparable to the solid content of many other food. So variation in the chemical composition is important in the nutritional aspect of milk in the human diet. Some attempts have been made by Warner (1951) to determine the composition of milk of Indian cows and buffaloes. Jenness and Patton (1959) have systematically given a quantitative and qualitative analysis of milk and thoroughly described the nutritional value of milk.

Because of the high nutritive value of milk in human diet, proper attention should necessarily be given to price fixation. The price of milk is generally determined in terms of fat present in milk. Other than butterfat, the most important constituents of whole milk are solids-not-fat. Both these constituents being variable, a correct estimation of milk fat and solids-not-fat is important. Judicious payment of milk to producers require qûick methods for estimation of fat and solids-not-fat. The solids-not-fat content of milk should receive an equally important consideration in the price fixation of milk. In recent years payment of milk is not only on fat content but also on total solids basis. This is receiving serious attention not only in developed countries, but in developing countries as well (Vyas, 1979).

The close relationship existing between specific gravity and fat has successfully been exploited for the estimation of total solids in milk. However, the gravimetric methods are more accurate but they are more time consuming and demand a better analytical skill. At the field level, the volumetric methods are being followed and well established procedures are available for cow milk.

Lactometric methods for the estimation of total solids are rapid and simple. Today more than 60 different equations for estimation of total solids or solids-not-fat content in milk from specific gravity and fat contents have been proposed by different investigators (Bector and Sharma, 1980). These equations generally give reliable estimates of milk solids when applied to data from which they were derived. Some research workers have proposed constants and corrections in the basic equations in order to make the computed value agree with the experimental values.

Lactometer is used in routine milk testing to determine the specific gravity of milk and thereby its quality. The simplicity and economy of the test within reasonable limits of accuracy is the basis of its popularity. Divergent views are held about the type of lactometers to be used, the proper temperature correction to be applied and the constants to be used in the different formulae. For a specific gravity lactometer of Quevenne type standardized at 15.6°C (60°F), the Richmond formula is commonly used with a constant factor of 0.14 to calculate total solids or solids-not-fat and there are other constant factors such as 0.66 and 0.72 for the density hydrometer standardized for 20°C (Davies and Macdonald, 1963). Recently Sebastian et al. (1974) suggested a correction factor of 0.50 for the determination of total solids content or solids-not-fat content of mi

The Indian Standards Institution in its revised specification for density hydrometers for use in milk has shown preference for density hydrometers calibrated at 27°C to suit tropical conditions but for some convenient reasons adopted a temperature of 20°C for calibration. Due to the non-availability of such a standard lactometer in the market, the commonly used lactometer in dairies in our country is a small sized specific gravity type lactometer. For this, a correction for temperature is suggested which approximates one lactometer unit for a difference in temperature of every 2.8°C (5°F). This is to be subtracted when the temperature of testing of milk is below 29°C and added when the temperature exceeds this limit. The application of the Richmond's formula for the determination of total solids with the lactometer reading and fat content by the Gerber method has given erroneous results and is not justifiable. This is especially true in the case of milk of animals that are having high fat content. In some of the crossbred animals the fat content of milk has been found to be very high particularly when the time interval between milkings are very short.

In our country, the different dairies are using different types of lactometers and there is no uniformity in the formulae followed to calculate the total solids or solids-not-fat content of milk. Eventhough several formulae are available for the determination of total solids content of milk, contradictory reports have appeared regarding the usage of these formulae. Errors in calculation of total solids or solids-not-fat affects payment related to the quality of milk in which the producer, the procurer, the processor and the consumer are affected. Hence the present investigation was undertaken with an attempt to find out a solution to this anomaly and help to reveal as to what should be the formula for calculating total solids and solids-not-fat content of milk especially having a high fat percentage.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The most important use of lactometers is in the estimation of total solids in milk and skim milk. The problem is relatively simple in the case of skim milk. The milk solids-not-fat have an average specific gravity of about 1.6, and this value is not affected to any great extent by the common variations in the composition of mixed milk. But the problem is more complicated in the case of whole milk because it contains an additional constituent, fat, which is quite variable in amount and has a specific gravity quite different from that of solids-not-fat. Fortunately it is relatively easy to determine the amount of fat present, and a correction can be made for its effect upon the specific gravity on theoretical grounds, this procedure should indicate the total solids with considerable accuracy (Herrington, 1948).

Many equations have been proposed for calculating the total solids of whole milk from determinations of fat and specific gravity. The fact that so many equations exist is itself an evidence to show that most of them have not proved satisfactory under all conditions, though each one has yielded good values in the hands of its originator. The reasons for this have not been understood for many years. Now, for example, it is known that it takes several hours for the fat in milk to crystallize when milk is cooled to 60°F. The specific gravity of a sample at 60°F, will depend not only upon the composition of the milk, but also upon the physical state of the fat, that is, whether the sample has been warmed or cooled, and how much time has been allowed for the sample to come to equilibrium. This factor may cause differences in the specific gravity as great as 0.0002 for each per cent of fat in the sample. Although this error does not seem very large, it will cause a difference of about 0.2 per cent in the calculated value for the solids content of 4.0 per cent milk (Herrington, 1948).

This source of error may be avoided by determining the specific gravity at a temperature high enough to ensure that the fat is completely melted. It has been proposed that the milk should be warmed to 45°C and then cooled to 30°C for the actual measurement. This procedure has not been generally adopted, possibly because the original equation proposed by those who advocated this procedure was faulty. Fundamentally, the method is sound, and when it is used in connection with the proper equation relating the fat and lactometer readings to total solids content, it should prove more reliable than the older methods.

Formulae for calculating the percentage of total solids and solids-not-fat in milk have been studied in the United States and various other countries for many years. Different equations for computing the relationship between the fat content and specific gravity and the solids of milk have been proposed by different investigators (Watson, 1957). They have suggested constants, and corrections in the basic equations. The different constants, corrections and divergencies in the calculated values have caused confusion and doubt concerning the fundamental reliability of the method.

Behrend and Morgan (1879) were probably the first to recognize the relationship existing between the total solids and specific gravity of milk. Fleischmann (1885) was the first to present a sufficiently acceptable equation as given below relating the fat percentage, specific gravity and total solids.

$$\text{Total solids} = 1.2\,F + 0.2665\,G/D$$

Where, F = Fat content of milk,

G = (Specific gravity of milk - 1) 100, or lactometer reading of milk,

D = Specific gravity of milk.

Richmond (1894) deduced the following formula on the basis of data collected during one year.

Total solids = 0.2625 G/D + 1.2 F

While arriving at this formula, Richmond had taken the values for specific gravity of milk, fat and solids-not-fat as 1.032, 0.93, 1.616 respectively. The formula was later presented in the well known form as follows:

T.S. = 0.25 G + 1.2 F + 0.14

Where, T.S. = Total solids,

G = Lactometer reading at 60°F,

F = Fat test.

Three important changes were made by British Standards Institution (B.S. 734, 1955) regarding the use of this formula.

1) Instead of a specific gravity lactometer, a density hydrometer was used.

2) The hydrometer was calibrated for use at 20°C instead of 60°F. It was realised that normal working temperature of laboratory was nearer to 20°C than 60°F and therefore taking reading at 20°C would be much more convenient.

3) Milk was required to be held at 40°C for 5 minutes and then cooled to 20°C for determination of density.

It was done to overcome the uncertainity regarding the completion of Recknagel phenomenon, since milk samples arrive at the laboratory in various stages of Recknagel effect, depending upon the age and previous heat treatment.

