

**Appraisal of Modification of Richmond Formula for
Calculation of SNF/Total Solids of Cows, Buffaloes
and Mixed Milk from Various Dairy Plants of
Gujarat State**

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**OF
Doctor of Philosophy**

**IN
DAIRY CHEMISTRY**

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***SPECIAL THANKS TO MY HUSBAND
AND
ALL MY FAMILY MEMBERS***

Appraisal of Modification of Richmond Formula for Calculation of SNF/Total Solids of Cows, Buffaloes and Mixed Milk from Various Dairy Plants of Gujarat State

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A B S T R A C T

Milk is a very variable biological fluid. Milk differs widely in composition; the greatest differences are found between among milks of different species of mammals. The variation in milks within a species depends on so many factors difficult to determine accurately the relationship between a specific factor and composition. Milk is in a quantitative sense, fairly constant in composition and properties; there is a considerable quantitative variation. Chemical composition, size and stability of structural elements, and physical properties may all differ among lots of milk. In recent years the solids-not- fat content of milk has come to be regarded as of equal or of greater importance, than the fat per cent.

Judicious payment for milk to producers requires quick methods for estimation of both fat and Solid-Not-Fat (SNF) in milk. Fat can easily be determined by the Gerber and Babcock method fairly accurately. The close relationship existing between specific gravity of fat and total solids in milk has successfully been exploited for the estimation of SNF content in milk. The SNF of milk purchased by different dairies can precisely be determined only through gravimetric method. But in practices, when

hundreds and thousands of samples are brought to the dairy for testing purpose and for determination of value of the milk supplied by milk co-operative societies, the gravimetric test has not been found practical. Under such circumstances, a physical method, lactometer reading method is being used for quick and accurate determination of total solids. While different dairies using different methods of SNF determination, it is observed that the same sample of milk subjected individually would give different SNF per cent results. Hence it is imperative that only a formula which gives closest results to gravimetric method could be adopted. In India there are 20 varieties of Richmond formula for SNF estimation by volumetric method.

Therefore, there is an urgent need for using a uniform Richmond formula by all dairies or otherwise a constant is implicated in basic Richmond equation to have computed value for large number of samples agreeable to gravimetric method.

Based on this available information and data, this study was under taker to develop a modified Richmond formula. Under this study, 5 well-known dairy plants of big capacity of Gujarat state were selected. Fifty samples, each of raw form of cows, buffaloes and mixed milk supplies were collected. In all 150 samples were taken for a period of study from each dairy plant. These samples were subjected to estimation of milk fat, total solids (gravimetric) and TS/SNF (lactometer) estimations.

For Dairy Plant A, total of 50 samples of buffaloes milk were analyzed for milk fat, total solids by gravimetric and lactometer (volumetric) methods. In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids were 15.54, 18.09 and 16.72 respectively, while using M_2 formula, these values were 15.75, 18.37 and 16.96 respectively. While addition of 1.30 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 16.83, 19.38 and 18.02 respectively, and addition of 1.05

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correction factor in M_2 formula, these values were 16.80, 19.42 and 18.02, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 16.55, 19.46 and 18.02, respectively.

Based on values of two sample t-test for TS contents in buffaloes milk from dairy plant, no significant difference was found between gravimetric and volumetric mean for TS in milk by M_1 and M_2 formulae. The frequency distribution was worked out for total solids of buffaloes milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test.

Based on analysis of 50 samples of buffaloes milk collected from dairy plant A, two probable equations are derived statistically which are mentioned given as under $TS = CLR/4 + 1.22 F + 1.3$, and $TS = CLR/4 + 1.2F + 1.05$.

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids of cows milk were 10.96, 13.70 and 12.13 respectively, while using M_2 formula, these values were 11.06, 13.87 and 12.26, respectively. Addition of 0.86 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 11.82, 14.56 and 12.99 respectively, while addition of 0.73 correction factor in M_2 formula these values were 11.79, 14.60 and 12.99, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 11.83, 14.55 and 12.99, respectively.

Based on values of two sample t-test for TS in raw cows milk from dairy plant A, no significant difference was seen between TS obtained by gravimetric and volumetric mean either by M_1 and M_2 formulae. The frequency distribution was worked out for total solids of cows milk by M_1 and M_2 formulae with equation factor.

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The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution.

Based on analysis of 50 samples of cows milk collected from Dairy Plant A, two probable equations are derived statistically are given as $TS = CLR/4 + 1.22F + 0.86$, and $TS = CLR/4 + 1.25F + 0.73$.

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids of mixed milk were 12.30, 15.22 and 13.88 respectively, while using M_2 formula, these values were 12.43, 15.43 and 14.06, respectively. Addition of 1.04 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.34, 16.26 and 14.92 respectively, while addition of 0.86 correction factor in M_2 formula, these values were 13.29, 16.29 and 14.92, respectively. The minimum, maximum and average values of total solids by using gravimetric method were 13.28, 16.45 and 14.92, respectively.

There was no statistical significant difference between gravimetric and volumetric mean for TS in mixed milk by corrected M_1 and M_2 formulae based on the sample t-test. Thus, it could be inferred that the TS finding by gravimetric and volumetric method were almost same for mixed milk from Dairy Plant A. The test for normality was carried out by using Kolmogorov-Smirnov test and plotting frequency distribution.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant A, two probable equations derived statistically are given as $TS = CLR/4 + 1.22F + 1.04$, and $TS = CLR/4 + 1.25F + 0.86$.

For Dairy Plant B, total of 150 samples of each buffaloes, cows and mixed milk were analyzed for milk fat, total solids by gravimetric and lactometer (volumetric) methods. In volumetric method using M_1 formula without correction

factor, the minimum, maximum and average values of total solids were 14.22, 21.26 and 17.20 respectively, while using M_2 formula, these values were 14.37, 21.62 and 17.45 respectively. While addition of 0.86 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 15.09, 22.12 and 18.07 respectively, and addition of 0.61 correction factor in M_2 formula, these values were 14.99, 22.24 and 18.07, respectively. The minimum, maximum and average values of total solids by using gravimetric method were 15.14, 22.22 and 18.07, respectively.

Based on values of two sample t-test for TS contents in buffaloes milk from dairy plant, no significant difference was found between gravimetric and volumetric mean for TS in milk by M_1 and M_2 formulae. The frequency distribution was worked out for total solids in buffaloes milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. Based on analysis of 50 samples, two probable equations derived statistically are given as $TS = CLR/4 + 1.22 F + 0.86$ and $TS = CLR/4 + 1.25F + 0.61$.

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids in cows milk were 10.27, 14.20 and 12.78 respectively, while using M_2 formula, these values were 10.37, 16.43 and 12.92, respectively. Upon addition of 0.57 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 10.83, 16.77 and 13.35 respectively, and addition of 0.42 correction factor in M_2 formula, these values were 10.80, 16.86 and 13.35, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 10.69, 17.01 and 13.35, respectively.

Based on values of two sample t-test for TS in raw cows milk from Dairy Plant B, no significant difference was seen between TS obtained by gravimetric and

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volumetric mean either by M_1 and M_2 formulae. The frequency distribution was worked out for total solids in cows milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. All the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range. Two probable equations derived statistically are $TS = CLR/4 + 1.22 F + 0.57$ and $TS = CLR/4 + 1.25 F + 0.42$.