Accordingly the following formula was recommended by British Standards Institution.

$$T.S. = 0.25D + 1.21F + 0.66$$

Where, T.S. = Total solids,

D = (Density - 1) 1000,

F = Fat test.

It was a mathematical derivation of Richmond's formula from the knowledge of the coefficient of cubical expansion of milk and density of water at 60°F. The same formula was adopted by the Indian Standards Institution also (I.S. 1183, 1957).

Rowland and Wagstaff (1959) observed that BSI formula slightly under estimated total solids. They therefore proposed the following modification to the BSI formula.

$$T.S. = 0.25 D + 1.22 F + 0.72$$

Where, T.S. = Total solids,

D = (Density of milk - 1) 1000,

F = Fat test.

The present BSI and ISI formulae are modifications of original Richmond's formula for cows milk and hence not been considered to give a true estimate of the total solids for buffalo's milk. This has been correlated by the findings of Mehta (1964) who observed that the ISI formula gives lower solids-not-fat value by about 0.25 per cent than gravimetric procedure for buffalo's milk. Subsequently Pruthi and Bhale Rao (1973) also made a similar observation and they proposed the following modification of the existing ISI formula for buffalo milk.

$$T.S. = 0.25\ D + 1.22\ F + 0.87$$

Where, T.S. = Total solids,

D = (Density of milk - 1) x 1000,

F = Fat test.

In India, Schneider *et al.*(1948) applied the Richmond formula to estimate total solids in milk and observed ± 1.0 difference. Kothavalla *et al.*(1949) who analysed 562 herd samples of cow as well as buffalo milk concluded that the calculated values for total solids were both higher as well as lower than values obtained by direct evaporation. Desai and Patel (1945) reported that the Richmond formula gave results that were higher than values obtained by evaporation by 1.3 to 3.6 and that the difference between two values increased when milk was adultrated with water or when the fat was extracted.

Watson (1957) proposed that lactometer reading should be taken at 102°F. He proposed the following formula to calculate the total solids of milk with the help of a Watson lactometer.

$$T.S. = 1.33\ F + \left(\frac{273\ L}{L + 1000}\right) - 0.40$$

Where, T.S. = Total solids,

L = Lactometer reading at 102°F,

F = Fat test.

The analysis of 200 samples of milk from about 25 herds revealed that the deviation of the calculated total solids from gravimetric method was + 0.05 per cent of total solids and standard error for 99 samples of individual cow's milk was ± 0.13 per cent. The average deviation was - 0.006 per cent for 101 samples of herd milk.

Madden (1957) studied the accuracy of a small watson lactometer over the Quevenne lactometer by determining the total solids in over 1000 milk samples and compared the results with gravimetric estimation. He found that the Quevenne lactometer gave high results at low fat per cent and low results at high fat per cent, while the watson lactometer gave more accurate results. In a subsequent study involving 350 individual samples of cows milk from different herds, Madden et al.(1958) found that the total solids measured with the help of the small watson lactometer did not differ significantly from the values obtained gravimetrically.

Vyas et al. (1973) studied the applicability of various lactometricmethods and compared the results with gravimetric method. In all 330 milk samples from Kankrej cows were analysed and the lactometer readings for Richmond's formula were taken at 60°F with the help of Deska type lactometer. For purposes of comparison, the same samples were used for taking readings with the Watson lactometer calibrated at 102°F. When the total solids was calculated with the help of Richmond's formula the results indicated a difference of about 1.17 per cent. But when the estimation was made with the Watson lactometer, the difference in total solids, varied from 0.01 to 0.05 indicating that the Watson lactometer can be used for the accurate estimation of total solids in the milk of Kankrej cows and the method can well replace the time consuming even drying method or gravimetric method.

In a study of the milk samples from Surti buffaloes

Vyas et al. (1973) reported that the gravimetric method gave 17.611 per cent total solids and by using Watson lactometer, the same samples gave 17.556 per cent total solids. This indicated that the values obtained by using Watson lactometer can be reasonably comparable with the results of oven drying method. When the same samples were studied by using Richmond's formula the results revealed 0.95 per cent less of total solids. Eventhough the Watson lactometer was designed in a foreign country, it was found to be suitable for the estimation of total solids in buffalo milk also. Mehta and Vyas (1977) studied 100 samples of Jersey milk and observed 13.6854 per cent total solids by Watson lactometer as compared to 13.7008 per cent obtained by A.O.A.C. method. The difference was found to be practically negligible (0.154%) while for the same sample the difference by Richmond's formula was 0.7870 per cent which was quite appreciable.

The formula suggested by Desai and Patel (1945) and El.sokkary and Hassan (1953) have been found to give higher solids-not-fat values as compared to the values obtained by gravimetric method. Sharp and Hart (1936) found that the total solids of milk calculated by their formula $1.2537 \text{ Fat} + 0.2680 \times \frac{\text{lactometer reading}}{\text{specific gravity of milk}}$ to have a deviation of 0.3 per cent from the gravimetric method. The specific gravity was determined at 30°C after previously warming the milk to 45°C.

Lambert (1940) and Rueda (1943) designed a nomograph for calculation of total solids and found it suitable for quick method of estimation of total solids in laboratories.

Yetagard <u>et al</u>.(1951) while determining the total solids in normal and watered milk by lactometric methods found that Babcock formula yielded satisfactory results for normal milk if the samples were warmed to 15.5°C and then read. It was also noticed that Richmond's formula yielded the best results among the formula checked if the milk were heated to 45°C and hold for 2 minutes, cooled to 15.5°C and read.

Ramachandran (1953) worked out the applicability of Richmond's formula for total solids in milk. He analysed a total of 1929 individual and herd samples of cows and buffaloes milk and found that the calculated values were both higher and lower than those obtained by gravimetric method to an extent of $\pm$ 0.1.

Madden (1957) analysed 974 cow's milk samples and found that there was little difference by the application of the formula for estimating total solids using Quevenne and BDI lactometers in comparison to the Mojonnier method.

O'Keefee (1967), while analysing 1082 drip samples of fresh milk taken at a creamery over a period of two years, reported that the hydrometric method over-estimated the total solids by 0.096 as compared to the gravimetric method.

Rosu et al. (1968) after comparing several formulae for densitometric estimation of total solids content of milk concluded that the best formula for cow's milk at 20°C is T.S. = 0.5 + 1.2 F + 266.5 (D - 1)/D.

Sharma et al.(1967) by analysing 927 samples of milk stated that Richmond's formula over estimated the total solids percentage by an average of 0.539, 0.577 and 0.513 in the milk of cow, buffalo and mixed herds, respectively with the range of 0.441 to 0.582 per cent in cow's milk and 0.495 to 0.663 per cent in buffalo's milk.

Dozet et al.(1973) compared the total solids content of milk both by Fleischmann formula and gravimetric method and observed that the difference between the two methods was insignificant.

Khalifa (1974) analysed 3500 milk samples from

Northern Sudan Zebu cattle by rapidly heating the milk to 105°F for 2 minutes and then held at 60°F for 12 hours. Mean specific gravity determined with lactometer was 1.0305. The percentage of total solids in the sample as determined by the Richmond's formula was on an average 0.07 per cent lower than that obtained by A.O.A.C. gravimetric method.

Royo *et al.*(1973) took 390 samples of milk and analysed for total solids using Richmond's formula and Ackermann's formula. The average deviation and standard deviation of the difference from the A.O.A.C. gravimetric method were 0.078% ± 0.186%, 0.197% ± 0.178% and 0.187% ± 0.191% respectively.

Bozet *et al.* (1976) tested 135 milk samples for total solids content by 3 methods viz. IDF gravimetric method, IR drying on an ultra - x balance and Fleischmann's formula. The 't' test indicated that differences between the average results were not significant. Analysis of frequency distribution showed that IDF gravimetric method gave the most standard results, and the other two methods were suitable for rapid testing.

Sebastian *et al.* (1975) carried out investigations on the use of specific gravity lactometers adjusted to

29°C (84°F) under conditions prevalent in the Southern States of India. Twenty-four samples of milk in each of five fat levels ranging from 2 to 10 per cent and five temperature levels ranging from 14° to 34°C (a total of 600 lactometer readings) were tested. Gravimetric analysis for total solids were also made under standard conditions. A correlation between total solids and lactometer reading was formulated on the basis of which Richmond formula has been modified for use in relation to these commonly used specific gravity type lactometers. A temperature correction chart has also been prepared for use along with the lactometer. Their modification to the Richmond's formula was,

$$T.S. = 0.25 L + 1.2 F + 0.50$$

Where, T.S. = Total solids,

L = Lactometer reading,

F = Fat test.

Vujicic <u>et al.</u> (1975) in their 2 series of analysis for total solids in milk on 127 and 202 samples respectively, a difference of 0.31 and 0.19 determined gravimetrically (by IDF method of drying 105°C) and those calculated by Fleischmann's formula. The differences were significant at $P < 0.05$ and $P < 0.01$ respectively. They have pointed out the need for corrections to be made in the Fleischmann's formula.

Lunder (1970) reported that Richmond's modified formula with its constant replaced by 0.81 gave satisfactory results for determination of total solids in milk. O'keefee (1967) has suggested the following formula for the estimation of total solids in milk.

T.S. = 0.25 L + 1.22 F + 0.72

Where, T.S. = Total solids,

L = Lactometer reading,

F = Fat test.

Bhatia (1960) who conducted investigation on the determination of total solids and solids-not-fat in milk by calculation and gravimetric method found that the calculated values for total solids or solids-not-fat in most cases were lower than the gravimetric method. The average differences in the case of four breeds were Red Sindhi 0.04, Sahiwal 0.03, Tharparkar 0.05, Thari 0.06 and for buffaloes, the difference was 0.09. The observed differences were fairly close in the cow samples while buffalo milk showed almost twice the difference. Taking the value of maximum deviation the results indicated that on an average about 95 per cent of the calculated values for cow milk could be expected to fall within (+) 0.05 and (+) 0.19 per cent of the gravimetric values or within (+) 0.14 and (+) 0.24. In the case of buffalo milk the results at 20°C could be expected to vary from (+) 0.09 to (+) 0.14 per cent or within (-) 0.05 and 0.23 per cent.

He also reported that the calculated values for solids-not-fat at 27°C were again, in a large majority of cases, lower than the gravimetric values, the differences varying from (+) 0.07 to (+) 0.09 in the above four breeds of cows. Taking the maximum observed deviation on an average, 95 per cent of the calculated values for cow's milk samples at 27°C could be expected to fall within (+) 0.08 and (+) 0.14 per cent ie, within (-) 0.06 and (+) 0.22 and for buffalo milk within (-) 0.02 and (+) 0.33.

El.Sokkary (1952) estimated the solids-not-fat content of both cow and buffalo milk, taking 100 samples each and observed the results of lactometric method agreed favourably with the gravimetric method. Wallance (1957) designed a monograph for calculating the solids-not-fat content of milk from the density hydrometer readings and fat percentage and the accuracy was found to be nearest of 0.05 per cent to standard method. Edwards (1960) compared the hydrometric and gravimetric methods for determination of solids-not-fat when applied to 569 individual milk samples from 45 cows in a single herd, and reported that the hydrometric method was considered to be of limited use when applied, to the milk of individual cows.

Medowell (1971) studied the comparison of various methods for the estimation of solids-not-fat in milk and whey. The total solids of milk was estimated using freeze drying followed by a Karl Fischer titration. The average solids-not-fat value for 12 milk samples calculated from the total solids results by this method was 0.003 ± 0.039 per cent lower than the total solids content calculated by the gravimetric method. Sen (1977) suggested a modified formula for estimation of solids-not-fat in milk when the temperature of milk ranges from 80 to 92°F. The formula for solids not fat is S.N.F. = 0.25 (CLR) + 0.2 (fat) - 0.16.

Where, SNF = Solids-not-fat,

CLR = Corrected lactometer reading,

F = Fat test.

Patel and Gandhi (1980) used a formula for determination of solids-not-fat which is followed in Amul Dairy, Anand.

$$S.N.F. = \frac{(L.R.\ at\ 60°F)}{4} + 0.2\ Fat + 0.36$$

Where, S.N.F. = Solids-not-fat,

L.R. = Lactometer reading.

They also reported a formula for determination of solids-not-fat which is followed in Dudhsagar, Mehsana and GDDC dairies.

$$S.N.F. = \frac{L.R.\ at\ 60°F}{4} + Fat$$

Where, S.N.F. = Solids-not-fat,

L.R. = Lactometer reading.

A considerable amount of research work has been carried out for the estimation of total solids in milk by gravimetric method. Several improvements have been suggested from time to time in the method of drying, temperature of heating and the use of infra-red moisture heaters.

Bakalor (1964) reported that the determination of total solids can be done using a mechanical oven (100° ± 1°C) after initial evaporation on a waterbath and the drying time can be reduced to one and a half hours, with additional checks at 30 minutes interval. The use of absorbant filter paper discs resulted in significantly lower values and the addition of 0.01 ml of 36 per cent formaldehyde solution gave significantly higher values than those obtained by standard method. Boon (1979) reported that the total solids in milk can be determined by the British Standard method by weighing 2 to 3 g of milk into a nickel basin and evaporating to dryness at 100°C for 2.5 hours. The method had the greatest reproducibility for fresh whole or skim milk. Claesson (1958) described a method for determination of total solids in milk in which 1 ml of milk was transferred onto a filter paper in aluminium milk bottle caps by means of a cornwell syringe. These samples of milk were dried in an infra-red heat drier and fed into the scale pan of a balance provided with an optical scale from which the weight could be read off directly. It has been claimed that one person can do the analysis at the rate of 100 samples per hour.

Budenkov (1958) evolved a method in which 5 ml of milk samples were spread over six dry gauze discs in a shallow disc and dried at 102 to 110°C to a constant weight. In the results of 18 whole and seperated milk samples the difference between the mean values for this and the standard (oven drying) method was 0.01 ± 0.021 in replicate test and the maximum deviation was 0.19 per cent solids. Laskouski (1969) designed automatic drier for determination of total solids in milk and the accuracy was within ± 3.6 per cent of drying to constant weight at 102 - 105°C. In this method, the dryness was achieved in 15 minutes and one worker can carry 200 measurements a day. Marchart and Hoffee (1974) used a microwave oven for rapid estimation of total solids in milk and the results obtained in 13 minutes were found to be very close to the values obtained in gravimetric method. Banks and Wilson (1978) reported that the open dish method for determination of total solids in milk samples from creamery tanks gave consistently higher values ($P \angle 0.001$) than the values obtained by the closed dish method. Ciusa and Barbiroli (1970) used "Pulsor" apparatus for total solids determination in milk and found that the repeatability was ± 0.2 per cent total solids.

Hamada et al. (1977) used a new instrument consisting of a microwave heater and an electrobalance for determination of total solids in milk. Cervinka et al. (1976) reported the use of infra-red milk analyser (IRMA) by the dairy farmers in California as a rapid accurate and economical method to measure the total solids and solids-not-fat in raw milk. They evolved a new equation for computing total solids.

$$T.S. = 2.76914 + (1.03111\ F) + 1.00097\ P + (.51934)$$

Where, T.S. = Total solids,

F = Fat percentage,

P = Protein percentage,

L = Lactose percentage.