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids in mixed milk were 13.22, 17.36 and 14.82 respectively, while using M_2 formula, these values were 13.37, 17.62 and 15.01, respectively. Upon addition of 0.75 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.94, 18.08 and 15.53 respectively, and addition of 0.58 correction factor in M_2 formula, these values were 13.90, 18.15 and 15.54, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 14.04, 18.20 and 15.54, respectively.

There was no statistical significant difference between gravimetric and volumetric mean for TS in mixed milk by corrected M_1 and M_2 formulae based on the sample t-test. Thus, it could be inferred that the TS by gravimetric and volumetric method were almost same for mixed milk. The test for normality was carried out by using Kolmogorov-Smirnov test and plotting frequency distribution. Two probable equations are derived statistically given as $TS = CLR/4 + 1.22 F + 0.75$ and $TS = CLR/4 + 1.25 F + 0.58$.

For Dairy Plant C, total of 50 samples of buffaloes milk were analyzed for milk fat, total solids by gravimetric and lactometer (volumetric) methods. The minimum, maximum and average values of total solids were 14.67, 17.06 and 15.81,

respectively in volumetric method using M_1 formula without correction factor, while these values were 14.87, 17.31 and 16.03, respectively using M_2 formula. Upon addition of 0.97 correction factor in M_1 formula, the minimum, maximum and average values of total solids in buffaloes milk were 15.64, 18.02 and 16.78 respectively, and addition of 0.75 correction factor in M_2 formula, these values were 15.62, 18.05 and 16.78, respectively. The minimum, maximum and average values of total solids were 15.38, 18.13 and 16.78, respectively by using gravimetric method.

Based on values of two sample t-test for TS contents in buffaloes milk from Dairy Plant C, no significant difference was found between gravimetric and volumetric mean for TS in milk by M_1 and M_2 formulae with correction factor. The frequency distribution was worked out for total solids of buffaloes milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. Two probable equations are derived statistically given as $TS = CLR/4 + 1.22 F + 0.97$ and $TS = CLR/4 + 1.25 F + 0.75$.

Based on the analysis for milk fat, TS (gravimetric) and TS (lactometer) of cows milk from Dairy Plant C, the minimum, maximum and average values of total solids were 11.81, 13.46 and 12.50 respectively, when M_1 formula without correction factor was used. While using M_2 formula, these values for TS were 11.93, 13.62 and 12.64, respectively. Addition of 0.66 correction factor in M_1 formula gave minimum, maximum and average values of 12.46, 14.11 and 13.16 per cent total solids respectively and addition of 0.52 correction factor in M_2 formula these values were 12.45, 14.14 and 13.16, respectively in the same method using M_1 formula without correction factor,. By using gravimetric method the minimum, maximum and average values of total solids were 12.39, 14.20 and 13.16, respectively.

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The values of two sample t-test of TS of in cows milk collected from Dairy Plant C revealed no significant difference between gravimetric and volumetric mean by corrected M_1 and M_2 formulae. The frequency distribution was derived for total solids of cows milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. Based on analysis of 50 samples of cows milk collected from Dairy Plant C, two probable equations are derived statistically are $TS = CLR/4 + 1.22 F + 0.66$, and $TS = CLR/4 + 1.25F + 0.52$.

In mixed milk from Dairy Plant C, the minimum, maximum and average values for TS content were 12.70, 14.96 and 13.74 and 12.85, 15.16 and 13.91 using M_1 and M_2 formula without correction factor in lactometer method respectively. Upon addition of 0.75 correction factor in M_1 formula, the minimum, maximum and average values of total solids changed to 13.45, 15.72 and 14.49 respectively, and addition of 0.58 correction factor in M_2 formula, these values altered to 13.43, 15.74 and 14.49, respectively. The minimum, maximum and average values of total solids were 13.41, 15.59 and 14.49, respectively by using gravimetric method.

The values of two sample t-test of TS content in mixed milk from Dairy Plant C indicated no significant difference between gravimetric mean and volumetric mean by M_1 and M_2 formulae. The frequency distribution was worked out for total solids of mixed milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. Based on analysis of 50 samples of mixed milk collected from Dairy Plant C, two probable equations are derived statistically are $TS = CLR/4 + 1.22 F + 0.75$, and $TS = CLR/4 + 1.25 F + 0.58$.

For Dairy Plant D, total of 50 samples of buffaloes milk were analyzed for milk fat, total solids (gravimetric) and TS/SNF (lactometer) methods. The minimum, maximum and average TS content in buffaloes milk by gravimetric and lactometric

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method without correction factor (M_1 and M_2 formulae) were 13.52, 18.98 and 16.47; 12.08, 17.24 and 14.81 and 12.25, 17.50 and 15.02, respectively. On addition of 1.66 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.74, 18.90 and 16.47 respectively, and on addition of 1.45 correction factor in M_2 formula, these values were 13.70, 18.95 and 16.47, respectively.

For values of two sample t-test of TS in raw buffaloes milk samples from Dairy Plant D, no significant difference was seen between gravimetric and volumetric mean by modified M_1 and M_2 formulae. The frequency distribution was calculated for total solids of buffaloes milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. Two probable equations derived statistically are $TS = CLR/4 + 1.22 F + 1.66$, and $TS = CLR/4 + 1.25 F + 1.45$.

The minimum, maximum and average values of total solids in cows milk from Dairy Plant D were 7.91, 13.33 and 11.49, respectively for M_1 formula while these values were 8.00, 13.50 and 11.62, respectively for M_2 formula without correction factor in volumetric method. On addition of 1.24 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 9.15, 14.57 and 12.72 respectively, and on addition of 1.11 correction factor in M_2 formula, these values were 9.10, 14.60 and 12.72, respectively. The minimum, maximum and average values of total solids were 8.95, 14.66 and 12.72, respectively in gravimetric method.

The values of two sample t-test for TS content in raw milk samples of cows from Dairy Plant D have been computed. The frequency distribution patterns were calculated for total solids of cows milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. Based on analysis of 50 samples of cows milk collected from Dairy Plant D, two probable equations derived statistically are $TS = CLR/4 + 1.22 F + 1.24$, and $TS = CLR/4 + 1.25 F + 1.11$.

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For mixed milk from Dairy Plant D, the minimum, maximum and average values for TS content by gravimetric method were 12.92, 17.66 and 14.68, respectively. For volumetric method using M₁ formula without correction factor, the minimum, maximum and average values of total solids were 11.73, 16.01 and 13.27 respectively, while using M₂ formula, these values were 11.87, 16.25 and 13.45, respectively. On addition of 1.41 correction factor in M₁ formula, the minimum, maximum and average values of total solids were 13.14, 17.42 and 14.68 respectively, and on addition of 1.23 correction factor in M₂ formula these values were 13.10, 17.47 and 14.68, respectively.

The values of two sample t-test for TS content in mixed milk from Dairy Plant D. The frequency distribution as well as the test for normality was carried out by using Kolmogorov-Smirnov test was carried out for total solids of buffalo milk calculated by modified M₁ and M₂ formulae. Based on analysis of 50 samples of mixed milk collected from Dairy Plant D, two probable equations derived statistically are $TS = CLR/4 + 1.22 F + 1.41$, and $TS = CLR/4 + 1.25 F + 1.23$.