White et al. (1978) reported that infra-red reflectance analyser can be used in determining the fat and total solids content of raw and pasturized whole milk.

Many reports are available with regard to the various factors that influence the composition of milk and especially the total solids. Legates (1960), Arora and Gupta (1969), Edwards (1960) and Willcox et al. (1958) reported that the factors that affect the composition and total production of milk include feed, individuality, nutrition, locality, bioclimatological factors, management, stage of lactation and physiological factors such as age, exercise, oestrum, gestation and sickness. Many of these factors are interrelated and for some the effect may be small except under experimental conditions. The major factors affecting the production of non-fat milk on which considerable work has been done are breed, individuality, nutrition and bioclimatological effects etc.

Anantakrishnan and Ghosh (1964) reported from their work that the total solids content of cow milk determined by the gravimetric method varied from 12.56 to 14.86 with an average of 13.61 per cent. The total solids content of buffalo milk showed maximum of 18.44 per cent towards the end of lactation with an average of

16.73 per cent. The total solids content in both milk started to increase above the average in the 5th month of lactation being more pronounced for the last one or two months for buffalo milk and for last three months in case of cow milk. Miletic (1971) on an analysis of 1654 samples of milk reported that the ranges for fat and total solids were 3.57 per cent in July to 3.93 per cent in December and 12.65 per cent in January to 15.15 per cent in August respectively. Gaunt and Corwin (1964) reported from a study of five breeds that milk fat, protein, solids-not-fat and total solids content for all breeds were highest in the tenth and eleventh month of lactation. Chawla and Mishra (1977) reported from their study of 142 karan swiss cross breds, 101 sahiwals and 45 Red Sindhis that the percentage of total solids in the milk averaged 13.55 ± 0.08, 14.32 ± 0.17 and 14.52 ± 0.21 in the 3 groups respectively. Bhatia (1960) from his study on over 1000 samples of cows milk reported that the ranges of variation for fat, 4.44 to 7.18 per cent, total solids, 13.03 to 16.14 per cent and solids-not-fat 8.11 to 9.55 per cent. In 92 samples of buffalo milk, the range was fat, 5.10 to 8.32 per cent, total solids, 15.00 to 18.34 per cent and solids-not-fat 8.65 to 10.30 per cent. Sharma _et al._ (1979) studied the average fat, and solids-not-fat percentage in the milk of three pure bred Zebu Cattle (Tharparkar, Sahiwal, and Red Sindhi) and their crosses with Brown-Swiss. The average fat percentage in a lactation ranged from 4.58 to 4.83 and that of solids-not-fat percentage from 9.00 to 9.13. They observed that the fat and solids-not-fat in cross bred cattle was significantly higher compared to pure bred Zebu cattle. The fat and solids-not-fat yield was the highest in F_1 generation half breds and decreased in successive generation as well as blood levels. Though the average fat and solids-not-fat yield ranged within narrow limits, the difference in fat and solids-not-fat yield was due to significant differences in productivity. They further observed that the season of calvings had significant influence on fat and solids-not-fat yield. Animals calving in winter season produced more total solids followed by rainy and summer season. The total solids yield increased upto the sixth lactation and thereafter showed a declining trend.

MATERIALSAND METHODS

MATERIALS AND METHODS

A total of 307 samples of cow milk were collected for determination of total solids content of milk. Out of this 207 samples were obtained from the University Livestock Farm, Mannuthy. The remaining 100 samples of milk were got from the Ollukara Co-operative Milk Society. These samples consisted of those from individual cows as well as pooled milk. A quantity of 250 ml of milk was collected for each sample.

Before analysis, all the samples were kept for one or two hours in order to avoid the Recknagel phenomenon. The collected samples were mixed thoroughly avoiding undue frothing or churning of the butterfat. Poured the sample into a clean dry vessel and back. Repeated this process of pouring to and fro until a homogenous mixture was obtained.

The samples were then analysed for fat by Gerber method as described in Indian Standards I.S. 1224 (1958). A small portion of the sample was used for determining the total solids content by gravimetric method as per the procedure described in Indian Standards I.S. 1479, Part II (1960).

The samples were brought to a temperature of about 15.5°C (60°F) for taking Quevenne's lactometer reading and later to about 84°F (29°C) for finding out the reading using Zeal lactometer.

<u>Determination of fat in milk</u> (Indian Standards IS.1224-1958)

Apparatus:

1) Butyrometers.
2) 10 ml pipette for sulphuric acid or automatic measure for sulphuric acid.
3) 11.04 ml pipette for milk.
4) 1 ml pipette for amyl alcohol.
5) Stopper for butyrometers.
6) Gerber's centrifuge.

Reagents:

1) Sulphuric acid with a density of 1.807 to 1.812 g/ml at 27°C corresponding with a concentration of sulphuric acid from 90 to 91 per cent by weight.
2) Amyl alcohol.

Procedure:

Transferred 10 ml of sulphuric acid into the butyrometer by means of the 10 ml pipette for sulphuric acid, taking care not to wet the neck of the butyrometer with sulphuric acid. Added 11.04 ml of milk sample into the butyrometer by means of the 11.04 ml pipette, the temperature of sample being brought to approximately 27°C when it was added. Added 1 ml of amyl alcohol into the butyrometer by means of the 1 ml pipette. Closed the neck of the butyrometer firmly with the stopper without disturbing the contents. The butyrometer was carefully shaken without inverting it, until the contents were thoroughly mixed, the curd was dissolved, and no white particles were seen in the liquid. Then inverted the butyrometer a few times to mix the contents thoroughly. Placed the butyrometers in Gerber's centrifuge with the neck facing towards the centre and balancing the rotating disc. Centrifuged at the maximum speed for 4 minutes. Transferred the butyrometers with the stopper downwards, into a waterbath having a temperature of 65° ± 2°C and allowed to stand for 3 minutes. They were taken out from the waterbath and the fat coloumn was read.

Determination of total solids. Gravimetric method (Indian Standards, I.S. 1479 (1960).

Apparatus:

Shallow flat bottomed dishes of nickel 7 to 8 cm diameter and about 1.5 cm in height.

Procedure:

Weighed accurately the clean, dry empty dish.

Pipetted into the dish about 5 ml of the prepared sample of milk and weighed quickly. Placed the dish, uncovered on a boiling water bath. Kept the base of the dish horizontal to promote uniform drying and protected it from direct contact with the metal of the waterbath. After 30 minutes, removed the dish. Wiped the bottom and transferred to a well ventilated oven at 98 to 100°C. After 3 hours, the dish was removed immediately transferred to a desciccator. Allowed to cool for about 30 minutes and weighed. Returned the dish, uncovered to the oven and treated for 1 hour. Removed to the desciccator, cooled and weighed as before. Repeated if necessary, until the loss of weight between successive weighings did not exceed 0.5 mg. Noted the lowest weight.

Calculation:

Total solids, per cent by weight = $\frac{100\ w}{W}$

Where, W = Weight in 'g' of the residue after drying.

W = Weight in 'g' of the prepared sample taken for t

<u>Determination of total solids using different formula.</u>

The total solids content of milk samples was determined by using, four different formulae viz. Richmond's formula, Richmond's formula as modified by Sebastian *et al.* ISI formula and Ling formula which are described below:

1) Richmond's formula (Davis and Macdonald, 1963):

Total solids content of milk was calculated using the Richmond's formula as given below:

$$T.S. = 0.25\ L + 1.2\ F + 0.14$$

Where, T.S. = Total solids,

L = Quevenne's lactometer reading at 60°F,

F = Fat test.