For Dairy Plant E, total of 50 samples of buffaloes milk were analyzed for milk fat, total solids (gravimetric) and TS/SNF (lactometer) methods. In volumetric method using M₁ equation without correction factor, the minimum, maximum and average values of total solids were 14.30, 17.75 and 16.32 respectively, while using M₂ equation, these values were 14.50, 18.00 and 16.56 respectively. On addition of 0.67 correction factor in M₁ equation, the minimum, maximum and average values of total solids were 14.97, 18.40 and 17.00 respectively, and on addition of 0.44 correction factor in M₂ equation, these values were 14.93, 18.43 and 17.00, respectively. The gravimetric method resulted 14.75, 18.50 and 17.00 per cent as minimum, maximum and average values of total solids respectively.

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The values of two sample t-test for TS content of raw buffaloes milk samples from Dairy Plant E were carried out. The frequency distribution was calculated for total solids of buffaloes milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant E, two probable equations were derived statistically given as $TS = CLR/4 + 1.22 F + 0.67$, and $TS = CLR/4 + 1.25F + 0.44$.

Cows milk was analyzed for TS by gravimetric method, milk fat by Gerber method, LR at 29 C and TS by lactometric method. In volumetric method using M_1 equation without correction factor, the minimum, maximum and average values of total solids were 9.74, 14.43 and 11.97 respectively, while using M_2 equation, these values were 9.83, 14.62 and 12.10, respectively. Addition of 0.68 and 0.54 correction factor yielded 10.42, 15.10 and 12.65 and 10.37, 15.16 and 12.65 as the minimum, maximum and average values of total solids in M_1 and M_2 equation respectively. By using gravimetric method the respective minimum, maximum and average values of total solids were 10.46, 14.94 and 12.65.

The values of two sample t-test for TS content in raw milk samples of cows supplies from Dairy Plant E was done the frequency distribution patterns for total solids of cows milk by M_1 and M_2 formulae and the test for normality was carried out by using Kolmogorov-Smirnov test. Based on analysis of 50 samples of cows milk collected from Dairy Plant E, two probable equations were $TS = CLR/4 + 1.22 F + 0.68$, and $TS = CLR/4 + 1.25 F + 0.54$.

For mixed milk from Dairy Plant E, in volumetric method using M_1 equation without correction factor, the minimum, maximum and average values of total solids were 11.87, 16.14 and 14.45 respectively, while using M_2 equation, these values were 12.00, 16.37 and 14.64, respectively. While on addition of 0.94 correction factor in M_1

equation, the minimum, maximum and average values of total solids were 12.81, 17.08 and 15.40 respectively, and on addition of 0.75 correction factor in M₂ equation these values were 12.74, 17.05 and 15.40, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 12.84, 17.14 and 15.41, respectively.

The values of two sample t-test for TS content of raw mixed milk supplies from Dairy Plant E was done. The frequency distribution patterns was worked out for total solids of mixed milk by M₁ and M₂ formulae as well as the test for normality was also carried out by using Kolmogorov-Smirnov test. Based on analysis of 50 samples of mixed milk collected from Dairy Plant E, two probable equations are $TS = CLR/4 + 1.22 F + 0.94$, and $TS = CLR/4 + 1.25 F + 0.75$.

The results revealed that maintaining all the aspects almost same, the correction factor varied from 0.44 to 1.45 for various Dairy Plants. It could be seen that a correction to be applied in M₁ equation ranged from 0.67 to 1.66, while it varied from 0.44 to 1.45 in M₂ equation. The overall equations for buffaloes milk derived were, $TS=CLR/4 + 1.22 F + 1.09$ and $TS = CLR/4 + 1.25 F + 0.86$.

In the cow milk of all Dairy Plants, the correction factor for the calculation of TS varied from 0.57 to 1.24 in M₁ equation while it ranged between 0.42 and 1.11 in M₂ equation. The overall proposed equations for calculating TS in cow milk are $TS = CLR/4 + 1.22 F + 0.86$ and $TS = CLR/4 + 1.25 F + 0.88$.

In the mixed milk of all Dairy Plants the correction factor to be applied ranged from 0.70 to 1.41 for M₁ equation while it varied from 0.51 to 1.23 for M₂ equation of TS calculation. The overall equations proposed for the calculation of TS in mixed milk from various dairy plants are $TS = CLR/4 + 1.22 F + 0.97$ and $TS = CLR/4 + 1.25 F + 0.79$.

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From this study, the modified Richmond formulas for calculating TS/SNF in different milks have been proposed for each individual specific dairy plant. The specific equation worked out for individual dairy plant reflects the region specific chemical composition of milk, array of factors affecting milk composition, numbers of samples taken for working out formulae and other unforeseen observations, which could be seen from correction factor ranging from 0.40 to 1.45 in M₁ and 0.57 to 1.66 in M₂ equation respectively to match with total solids measurements by official method for different milks.

These dairy plants can adopt the overall equations specified for each type of milk, if they enter into agreement for the purchase and sale of milk among dairy plants.

It showed that the equation $TS = CLR/4 + 1.25 F + \text{correction factor}$ was more convenient, and provided the TS/SNF values very close to the results for TS obtained by gravimetric method.

It reflected that these variations in equations proposed for each dairy plant might be from non assignable causes and therefore, every dairy plant has to evolve its own equation for TS/SNF faster measurement by lactometer method.

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CERIFICATE

This is to certify that the thesis entitled “**Appraisal of Modification of Richmond Formula for Calculation of SNF/Total Solids of Cows, Buffaloes and Mixed Milk from Various Dairy Plants of Gujarat State**” submitted by Ms. **Kinjalben Jagdishchandra Patel** Reg. No. **04-1148-2009** in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Dairy Chemistry to the Anand Agricultural University is a record of bonafied research work carried out by her under my guidance and supervision.

Place: Anand

Date: /10/2013

(V. R. Boghra)

Major Guide

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With great reverence, I submit this small piece of work before my lord “Jay shree Swaminarayana”.

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ement**

Place: Anand

Date: /10/2013

(Kinjal Patel)

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CHAPTER 1

INTRODUCTION

Milk is a very variable biological fluid. Milk differs widely in composition; the greatest differences are among milks of different species of mammals. The variations in milks within a species depend on so many factors that it is difficult to determine accurately the relationship between a specific factor and composition. Differences in the composition of milks may be compared in two ways: by comparing the percentages of individual components as they occur in whole milk, or by comparing the percentages of individual components as they occur in the total solids of milk (Webb and Johnson, 1974). Milk is in a qualitative sense, fairly constant in composition and properties; there is a considerable quantitative variation. Chemical composition, size and stability of structural elements, and physical properties may all differ among lots of milk. In recent years, the solids-not-fat content of milk has also been regarded as of equal or of greater importance, than the fat percentage.

Milk payment systems for farm milk vary from country to country. Some countries determine the price of milk per unit volume, for example \$/lit and others per unit weight, such as \$/kg (Bulletin of IDF, 1995). In countries where dairying is well developed, a classified pricing system is followed. The basis of this classification is the use to which milk is put, i. e. where it is intended for liquid consumption or for manufacture of products. Milk for liquid consumption receives a different price as compared with milk intended for manufacture of products. The former is priced higher and is regarded as “premium price”. Both quality and quantity are considered in this system of pricing. In India, different situation exists. The procurement price is generally the same for fluid and for manufacturing milk. The reasons for this are (a)

milk producers have to be given better prices to produce more milk (b) at the same time, consumer on an average can't afford to pay an escalating milk price corresponding the incentive price for producers. Therefore, many payment schemes started by paying on fat only, mainly because this was the only parameter which could be easily tested for a large number of samples. Other components used for milk assessment are solids-non-fat, lactose, and milk solids (IDF, 1995). Milk fat is therefore, most widely used component, determining milk price in many countries.

Judicious payment of milk to producers requires quick methods for estimation of both fat and Solid- Not- Fat (SNF) in milk. Fat can easily be determined by the Gerber and Babcock method fairly accurately. The close relationship existing between specific gravity, fat and total solids of milk has successfully been exploited for the estimation of SNF content in milk (Pruthi and Dutt, 1977). The SNF of milk purchased by different dairy can precisely be determined only through gravimetric method. But in practices, when hundreds and thousands of samples are brought to the dairy for testing purpose and for determination of value of the milk supplied by milk co-operative societies, the gravimetric test has not been found practical. Under such circumstances, a physical method, lactometer reading method is being used for quick and accurate determination of total solids.

The lactometer or hydrometer is used for estimation of specific gravity of milk. Specific gravity determination is generally performed only on liquid products. The Specific gravity can be measured in a number of ways (a) by measuring the weight of known volume either with a pyknometer or with a hydrostatic balance or (b) by measuring the volume of a known weight with the help of a hydrometer or lactometer. The measurement performed either with pyknometer or hydrostatic balance or hydrometer is based on a well- known Archimedes's principal "that buoyed

up by a force equal to the weight of the liquid it displaces”. In other words a floating object sinks until it has displaced a weight of fluid equal to its own weight.

Specific gravity is the ratio of the density (mass of a unit volume) of a substance to the density (mass of the same unit volume) of a reference substance. At the same temperature apparent specific gravity is the ratio of the weight of a volume of the substance to the weight of an equal volume of the reference substance. The reference substance is nearly always water for liquids or air for gases. Temperature and pressure must be specified for both the sample and the reference. An instrument to find out the content of the water in the milk or to test the richness of the milk is thus termed as 'lactometers'. The construction of this instrument is very unique as there is long vessel test tube and meter bulb attached to it so that whenever the milk is poured into the vessel the meter bulb starts floating on it. The purity of the milk gets tested without any dilution of water content in it. The various lactometers are known for their precision design, accurate measurement and reliability. These lactometers are used highly at milk processing units and at dairies. Similarly, all lactometers are required to be calibrated at a particular temperature and only if that particular temperature is maintained in the milk then lactometer will give the correct reading. For day to day use in milk testing laboratory small size lactometer is available. Mostly, lactometer (Zeal lactometer) calibrated at 84 F is available and many dairies are using this lactometer for determination of SNF content of milk (Patel and Gandhi, 1980). Zeal lactometer at 84 F is widely used but they maintain different temperatures, where as Zeal lactometer works précised at 84 F only.

In dairy industry, Richmond formula based on relation among milk constituents for calculation of SNF of milk plays an important role. SNF is the second important component of milk after fat. It is extensively used while receiving,

dispatching and in- processing standardization of milk. Farmers get due price for their milk as they are paid correctly on fat and SNF (Sandhu, 2003). The corrected lactometer reading coupled with the fat content of milk as determined by Gerber test provides data for application of Richmond formula by which either the total solid content or the solids- not- fat of milk tested could be calculated. However, experience has proved that the Richmond formula suggested for specific gravity lactometers was not justifiable when applied to different lactometers and erroneous results were obtained. This error in calculation would also affect payment related to the quality of milk in which the producer, the procurer, the processor and the consumer are affected.

Different investigators have proposed different equations for estimation of total solids and SNF content in milk from the specific gravity and fat contents. There are several equations. Rapid lactometric estimation of SNF in milk with reasonable accuracy is of paramount important in procurement and payment of milk. Lactometric measurements and the mathematical formula for estimating SNF, contribute to errors under different situations. Every investigator has proposed a new constant or correction in the basic equation (Murlidhar and Prasad, 1993). A formula for calculating the percentage of total solids and solids-not-fat in milk has been studied in the United States and abroad for many years. More than 60 different equations for computing the relation between the fat content and specific gravity and the solids of milk have been submitted by investigators (Watson, 1957). These equations appear to give reliable estimates of milk solids only when applied to data from which they were derived. Many researchers have substituted constants and corrections in the basic equations, in order to make the computed values agreeable with the experimental values. The different constants, corrections, and divergences in the calculated values have caused confusion and doubt concerning the fundamental reliability of the

method. The lag in the development of a more satisfactory method may be due to the emphasis that has been placed for many years on the fat content of milk as the basis for paying producers. The growing importance of the non fat milk solids in the economy of the dairy industry has made it urgent to have a quick and economical method for determining milk solids, which would be comparable in speed and accuracy to the test for fat (Watson, 1957).

While different dairies using different methods of SNF determination, it is observed that the same sample of milk subjected to them individually would give different SNF % results. Hence it is imperative that only a formula which gives closest results to gravimetric method should be adopted. In India there are 20 varieties of Richmond formula for SNF estimation by volumetric method (Ganguly and Kuchroo, 1980). When different dairies get into contract for purchase and sale of milk in large quantities, it is quite likely that shortages in SNF contents will create big disputes (Patel and Gandhi, 1980). Therefore there is a urgent need for using a uniform Richmond formula for all dairies or otherwise use constant in basic Richmond equation to have computed value for large number of samples agreeable to gravimetric method. Keeping in view the above facts, the present study was undertaken with the following objectives.

Objectives:

1. To estimate the SNF/ TS of cow's, buffaloes and mixed milk by lactometer method and gravimetric (oven) method.
2. To validate the lactometer reading with measurement of weight of known volume of milk using sp. gravity bottle method.
3. To equate the data of SNF/TS by both the methods in basic and to modify either the fat factor or to introduce correction factor for Richmond formula.

4. To suggest the modified Richmond formula for all the three types of milk.
5. Statistical analysis.

REVIEW OF LITERATURE

Milk has long been recognised as the most complete single food available in nature for the maintenance of health and promotion of growth of the mammal. Milk is a fluid secreted by the female of all mammalian species for the primary function of meeting the complete nutritional requirements of the neonate of the species. In addition, milk serves several physiological functions for the neonate. Most of the non-nutritional functions of milk are served by proteins and peptides which include immunoglobulin, enzymes and enzyme inhibitors, binding or carrier proteins, growth factors and antibacterial agents (Singh *et al.*, 1997).

2.1 Milk composition

Milk may be defined as the whole, fresh, clean, lacteal secretion obtained by complete milking of one or more healthy milch animals, excluding that obtained within 15 days before or 5 days after calving or such periods as may be necessary to render the milk practically colostrums-free and containing the minimum prescribed percentages of milk fat and Milk-Solids-Not-Fat (MSNF). As per PFA (2009) Milk, is the normal mammary secretion derived from the complete milking of healthy milch animal without either addition thereto or extraction there from. It shall be free from colostrum. Milk is a heterogeneous product in which fat, protein, sugar, vitamins and mineral salts are held in emulsion, colloidal suspension or solution in the major constituent, water.