The lactometer reading was taken with the Quevenne's lactometer which has been previously tested for accuracy, since the Quevenne lactometer is calibrated to give correct reading only at a temperature of 60°F, suitable corrections have to be made in the lactometer reading taken at a temperature other than 60°F. The temperature of milk was adjusted to somewhere between 50 and 70°F for taking the lactometer reading and applying the correction factor to give correct reading. The correction factor of 0.1 was added to the observed lactometer reading for each degree of temperature above 60°F and subtracted for each degree below 60°F (Judkins and Keener, 1960). Fat was determined using the Gerber method.

2) Richmond's formula as modified by Sebastian _et al_.(1974):

Total solids content of milk was calculated using the formula indicated below as suggested by Sebastian _et al_.

$$T.S. = 0.25\ L + 1.2\ F + 0.50$$

Where, T.S. = Total solids,

L = Zeal lactometer reading at 84°F,

F = Fat test.

The lactometer readings were taken with the Zeal lactometer at 84°F which was previously tested for accuracy. The samples of milk were brought to about 84°F to take Zeal lactometer reading. The Fat test was done according to the Gerbar method. The temperature correction was done according to the chart prepared by Sebastian _et al._ (1974).

3) ISI Formula (Indian Standards I.S. 1183, 1965):

Total solids content of milk was calculated using the ISI formula which is given below:

$$T.S. = 0.25D + 1.22\ F + 0.72$$

Where, D = 1000 (d-1),

d = Density of the sample of milk at 20°C,

T.S. = Total solids,

F = Fat content of the sample.

Since density hydrometers for milk testing are not usually available in the market and weighing of milk after warming it to 40°C and again cooling the same to 20°C will be time consuming. Krishnamurthi _et al._ conducted a study to find out whether specific gravity lactometers can be used with suitable modifications to obtain density readings. In this study, lactometer readings were taken without cooling the milk (ie, at 85°F) and a regression equation was arrived at. The lactometer readings obtained at room temperature were converted to density readings by applying the formula suggested.

$$Y = 1.05\ X + 0.26$$

Where, Y = Density reading at 20°C,

X = Lactometer reading at 85°F.

The value of 'Y' was used as the density reading and used in the formula for calculation of total solids. The Fat test was done according to the Gerber method.

4) Ling Formula (Ling, 1956):

$$T.S. = 0.25\ D + 1.21\ F + 0.66$$

Where, T.S. = Total solids,

D = Density hydrometer reading at 20°C,

F = Fat test.

The density hydrometer readings were obtained from the regression equation suggested by Krishnamurthi *et al.* (1977) as described above. The fat content was determined according to the Gerber method.

The density hydrometer readings were obtained on the calculation of total solids by using different formulae and by the gravimetric method were arranged in tables for statistical analysis. Statistical analysis were done according to the standard methods (Snedecor and Cochran, 1967). The values obtained by the gravimetric method and by different formulae for determination of total solids content was compared using paired 't' test.

RESULTS

RESULTS

A total of 307 milk samples were analysed for the determination of total solids content. The average mean values with their standard error of the total solids content of milk by gravimetric method and those calculated by different formulae such as Richmond's formula, Richmond's formula as modified by Sebastian et al.(1974), ISI formula, Ling formula are given in Table 1. In the samples analysed the percentage of fat ranged from 3.0 to 9.0.

The percentage of total solids as determined by the gravimetric method in the milk having different fat percentages from 3.0 to 4.0, 4.1 to 5.0, 5.1 to 6.0, 6.1 to 7.0, 7.1 to 8.0 and 8.1 to 9.0 were 10.95 ± 0.31, 12.86 ± 0.11, 15.03 ± 0.10, 16.08 ± 0.09, 16.53 ± 0.33 and 17.83 ± 0.35 respectively. The frequency distribution of differences in total solids of milk by gravimetric method and calculation by different formulae is given in Table 7. The values obtained for total solids as calculated by the Richmond's formula for the samples containing different ranges of fat percentage from 3.0 to 4.0, 4.1 to 5.0, 5.1 to 6.0, 6.1 to 7.0, 7.1 to 8.0 and 8.1 to 9.0 were 10.88 ± 0.28, 12.78 ± 0.16, 14.87 ± 0.07, 15.89 ± 0.06, 16.95 ± 0.26 and 17.88 ± 0.21 respectively. On calculation by the Richmond's formula as modified by Sebastian et al. the values were

10.38 ± 0.25, 12.33 ± 0.10, 14.38 ± 0.06, 15.33 ± 0.06, 16.23 ± 0.06 and 17.25 ± 0.21 for the samples containing different percentages of fat as indicated above. When ISI formula was used in samples containing 3.0 to 9.0 per cent fat, the percentage of total solids was 11.21 ± 0.29, 13.02 ± 0.08, 15.10 ± 0.01, 16.10 ± 0.25, 16.94 ± 0.08 and 17.89 ± 0.21 respectively. The results of total solids calculated by the Ling formula for milk samples containing 3.0 to 9.0 fat per cent were 11.11 ± 0.29, 12.93 ± 0.11, 15.00 ± 0.05, 15.97 ± 0.08, 16.83 ± 0.03 and 17.89 ± 0.25 respectively. From Table 1, it can be seen that the percentage of otal solids as calculated by the four different formulae were both higher and lower than those obtained by the gravimetric method.

The results obtained for the percentage of total solids by gravimetric method and by calculation using Richmond's formula were statistically analysed for paired 't' test and the 't' values calculated are given in Table 2. It was found that for samples containing 5.1 to 6.0 and 6.1 to 7.0 per cent fat, the 't' values were significant ($P < 0.01$). In order to get a close agreement with the values obtained by gravimetric method, a correction factor of 0.15 and 0.18 has to be added to the value calculated on the basis of Richmond's formula for milk samples containi

5.1 to 6.0 and 6.1 to 7.0 per cent fat respectively. However, no correction factor was found necessary for samples containing 3.0 to 5.0 and 6.1 to 9.0 per cent fat, since the 't' values were not significant.

Table 3 shows the statistical analysis for paired 't' test and the calculated 't' values for the determination of total solids by gravimetric method and Richmond's formula as modified by Sebastian *et al.* (1974). It was found that for milk sample having fat percentage levels from 3.0 to 7.0, the 't' values were significant ($P < 0.01$). For milk samples containing percentages of fat 3.0 to 4.0, 4.1 to 5.0, 5.1 to 6.0 and 6.1 to 7.0, a correction factor of 0.57, 0.53, 0.66 and 0.75 respectively has to be added to the values obtained by using the modified Richmond's formula as suggested by Sebastian *et al.* (1974) in order to have an agreement with the values obtained by the gravimetric method. No correction factor was required to be added for samples having percentage of fat from 7.1 to 9.0, since the 't' values were not significant.

The values obtained from the estimation of total solids by gravimetric method and those calculated on the basis of the ISI formula were statistically analysed for paired 't' test and the calculated 't' values are indicated in Table 4. The 't' value was found to be significant

(P $<$ 0.01) for milk samples containing 4.1 to 5.0 per cent fat. A correction factor of 0.16 was found necessary to be added to the value calculated by the ISI formula in order to get the total solids percentage to be in close agreement with the value determined by gravimetric method. There was no necessity for adding any correction factor for milk sample containing 3.0 to 4.0 and 5.1 to 9.0 per cent fat in as much as 't' values were not significant.