Milk is a unique biological secretion of mammary gland, endowed by nature with nutrients. Milk is closely associated with reproduction among mammals, and its yield and composition varies among various species to meet the post- natal growth requirements of their offspring (Aneja and Mathur, 2002). Altogether, milk probably

*.....Review of
Literature*

contains on the order of 1,00,000 different molecular species (Walstra and Jenness, 1984). An average composition of buffalo and cow milk from different countries are given in Table 2.1 and Table 2.2 respectively.

Table 2.1 Average composition (per cent) of buffalo milk from different countries

Breed	Water	Fat	Protein	Lactose	Minerals	SNF
Bulgarian	82.6	7.5	4.3	4.8	0.8	9.9
Carabaos	78.5	9.7	6.0	4.3	0.8	11.2
Caucasian	82.7	7.6	4.0	5.2	0.7	9.8
Chiness	76.8	11.55	6.0	3.7	0.9	10.6
Egyptian	82.1	7.2	4.2	4.9	0.8	10.0
Hungarian	83.8	7.2	3.6	4.6	0.8	9.0
Italian	81.9	7.3	4.3	5.0	0.8	10.2
Murrah (Indian)	82.75	7.95	4.3	5.1	0.8	10.0
Rumanian	81.8	8.2	4.8	4.5	0.8	10.0
Russian	81.0	8.35	4.8	4.8	0.9	10.5
Sichum	77.6	10.3	5.2	6.1	0.8	12.1

(Rao and Nagarcenkar, 1977)

Table 2.2 Average composition (per cent) of cow milk from different countries

Breeds	Water	Fat	Protein	Lactose	Ash	SNF
Jersey	85.27	5.14	3.80	5.04	0.75	9.59
Guernsey	85.47	4.96	3.84	4.98	0.75	9.57
Ayrshire	87.10	3.85	3.34	5.02	0.69	9.05
Shorthorn	87.43	3.03	3.32	4.89	0.73	8.94
Friesian	88.01	3.45	3.15	4.65	0.68	8.48

(Rai, 1964)

In India, the term 'milk', when unqualified, refers to cow or buffalo milk, or a combination thereof. Milk might seem to be a simple white liquid, but in fact, it is a complex mixture of a wide range of compounds. The components include water, fat, protein, lactose, mineral substances, organic acids, and other miscellaneous compounds. Milk is an emulsion of fat globules and a suspension of casein micelles (calcium casinate phosphate complex), all of which are suspended in an aqueous phase that contains soluble lactose, whey proteins, and some minerals. Leukocytes in milk

are part of the suspended phase. Gross compositions of milk of different species are shown in Table 2.3.

Table 2.3 Gross composition of milk from different species

Species	Constituents (Per cent)				
	Water	Fat	Protein	Lactose	Ash
Buffalo	84.2	6.6	3.9	5.0	0.7
Cow	86.3	4.9	3.4	4.1	0.7
Goat	86.5	4.5	3.5	4.7	0.8
Sheep	83.7	6.0	4.8	4.9	0.8
Human	87.43	3.75	1.63	6.98	0.21
Porpoise	42.11	45.8	1.19	1.33	0.57
Rabbit	69.50	10.45	15.54	1.95	2.56
Elephant	68.00	19.60	3.10	8.80	0.50
Ass	91.23	1.15	1.50	6.00	0.40
Mare	90.18	1.59	2.14	6.73	0.42
Reindeer	85.32	19.73	1.91	2.61	1.43
Camel	87.61	5.38	2.98	3.26	0.7
Monkey	-	3.93	2.09	5.89	0.26

(Jensen, 1995)

Milk solids are basically composed of fats, protein, lactose, and ash (Jacobson, 1992). The solid constituent of milk, other than fat, is often grouped as solid-not-fat, the percentage of which is calculated as the difference between the total solids and fat content (Jenness and Patton, 1959). Milk SNF means milk solids-not-fat, comprising protein, carbohydrates, vitamins, minerals, etc in milk. This selection deals only with the variation in gross composition that is in the contents of water, fat, lactose, proteins and ash. These constituents are almost constant in milk but variation exists in fat content.

2.1.1 Water

Water is major component in milk. Water plays important role in many physico-chemical properties of milk. Water is an important plasticizer of non-fat milk solids. Water has higher melting and boiling temperature, surface tension, heat capacity than similar molecules. Water, has maximum density at 3.98 C (Lewin, 1972). However, the changes of volume of milk with temperature are greater than that

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of water (Fleischmann, 1885). Water is the medium in which all the other components of milk (Total Solids) are dissolved and suspended (Aneja and Mathur, 2002). The addition of water is the simplest way to increase the supply that changes the density of various constituents and physico- chemical properties. The presence of extraneous water in milk is illegal in most countries (Harding, 1983). Water is lighter than milk, and therefore a given volume of milk weighs less if it contains some extraneous water (Walstra and Jenesse, 1984).

2.1.2 Milk fat

Milk fat is the most variable of all milk components. In milk fat, triacylglycerol are the major lipid class accounting for 97-98 per cent of the total lipid. In addition, small amounts of several substances such as di- and mono-acylglycerols, free cholesterol and cholesterol esters, unesterified fatty acids, and phospholipids are present (Christie, 1983). Each fat globule is surrounded by a membrane consisting of phospholipids and proteins; these emulsifiers keep the individual globules from joining together into noticeable grains of fat and also protect the globules. In un-homogenized cow's milk, the fat globules average about four micrometers across. The fat-soluble vitamins A, D, E, and K are found within the milk fat portion of the milk (William and Lawrence, 2005).

2.1.3 Milk protein

Milk contains number of protein components, which differ in composition. They are the principal nitrogenous constituents of milk, made up of several amino acids bound together by peptide bonds. In milk they are present partly in true solution and mostly as colloidal suspension. The main proteins of milk are caseins, α -lactalbumin and β -lactoglobulins. The protein fraction of milk has unique nutritional

value due to its favorable balance of essential amino acids (Henry, 1957 and Kon, 1962). The percentage of protein in milk is always less than fat. Milk protein might bear the increased economic value that would be essential to encourage greater relative production of protein than fat in future dairying. The largest structures in the fluid portion of the milk are casein micelles aggregates of several thousands of protein molecules, bonded with the help of nanometer-scale particles of calcium phosphate. Each micelle is roughly spherical and about a tenth of a micrometer across. There are four different types of casein proteins, and collectively they make up around 80 per cent of the protein in milk by weight. Most of the casein proteins are bound into the micelles. There are several competing theories regarding the precise structure of the micelles, but they share one important feature: the outermost layer consists of strands of one type of protein, k-casein, reaching out from the body of the micelle into the surrounding fluid. These kappa-casein molecules all have a negative electrical charge and therefore repel each other, keeping the micelles separated under normal conditions and in a stable colloidal suspension in the water-based surrounding fluid (Archibald, 1958).

2.1.4 Milk carbohydrates

Lactose is unique to milk. It gives milk its sweet taste and responsible for many colligative properties of milk. Lactose is a disaccharide composite of two **simple sugars, glucose and galactose** (Guleria, 1998). It is a reducing sugar and the reducing group lies at carbon number one of the glucose moiety. Milk also contains traces of glucose, galactose and sialic acid derivatives such as N-acetyl Neuraminic acid (Mathur *et al.*, 1952).

2.1.5 Milk minerals

The amount of non combustible matter in milk is designated as the ash content of milk. In normal milk the value remains constant at 0.7 per cent. A much higher

value than this is indicative of abnormal conditions in secreting mammary gland. The minerals in milk are inorganic salts, partly ionized and partly present as complex salts (Webb and Johnson, 1974). The major elements are calcium, phosphorus, potassium, magnesium, chlorine and sodium. In addition to major minerals, milk contains several trace elements.

2.2 Variations in milk composition

Milk is not a uniform article of commerce, but varies considerably in composition. The variations are caused for the most part by the interplay of a number of factors affecting the physiology of the cow and buffalo, but some variation may result from treatments following milking. Since the extent of variation is appreciable, various analyses are necessary to insure that buying and selling are conducted on an equitable basis, and that minimum nutritive requirements as defined by legal standards are met (Jenness and Patton, 1959). Milk is a very variable biological fluid. Milk differs widely in composition, the greatest differences between among milks of different species of mammals. Apart from the gross variation, minor differences are noticeable in the proportion of the constituents of milk of animals of the same species maintained in different parts of the world. The variations in milks within a species depend on so many factors difficult to determine accurately the relationship between a specific factor and composition. Differences in the composition of milks may be compared in two ways: by comparing the percentages of individual components as they occur in whole milk, or by comparing the percentages of individual components as they occur in the total solids of milk (Webb and Johnson, 1974). Milk is in a quantitative sense, fairly constant in composition and properties but there is a considerable quantitative variation. Chemical composition, size and stability of structural elements, and physical properties may all differ among lots of milk. Variation in fat content has been studied far more extensively than those in the other

constituents because of the greater economical value that has been attached. The recently reviewed interest in the solids- not- fat content of the milk has been stimulated the current surplus of fats, calorie- conscious milk consumers, and a recognition of the presence of high quality proteins in this portion of the milk. Ultimately, these factors may bring forth a greater effort on the part of dairy cattle breeders to increases the SNF content of milk, along with a more realistic milk pricing plan designed to recognize the real value of SNF. Such plans, in varied versions, are being employed presently in a few manufacturing areas. Despite the apparent selling points, one must recognize that such pricing schemes have little merit in a fluid milk market. It should be stated that the present situation of surplus and subsidy is not conducive to a change in the pricing structure. In such a market, the dairy plant must be ready to launch into a breeding and testing program geared to the SNF portion of milk (Brunner, 1958).

In appraising the opportunity to improve the quality of milk, the important roles which both the genetic and environmental elements can play must be recognized and understood. In the genetic analysis of milk composition, the importance of accounting for general environmental factors is well recognized. Legates (1960) suggested that there also should be awareness of the genetic influences on SNF when the assessments of non genetic influences are undertaken. In recent years the solids- not- fat content of milk has come to be regarded as of equal or of greater importance than the fat percentage. This change is the result of an increased awareness of the nutritive value of milk protein and the other non-fatty constituents, in particular calcium and vitamins. Partly because of this nutritional interest and partly because of the number of milk samples failing to satisfy the presumptive legal standards, the level of SNF in milk during the last 10 years has been subjected to considerable scrutiny and the figures comparable with earlier records (Waite *et al.*, 1956). The

increased emphasis now being placed on the solids-not-fat (SNF) and total solids portion of milk makes it essential that the dairy breeder and the producer should know more about factors that cause variation in these constituents in the milk of individual cows. The effect of certain environmental factors on the composition of milk under various conditions has been reported by several workers (Johnson *et al.*, 1959; Jenness and Patton, 1959; Webb and Johnson, 1974). This may be the result of natural variation or change occurring after the milk has been drawn. Natural variations in milk composition may have the following causes:

- A. Genetic, between breeds of cow or between individual,
- B. Physiological, particularly stage of lactation, and also age of cow, estrus and gestation
- C. Environmental, particularly feed and also climate

Variability in the composition and properties of milk has several consequences for the dairy industry. There are many factors which influence the TS quantity and milk composition include breeds, environmental conditions, animal health, udder condition and nutritional quality of the cows and buffaloes (Jacobson, 1992).

2.2.1 Genetic variation

The current approach to the genetic improvement of traits, e.g., the composition of milk, requires a thorough appraisal of the existing genetic and environmental relationships both between and within breeding groups. Breed differences in SNF have long been recognized but the economic emphasis on fat content and the lack of satisfactory field procedures for determining the composition of SNF deterred the study of variation within breeds (Legates, 1960). These several strains of dairy cattle have inherited varieties as a result of long continued segregation and inbreeding, rather pronounced and characteristics differences in the composition of milk that they produce. The variability in composition of milk among cows within

the breed results partly from hereditary differences and partly from environmental factors (Ozrenk and Inci, 2008). There is a maximum variation in per cent of fat content due to breed. Milk produced by an individual cow or a group of cows of the same breed is generally quite uniform in composition so long as the cows are receiving diets adequate in roughage and balanced for other nutrients. Milk of different breeds of cows and buffaloes varies in fat, solids-not-fat (SNF), energy value, and certain vitamins (Webb and Johnson, 1974).

2.2.1.1 Species

The composition of milk also differs within species. An average composition of some important species is presented in Table 2.4.

Table 2.4 Average composition (per cent) of milk from different species

Milk constituent	Buffalo	Cow	Sheep	Goat	Human
Fat	7.0	4.3	6.0	4.5	3.5
Protein	4.0	3.4	4.8	3.8	1.9
Lactose	5.1	4.8	5.0	4.7	6.5
Minerals	0.8	0.7	0.5	0.5	0.2
SNF	9.8	9.0	10.3	9.0	7.3
Total solids	16.7	13.3	16.3	13.5	12.1

(Rao and Ramamurthy, 1973; Sindhu and Singhal, 1988; Tzankova, 2001)

2.2.1.2 Breed and individual cow and buffalo

Milk composition varies considerably among breeds of dairy cattle. Jersey and Guernsey breeds give milk of higher fat and protein content than Shorthorns and Friesians. Zebu cows can give milk containing up to 7 per cent fat. The breed averages for percentage of milk fat, total protein, true protein and total solids is given in Table 2.5. Rangappa and Achaya (1973) found such variations to be greater among buffaloes than among cows. The departure from the average composition naturally decreases with the bulking of milk of increasing numbers of animals. The

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composition of milk of individual cows and buffaloes, each belonged to the same breed has been given in Table 2.6.