The value obtained by the gravimetric method as well as those calculated using Ling formula were statistically analysed for paired 't' test and the 't' values obtained are presented in Table 5. It was noticed that the 't' values were not significant for milk samples having a fat percentage from 3.0 to 9.0. Therefore a correction factor was not found necessary to be added to the value obtained by the Ling formu in order to get it in agreement to the value obtained by gravimetric method. For all the sample of milk studied, the calculated value obtained by using the Ling formula was in full agreement to that of the gravimetric method.

Table 6 shows the various correction factors to be applied to the value obtained by the different formulae for milk samples of varying fat percentage in the estimation of total solids content of milk in order to be in close agreement with the values of the gravimetric method.

TABLES

Table 1. Mean values of total solids content of milk samples determined by gravimetric method and by calculation with different formulae.

Fat % Range	No. of samples	Gravimetric method	Richmond's formula	Richmond's formula as modified by Sebastian *et al.*	I.S.I. formula	Ling formula
3.0 - 4.0	26	10.95 ± 0.31	10.88 ± 0.28	10.38 ± 0.25	11.21 ± 0.29	11.11 ± 0.29
4.1 - 5.0	90	12.86 ± 0.11	12.78 ± 0.16	12.33 ± 0.10	13.02 ± 0.08	12.93 ± 0.11
5.1 - 6.0	102	15.03 ± 0.10	14.87 ± 0.07	14.38 ± 0.06	15.10 ± 0.01	15.00 ± 0.05
6.1 - 7.0	71	16.08 ± 0.09	15.89 ± 0.06	15.33 ± 0.06	16.10 ± 0.25	15.97 ± 0.08
7.1 - 8.0	12	16.53 ± 0.33	16.99 ± 0.26	16.23 ± 0.06	16.94 ± 0.08	16.83 ± 0.03
8.1 - 9.0	6	17.83 ± 0.35	17.88 ± 0.21	17.25 ± 0.21	17.89 ± 0.21	17.89 ± 0.25

Table 2. Paired 't' test values calculated for total solids by gravimetric method and Richmond's formula and correction factors to be applied.

Fat % Range	Number of samples	't' values calculated	Correction factors
3.0 - 4.0	26	0.4429	-
4.1 - 5.0	90	1.2754	-
5.1 - 6.0	102	2.2127**	+ 0.15
6.1 - 7.0	71	2.1052**	+ 0.18
7.1 - 8.0	12	1.5022	-
8.1 - 9.0	6	0.1687	-

** Significant P ∠ 0.01.

Table 3. Paired 't' test calculated values for total solids by gravimetric method and Richmond's formula as modified by Sebastian _et al._ and correction factors to be applied.

Fat % Range	Number of samples	't' values calculated	Correction factors
3.0 - 4.0	26	3.5723**	+ 0.57
4.1 - 5.0	90	8.1371**	+ 0.53
5.1 - 6.0	102	9.2072**	+ 0.66
6.1 - 7.0	71	7.8016**	+ 0.75
7.1 - 8.0	12	0.9224	-
8.1 - 9.0	6	2.1547	-

** Significant $P < 0.01$.

Table 4. Paired 't' test calculated values for total solids by gravimetric method and ISI formula and correction factors to be applied.

Fat % Range	Number of samples	't' values calculated	Correction factors
3.0 - 4.0	26	1.1376	-
4.1 - 5.0	90	2.4627**	+ 0.16
5.1 - 6.0	102	0.9766	-
6.1 - 7.0	71	0.2218	-
7.1 - 8.0	12	1.2378	-
8.1 - 9.0	6	0.2579	-

** Significant P ∠ 0.01.

Table 5. Paired 't' test calculated values for total solids by gravimetric method and Ling formula and correction factors to be applied.

Fat % Range	No. of samples	't' values calculated	Correction factors
3.0 - 4.0	26	0.7113	-
4.1 - 5.0	90	1.0051	-
5.1 - 6.0	102	0.3828	-
6.1 - 7.0	71	1.0793	-
7.1 - 8.0	12	0.9104	-
8.1 - 9.0	6	0.2303	-

Table 6. Determination of total solids content of milk by specific gravity lactometer.

Correction factors to be applied to different formulae in relation to the gravimetric method for milk samples of varying fat percentage.

Fat % Range	Richmond's formula	Richmond's formula as modified by Sebastian *et al.*	ISI formula	Ling formula
3.0 - 4.0	-	+ 0.57	-	-
4.1 - 5.0	-	+ 0.53	+ 0.16	-
5.1 - 6.0	+ 0.15	+ 0.66	-	-
6.1 - 7.0	+ 0.18	+ 0.75	-	-
7.1 - 8.0	-	-	-	-
8.1 - 9.0	-	-	-	-

Table 7. Frequency distribution of differences in total solids of milk by gravimetric method and calculation by different formulae.

Differences in total solids range	Frequency: Richmond's formula	Richmond's formula modifed by Sebastian *et al*.	ISI formula	Lin formu
above - 1.00	14	9	18	13
- 0.99 to - 0.90	0	1	5	3
- 0.89 to - 0.80	2	2	6	3
- 0.79 to - 0.70	4	1	11	11
- 0.69 to - 0.60	8	1	19	9
- 0.59 to - 0.50	7	1	14	14
- 0.49 to - 0.40	12	0	18	14
- 0.39 to - 0.30	11	3	23	16
- 0.29 to - 0.20	16	8	17	20
- 0.19 to - 0.10	21	6	16	20
- 0.09 to - 0.00	20	6	20	19
+ 0.01 to + 0.10	28	24	33	36
+ 0.11 to + 0.20	30	24	26	25
+ 0.21 to + 0.30	25	15	17	27
+ 0.31 to + 0.40	28	21	15	18
+ 0.41 to + 0.50	22	17	10	16
+ 0.51 to + 0.60	13	24	6	8
+ 0.61 to + 0.70	9	26	5	6
+ 0.71 to + 0.80	9	25	4	9
+ 0.81 to + 0.90	5	19	5	2
+ 0.90 to + 1.00	5	15	4	2
above + 1.00	18	59	15	22

DISCUSSION

DISCUSSION

The determination of total solids content of milk has always been a serious problem - not a problem of process - but a problem of time. For that reason, it has been seldom used as a routine test by the dairy plants. Therefore a simple and economic test within reasonable limits of accuracy is essential in order to become popular in its usage. In general, there are two methods for the determination of total solids in milk. One is based on calculation by different formulae using the lactometer reading and the percentage of fat in milk. The other is the gravimetric method which is a standard one. The latter is time consuming and cannot be used to estimate the total solids in milk in a short time. Among the various methods used to determine the total solids present in milk, the lactometric methods have been recognized as the quickest and simplest.

Eventhough several formulae are available for the determination of total solids in milk contradictory reports have appeared regarding the usage of these formulae. This is especially true in the case of milk having a high percentage of milk fat. The present study was undertaken to derive a suitably modified formula using specific gravity lactometer for the determination of total solids content of of 4 per cent milk (Herrington, 1948). Watson (1957) stated that there are more than 60 different equations suggested by investigators for computing the relation between fat content and specific gravity and solids of milk. These equations appear to give reliable estimates of milk solids only when applied to data from which they were derived and therefore many researchers have suggested constants and corrections in the basic equations in order to make the computed values agree with the experimental ones.

Calculation of total solids using Watson lactometer has been found to be a satisfactory method. Watson (1957) on an analysis of 200 samples of milk from about 25 herds reported that the deviation of the calculated value of total solids from gravimetric method was ± 0.5 per cent of total solids.