Table 2.5 Breed averages for percentages of milk fat, total protein, true protein and total solids

Breed	Total fat	Total protein	True protein	Total solids
	Per cent			
Ayrshire	3.88	3.31	3.12	12.69
Brown Swiss	3.98	3.52	3.33	12.64
Guernsey	4.46	3.47	3.28	13.76
Holstein	3.64	3.16	2.97	12.24
Jersey	4.64	3.73	3.54	14.04
Milking shorthorn	3.59	3.26	3.07	12.46

(Mahana, 1995)

Table 2.6 Variations in composition of milk due to individuality of animal

Animal	Sp.gravity at 60 F	Fat (per cent)	SNF (per cent)
Red Sindhi cow			
1	1.0322	5.69	9.03
2	1.0324	4.81	8.46
3	1.0293	4.66	8.16
Murrah buffalo			
1	1.0334	7.05	9.49
2	1.0334	7.38	9.64
3	1.0340	6.57	9.41

(Rangappa and Achaya, 1973)

2.2.1.3 Variations among breeds

The widest variations in the composition of milk are due the differences in the breed of cattle. The potential fat content of milk from an individual cow is determined genetically as are protein and lactose levels. Thus, selective breeding can be used to upgrade milk quality. Heredity also determines the potential milk production of the animal. However, environment and various physiological factors greatly influence the amount and composition of milk that is actually produced. The summary of breed differences in the composition of milk which Turner (1936) prepared has been used widely to depict breed averages. However, the information summarized by Armstrong (1959) includes some data and the values for fat and SNF percentage are included in

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Table 2.7. The variations in composition of buffalo milk are shown in Table 2.8. Great variations occur in the composition of milk from animal to animal in to same breed. The more important breeds of dairy cattle in India are the Red Sindhi, Tharparkar, Gir, Hariana, Kankrej, Ongole and Sahiwal cows and the Murrah, Jaffarabadi, Surti, Mehsana the Nagpuri buffaloes. The average composition of milk of different breeds of Indian cows and Murrah buffalo has been shown in Table 2.9. The sp. gravity, total dry matter as well as the other constituents of buffalo milk appreciably exceeds those of cow milk. But the greatest disparity occurs in the fat content. There seems to be no reason therefore why the buffalo should not entirely replace the cow in the dairy unless it to satisfy differences, if any, between the two types of milk in their physiological and perhaps psychological functions in the human consumer. To recommend if further is the large immunity to tuberculosis which the buffalo is said to enjoy, to which even the Indian cow is susceptible. The preponderance of buffaloes in large commercial dairies coming up in the country exhibit a positive trend in this direction (Rangappa and Achaya, 1974).

Table 2.7 Breed differences in the percentage composition of bovine milk

Breed	Turner (1936)				Armstrong (1959)			
	Fat	Protein	Lactose	Ash	T.S	S.N.F.	Fat	S.N.F.
Ayrshire	4.00	3.53	4.67	0.68	12.90	8.90	4.15	8.96
Brown Swiss	4.01	3.61	5.04	0.73	13.41	9.40	4.02	9.39
Guernsey	4.95	3.91	4.93	0.74	14.61	9.66	4.99	9.32
Holstein	3.40	3.32	4.87	0.68	12.26	8.86	3.49	8.61
Jersey	5.37	3.92	4.93	0.71	14.91	9.54	5.51	9.49
Range	1.97	0.60	0.37	0.06	2.65	0.80	2.02	0.88

(Legates, 1960)

Table 2.8 Variation of composition of milk according to the breed of buffalo

Breed	Fat	SNF
Murrah	6.8	10.1
Jaffarabadi	7.3	10.1
Surti	8.4	10.3

(Rangappa and Achaya, 1974)

Table 2.9 Average composition (per cent) of milk of different breeds of Indian cows and Murrah buffalo

Composition	Cow					Murrah Buffalo
	Red Sindhi	Gir	Tharparkar	Sahiwal	Cross bred	
Lactometer reading (68 F)	29.41	29.03	29.36	29.88	29.27	30.6
Acidity (% Lactic acid)	0.15	0.16	0.16	0.16	0.16	0.15
Fat	4.90	4.73	4.55	4.55	4.50	6.56
SNF	8.76	8.63	8.70	8.82	8.63	9.19
Total solids	13.66	13.30	13.25	13.37	13.13	15.75
Lactose	4.91	4.85	4.83	5.04	4.92	5.23
Crude proteins	3.42	3.32	3.36	3.33	3.37	3.88
Ash	0.70	0.66	0.68	0.66	0.67	0.17
Calcium	0.20	0.21	0.19	0.22	0.19	0.24
Phosphorus	0.28	0.24	0.25	0.25	0.23	0.26
Citric acid	0.20	0.19	0.18	0.18	0.18	0.18
Chloride	0.09	0.09	0.09	0.09	0.09	0.07
Casein	2.61	2.56	2.59	2.55	3.59	3.00
Non protein nitrogen	0.03	0.03	0.03	0.03	0.03	0.03

(Rangappa and Achaya, 1974)

2.2.1.4 Intra-breed genetic variation

The probable response of a trait to selection demand is a function of the nature and magnitude of its hereditary variation, often incompletely summed up as its heritability, and its genetic and environmental inter-relationships with other traits. For dairy cattle, heritability and genetic and environmental inter-relationships are most conveniently estimated from the daughter-dam regression and by an assessment of the variation between paternal half-sisters. There is a glaring paucity of data which is satisfactory for such genetic analysis of SNF (Legates, 1960). If the interrelationships between the percentages of fat, SNF and protein as determined in future studies are as strong as present information suggest, some increase in fat content will rather consistently be expected as selection pressure is applied to increase SNF or protein. Some decline in milk yield also may be anticipated as the genetic level for SNF is increased, but the expected decline on the basis of current information would not be excessive. Moreover, it should be recognized that the total yield of SNF can be

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enhanced most rapidly by increasing milk yield, even though the percentage composition of the individual constituents may decline slightly (Legates, 1960).

Bowman (1972) defined a genotype X environmental interaction as a change in the relative performance of a character of two or more genotypes measured in two or more environments. McBride (1958) and Dickerson (1962) have discussed problems of genotype by environmental interaction in animal breeding. Table 2.10 shows the genetic correlations between constituents as reported by Robertson et al. (1956). The genetic correlations between casein and both fat and lactose were positive and significant. The genetic correlation measures the association between two characters, because the same genes have effects on both characters. The phenotypic correlation contains this genetic component and also a contribution from environmental factors affecting both traits. The genetic correlation is useful in predicting change in one character while selecting for another.

Table 2.10 Phenotypic and genetic correlations (within herds) between constituents

	Yield	Fat	SNF	Crude protein	Casein	Lactose	Ash	
Yield		-0.14	-0.18	-0.26	-0.20	0.08	-0.05	Phenotypic correlation
Fat	-0.01		0.40	0.42	0.43	0.11	-0.03	
SNF	-0.02	0.46		0.81	0.87	0.50	0.12	
Crude protein	0.22	0.48	0.94		0.93	-0.01	0.10	
Casein	0.05	0.56	0.82	0.96		0.17	0.00	
Lactose	-0.16	0.37	0.67	0.41	0.41		-0.28	
Ash	-0.10	-0.42	-0.42	-0.10	-0.24	-0.86		
	Genetic correlation							

2.2.2 Environmental factors

2.2.2.1 Season and climate

The influence of season and climate are difficult to separate from nutritional factors. Seasonal influences on milk composition vary from area to area. There

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appears a tendency for SNF and protein to increase and fat to decrease when grazing begins on lush pasture (Rook, 1961). Lowering of environmental temperatures from 50 to 5 F increased the milk fat, total nitrogen and SNF (Rook, 1961). In addition, studies involving herd milks have suffered from the confusing impact of stage of lactation when seasonal calving" was practiced. Studies both in the United States (Davis *et al.*, 1947; Specht *et al.*, 1956; Wilcox *et al.*, 1959) and in Europe (Bailey, 1952; Waite *et al.*, 1956; Griffith and Featherstone, 1957) have shown that the SNF content in June and July were rather consistently lower than in other months of the year. The lactose content generally was highest when the protein content was lowest, and vice versa. Nonetheless, when the average composition was compiled for a cow's entire lactation, each lactation extended over the greater part of the year and season of calving differences are usually small (Robertson *et al.*, 1956). In controlled climatic chambers, Cobble and Herman (1951) found that SNF content decreased as the temperature rose above 90 F. Presumably, environmental temperature from 30 to 70 F did not appreciably influence the composition of milk (Legates, 1960). Seasonal effects on the fat and SNF percentage of milk have been found the percentage of fat and SNF in milk to be lowest in the summer months and highest during the winter months (Davis *et al.*, 1947; Sherman 1906 and Specht *et al.*, 1956). The data given in Table 2.11 shows the effect of season on composition and yield of milk.