Vyas *et al.* (1973) using Watson lactometer found that the difference in total solids varied from 0.01 to 0.05 and indicated that the Watson lactometer can be used for accurate estimation of total solids of Kankrej cows and can replace the gravimetric method. But due to non-availability of such a Watson lactometer in the market, one has to depend on the lactometer commonly used in milk especially having a high fat percentage. In this study, the gravimetric method has been taken as the standard method and the results of total solids obtained by the calculation by four different formulae viz. Richmond's formula, Richmond's formula as modified by Sebastian et al. (1974), ISI formula and Ling formula have been compared with the gravimetric method. The results obtained in the study are discussed below.

From the values obtained for the total solids in milk as calculated by the different formulae and presented in table 1, it will be seen that the calculated values were lower as well as higher than those obtained by the gravimetric method for samples containing different percentages of fat. A similar observation has also been made by Kothavalla et al. (1949) by analysing 562 herd samples from cows as well as buffaloes. They concluded that the calculated values for total solids were higher as well as lower than the values obtained by direct evaporation.

Bhatia (1960) reported that the calculated values for total solids or solids-not-fat in most cases were lower than those obtained by gravimetric method. He also observed that the differences in the values by the two methods were fairly close in the samples of milk from cows, whereas in the case of buffalo milk the difference noticed was almost twice.

In the present study it was noticed that the values obtained by calculation using the different formulae were in agreement with those of the gravimetric method for milk samples containing a higher percentage of fat especiall above 7.0 per cent.

Sharma *et al*. (1979) reported that the fat and solids-not-fat yield in cross bred cattle was significantly higher compared to pure bred Zebu cattle. Therefore it is essential to evolve a suitable correction factor for the values obtained by the different formulae for milk samples with a higher percentage of fat. Eventhough many equations are in existence for the determination of the total solids in milk most of them have not proved satisfactory under all conditions, though each has yielded good results in the hands of its originator. It has been reported that it takes several hours for fat in milk to crystallize when the milk is cooled to 60°F. Therefore, the specific gravity of a sample at 60°F depends not only on the composition of milk, but also on the physical state of fat, whether the sample has been warmed or cooled and how much time was allowed for the sample to reach in equilibrium. This factor has been found to cause differences in specific gravity as great as 0.0002 for each per cent of fat in the sample. The error eventhough not large enough, could produce a difference of 0.2 per cent in the calculated value for solids content dairies in the southern region of this country and normally a small sized specific gravity type lactometer zeal or similar type adjusted to 29°C is used for estimation of total solids in milk.

The hydrometric and gravimetric methods for determination of solids-not-fat in milk were compared by Edwards (1960). He reported that the hydrometer method was of limited use when applied to milk of individual cows. In the analysis of individual samples of milk from cows undertaken during the course of the present study, it has been noticed that there are variations between the calculated values using different formulae as compared to those of the gravimetric method.

Since the calculation of total solids by the four different formulae did not give a correct estimate it was required to apply correction factors to the existing formulae. The data collected in the study were statisticall analysed for paired 't' test and the values obtained by the formula method differed significantly with those of the standard gravimetric method in certain instances. It was observed that addition of a single correction factor to the values obtained by all the different formulae was not enough to give values close to the gravimetric method.

Therefore a number of corrections needed to be applied to the different formulae depending upon the ranges of fat percentage in the samples of milk. The frequency distribution of differences in total solids of milk by gravimetric method and calculation by different formulae is given in Table 7.

The values obtained by calculation using the Richmond's formula were found to be both higher and lower than those obtained by gravimetric method (Table 1). Ramachandran (1953) worked out the applicability of Richmond's formula by analysing a total of 1929 individual herd samples of cows and buffaloes milk and found that the calculated values were both higher and lower than those obtained by gravimetric method. Desai and Patel (1945) reported that the Richmond's formula gave results that were higher than the values obtained by direct evaporation by 1.3 to 3.6. Vyas et al.(1973) noticed that by using Richmond's formula, the results were found to be 0.95 per cent less of total solids. Khalifa (1974) also made a similar observation. In India Schneider et al.(1948) applied Richmond's formula to estimate the total solids in milk and observed ± 1.0 difference. Sharma et al. (1967) stated that the Richmond's formula over estimated total solids percentage by an average of 0.539, 0.557 and 0.518 in the milk of cow, buffalo and mixed herds with a range of 0.441 to 0.582 per cent in cows milk and 0.495 to 0.663 per cent in buffalo milk. From these observations made by different workers it can be seen that there are variations, both lower and higher, in the calculated values by Richmond's formula as compared to be the values of the gravimetric method. Lunder (1970) reported that the Richmond's modified formula with its constant of 0.72 replaced by 0.81 gave satisfactory results for determination of solids in milk.

The results obtained by the gravimetric method and calculated by Richmond's formula were statistically analysed for paired 't' test to get the desired correction for existing Richmond's formula (Table 2). From this table it was noticed that the 't' values were significant ($P \angle 0.01$) for milk samples containing 5.1 to 7.0 per cent, whereas for samples having percentage of fat less than 5.1 or more than 7.0 there was no significant difference. This indicated a need that the two methods were in close agreemen for milk samples having a fat percentage upto 5.0 and those having 7.1 to 9.0 per cent fat. In order to get the results in agreement with standard gravimetric method correction factor of 0.15 and 0.18 was necessary to be added to the calculated values for milk samples containing 5.1 to 6.0 and 6.1 to 7.0 per cent fat respectively. No correction factor was necessary for the other samples having varying percentages of fat.

Similarly the results obtained by the Richmond's formula as modified by Sebastian *et al.* and those determined by gravimetric method were statistically analysed for paired 't' test to get the necessary correction factor. In this case also there was a remarkable variation between the results of two methods and the 't' values were significant ($P < 0.01$) for the samples of milk containing upto 7.0 per cent fat. For milk samples containing milk fat above 7.0 per cent 't' values were not significant and no correction factor was necessary for the values obtained by the formula. The various correction factors that have to be applied to the values of total solids obtained by the use of Richmond's formula as modified by Sebastian *et al.* ($T.S. = 0.25\ L + 1.2\ F + 0.50$) are given in Table 3. In order to get the values obtained by modified Richmond's formula in close agreement with those determined by gravimetric method, a correction factor of 0.57, 0.53, 0.66 and 0.75 was necessary to be added to the values obtained by formula for milk samples containing 3.0 to 4.0, 4.1 to 5.0, 5.1 to 6.0 and 6.1 to 7.0 per cent fat respectively.

From Table 1, it was observed that the values obtained by the ISI formula were slightly higher than those determined by gravimetric method for all the samples. But on statistical analysis of the values, it was found that the differences were not much significant except in the case of samples containing 4.1 to 5.0 per cent fat. The 't' value was significant ($P < 0.01$) for the samples containing 4.1 to 5.0 per cent fat. The analysis of the data obtained in the study revealed that the ISI formula gave lower values for total solids only in the case of milk samples containing 4.1 to 5.0 per cent fat and a correction factor of 0.16 need to be added to the ISI formula (T.S. = 0.25 DH + 1.22 F + 0.72) to get the values in agreement with the values of the gravimetric method. For milk samples having 3.0 to 4.0 and 5.1 to 9.0 per cent fat, no correction factor was required. Mehta (1964) observed that the ISI formula gave lower values for solids-not-fat in buffalo milk by about 0.25 per cent as compared to the values of the gravimetric method. Pruthi and Bhale Rao (1973) also obtained lesser values for total solids in buffalo milk for the ISI formula as compared to the values of the gravimetric method. They have suggested a constant of 0.87 instead of 0.72 in the ISI formula for getting the values close to the gravimetric method.

The paired 't' test calculated values for total solids by gravimetric method and Ling formula are given in Table 5. The statistical analysis of the data for paired 't' test did not reveal any significant difference between the two methods for the different samples of milk containing 3.0 to 9.0 per cent, fat. Therefore no correction factor was needed for getting the values calculated by using the Ling formula to be in close agreement with those of the gravimetric method. The Ling formula (T.S. = 0.25 DH + 1.21 F + 0.66) was found to give results in close agreement with those of the standard gravimetric method without the application of any correction factor.

From the foregoing discussion it would be observed that the values of total solids calculated using the Ling formula were in close agreement with those obtained by the gravimetric method for milk samples containing 3 to 9 per cent milk fat. No correction factor was found necessary to be applied to the formula. When the values obtained by the ISI formula were compared with those of gravimetric method, a correction factor of 0.16 was necessary to be added to the calculated values of total solids in order to be in agreement with the values of the gravimetric method for milk samples containing 4.1 to 5.0 per cent fat and no correction factor was necessary for the other milk samples. The values of total solids determined by gravimetric method were found to be greater than those calculated by the Richmond's formula as modified by Sebastian *et al.* for milk samples having a fat percentage of 3.0 to 7.0. The correction factor to be added to the calculated values obtained by Richmond's formula as modified by Sebastian *et al.* varied from 0.53 to 0.75. In the case of Richmond's formula the value obtained for total solids were less to an extent of 0.15 and 0.18 for milk samples having a fat percentage of 5.1 to 6.0 and 6.1 to 7.0 respectively in order to be in agreement with the values of gravimetric method.

SUMMARY

SUMMARY

The present study was undertaken to derive a suitably modified formula using specific gravity lactometer for the determination of total solids content of milk especially having a high fat percentage. A total of 307 samples of milk, 207 from University Livestock Farm, Mannuthy and 100 from the Ollukara Co-operative Milk Society were collected for determination of total solids content of milk. The fat percentage of samples of milk collected varied from 3 to 9 and 281 out of 307 (91.5%) were above 4 per cent milk fat. These samples were obtained from individual cows as well as from pooled milk. The samples were analysed for the percentage of fat using Gerber method. Total solids content in milk was determined both by the gravimetric method and by calculation using four different formulae viz. the Richmond's formula, the Richmond's formula as modified by Sebastian et al. (1974), ISI formula and Ling formula. The calculated values of total solids were compared with those of gravimetric method which was taken as the standard. The following inferences were drawn.

It was observed from the study that the calculated values of total solids using the four different formulae were both higher and lower than those obtained by the gravimetric method.

Since the calculation of total solids by the four different formulae did not give a correct estimate, it was required to modify the existing formulae by applying a correction factor. The data obtained during the course of study were statistically analysed for paired 't' test and the values obtained by the formula method differed significantly with those of the standard gravimetric method in some cases. It was observed that addition of a single correction factor to the values obtained by the different formulae was not enough to give values to be in agreement to the gravimetric method. Depending upon the range of fat percentage in the milk samples different correction factors were needed to be applied to the different formulae in order to get the values in close agreement with those of the gravimetric method.

The values obtained for determination of total solids by the gravimetric method and those calculated by the Richmond's formula were found to be significant ($P < 0.01$) for milk samples containing 5.1 to 6.0 and 6.1 to 7.0 per cent milk fat. In order to get a close agreement with the values obtained by gravimetric method, a correction factor of 0.15 and 0.18 was necessary to be added to the value calculated by the Richmond's formula for milk samples containing 5.1 to 6.0 and 6.1 to 7.0 per cent fat respectively. However, no correction factor was found necessary for milk samples containing 3.0 to 5.0 and 6.1 to 9.0 per cent fat.

The statistical analysis for paired 't' test for the determination of total solids by gravimetric method and Richmond's formula as modified by Sebastian et al. (1974) were found to be significant ($P \angle 0.01$) for milk samples having fat percentages from 3.0 to 7.0. For milk samples containing fat percentages 3.0 to 4.0, 4.1 to 5.0, 5.1 to 6.0 and 6.1 to 7.0, a correction factor of 0.57, 0.53, 0.66 and 0.75 respectively was necessary to be added to the values obtained by using the modified Richmond's formula suggested by Sebastian et al. (1974) in order to be in agreement with those of the gravimetric method. No correction factor was necessary for samples having fat percentages from 7.1 to 9.0.

The values obtained from the determination of total solids by gravimetric method and those calculated on the basis of the ISI formula were found to be significant ($P \angle 0.01$) for milk samples containing 4.1 to 5.0 per cent fat. The addition of a correction factor of 0.16 to the values obtained by the ISI formula was essential in order to be in agreement with the gravimetric method. For milk samples having a fat per cent from 3.0 to 4.0 and 5.1 to 9.0, no correction was required.

On statistical analysis of the data obtained it was found that no correction was necessary for the values of total solids obtained by using Ling formula to be in agreement with those of the gravimetric method for all the samples of milk studied.

Taking into consideration the above findings it was observed that the Ling formula can be used as such without any correction factor for the determination of total solids content of milk for varying percentages of fat. The order of preference for using the four different formulae for calculation of total solids in milk of varying fat percentage with therefore be (i) Ling formula (ii) ISI formula (iii) Richmond's formula and (iv) Richmond's formula as modified by Sebastian _et al_. (1974).

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BY

BABU MATHEW

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the

requirement for the degree

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Faculty of Veterinary and Animal Sciences

Kerala Agricultural University

Department of Dairy Science

COLLEGE OF VETERINARY AND ANIMAL SCIENCES

Mannuthy - Trichur.

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and 6.1 to 7.0 per cent fat respectively. For the modified Richmond's formula, addition of 0.57, 0.53, 0.66 and 0.75 was necessary for samples containing 3.0 to 4.0, 4.1 to 5.0 and 5.1 to 6.0 and 6.1 to 7.0 per cent fat. The addition of a correction factor of 0.16 to the ISI formula was essential for samples containing 4.1 to 5.0 milk fat to get the values in agreement with the gravimetric method. No correction factor was necessary, if Ling formula was used. The order of preference for using various formulae will be (1) Ling formula (2) ISI formula (3) Richmond's formula (4) modified Richmond's formula.

Ling formula can be used without any correction factor for determination of total solids content of milk for varying percentages of fat from 3.0 to 9.0.

ABSTRACT

The methods of estimating total solids content of milk having a high fat percentage by Richmond's formula ($TS = 0.25\ L + 1.2\ F + 0.14$) using Quevenne's specific gravity lactometer, modified Richmond's formula ($TS = 0.25\ L + 1.2\ F + 0.50$) using Zeal specific gravity lactometer, ISI formula ($TS = 0.25\ DH + 1.22\ F + 0.72$) and Ling formula ($TS = 0.25\ DH + 1.21\ F + 0.66$) using the density hydrometer, along with the percentage of fat estimated by Gerber method were compared with the values obtained by gravimetric method using 307 samples of milk. In all the milk samples analysed the calculated values of total solids by the formulae methods were both higher and lower than the gravimetric values.

Since the formulae methods did not give a true estimate of the total solids in milk, modifications to the existing formulae were required by applying a correction factor. It was observed that depending upon the percentage of fat in milk samples, different correction factors were needed to be applied to the different formulae for getting the values close to the gravimetric method. Addition of a correction factor of 0.15 and 0.18 was necessary to the Richmond's formula for milk samples containing 5.1 to 6.0

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