Table 2.11 Effect of season on yield and composition of cow milk

Month	Season	Yield	Total solids	Fat	SNF	Lactose	Ash	Protein
		liter	Per cent					
January	Winter	5.12	13.83	5.14	8.65	4.65	0.7	3.3
February	Spring	4.92	13.43	4.86	8.57	4.69	0.7	3.1
March		4.34	13.57	5.03	8.54	4.66	0.7	3.1
April		4.82	13.31	4.82	8.45	4.73	0.7	3.1
April		4.82	13.31	4.82	8.45	4.73	0.7	3.1
May		4.01	13.54	5.19	8.36	4.15	0.7	3.2

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June	Summer	4.00	13.23	4.84	8.35	4.48	0.7	3.1
July	Rains	3.34	13.35	5.11	8.24	4.23	0.7	3.2
August		4.80	13.61	5.18	8.43	4.44	0.7	3.2
September		5.38	13.14	4.85	8.29	4.60	0.7	3.0
October		6.16	13.44	4.82	8.68	4.60	0.7	3.2
November	Winter	6.01	13.33	4.72	8.60	4.70	0.7	3.2
December		5.01	13.45	4.84	8.61	4.57	0.7	3.2

(Rangappa and Achaya, 1974)

2.2.2.2 Interval between milking

The fat content of milk varies considerably between the morning and evening milking because there is usually a much shorter interval between morning and evening milking than between evening and morning milking. Table 2.12 shows a definite variation generally observed in the fat content of both the individual and herd milk between the morning and evening bulk milk samples. These difference ranges from 0.3 to 1.5 per cent according to the season, breed and individuality of the animal. The fat contents of the bulk samples of Surti buffaloes and Red Sindhi cows, for instance, differ by hardly 0.2 to 0.3 per cent, but those of Gir cow and Delhi buffalo herd vary from 0.9 to 1.2 per cent between the two milkings. Such variation is said to be caused by the difference in the intervals between the milking, the longer the interval, the lower the fat content and higher the yield of milk, and the more frequent the milking, the greater the fat variation (Rangappa and Achaya, 1974).

Table 2.12 Variations in fat content of milk due to the time of milking

Time of milking	Red Sindhi cow	Gir cow	Buffalo
Morning	6.0	3.2	7.1
Evening	6.3	6.2	7.9

(Rangappa and Acharya, 1974)

If cows were milked at 2 hour intervals, the variation in fat content between milkings would be negligible, but this is not practicable on most farms. Normally,

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SNF content does not vary with the length of time between milking. The percentage of fat increases markedly during milking; hence the udder must be affectively stripped if the highest percentage of possible fat is desired in the milk. If high fat milk is left in the udder at one milking, it may be obtained by stripping at a subsequent milking. However, in general it was observed that the first portion of the milk drawn is richest in solids-not-fat but poorest in fat and vice-versa. In other words the fat content increases and the SNF decreases with the progress of milking (Rangappa and Acharya, 1974). The changes in fat and SNF content with the progress of milking have been shown in Table 2.13.

Table 2.13 Composition of different portion of a milking

Portions	Fat per cent	SNF per cent
1	1.04	8.64
2	1.92	8.63
3	3.02	8.51
4	4.40	8.37
5	5.32	8.15
6	7.63	7.77

(Rangappa and Acharya, 1974)

2.2.2.3 Stage of lactation

In the initial and last stage of lactation, there is a significant change in the composition of milk. The milk obtained immediately after calving (colostrum) has entirely different composition as compared to normal milk. The gradual change from colostrums to normal milk has been given in Table 2.14. The month or season of calving had no effect on the milk yield of Red Sindhi cows (Rangappa and Achaya, 1974). Ragab *et al.* (1958) found that, on the other hand, that buffaloes calving in summer averaged a slightly richer chemical composition than winter calvers, while winter calving cows produced more milk. Effect of calving season on buffalo milk has been given in Table 2.15.

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The concentration of milk fat and protein is highest in early and late lactation and lowest during peak milk production through mid- lactation. Normally, an increase in milk yield is followed by a decrease in the per cent of milk fat and protein, while the yields of these constituents remain unchanged or increase (Legates, 1960).

Table 2.14 Gradual change from colostrums to normal milk

Time after calving (hr)	Per cent				
	Fat	Protein	Lactose	Ash	Total solids
0	5.1	17.57	2.19	1.01	26.99
6	6.8	10.00	2.71	0.91	20.46
12	3.8	6.05	3.71	0.89	14.53
24	3.4	4.52	3.98	0.86	12.77
30	4.9	4.01	4.27	0.83	13.63
36	3.5	3.98	3.97	0.84	12.22
48	2.8	3.74	3.97	0.83	11.46
72	3.10	3.86	4.37	0.84	11.86
96	2.8	3.76	4.72	0.83	11.85
120	3.7	3.86	4.76	0.85	12.67

(Webb and Johnson, 1974)

Table 2.15 Effect of calving season on buffalo milk

Calving season	Fat	SNF	TS	Protein	Chloride (mg/100g milk)	Sp.gravity
Summer	6.52	10.10	16.62	3.90	56.05	1.0338
Winter	6.30	10.03	16.33	3.89	59.14	1.0336

(Ragab *et al.*, 1958)

Stage of lactation becomes most important when the influence of certain factors on SNF is being examined in short-term experiments (Legates, 1960). The fat, lactose and protein contents of milk vary according to stage of lactation. Solids-not-fat content is usually highest during the first two to three weeks, after which it decreases slightly. Fat content is high immediately after calving but soon begins to fall, and continues to do so for 10 to 12 weeks, after which it tends to rise again until the end of the lactation. The high protein content of early lactation milk is due mainly to the high globulin content. The content of total solids, SNF, and protein drop rather

precipitously after the first test for the lactation, reaching a low value by the second month in lactation. (Bartlett, 1934; Bailey, 1952; Waite and White, 1956; Nicholson 1958). Lactose content is highest at the beginning of the lactation and declines linearly during the remainder of the lactation (Waite and White, 1956). Gestation also can make an important contribution to the change in SNF during lactation (Gorrie and Harvey, 1953). Bartlett (1934) and Wilcox *et al.* (1959) had found that the content of SNF raised in beginning with the fourth or fifth month of gestation.

2.2.2.4 Age and health

The average fat percentage of milk decreases slightly with the age of the cow (Turner, 1936). The importance of age- yield relationships in dairy records has been recognized for years. Yields of milk, fat, protein and SNF generally increase over the first four lactations (Gravir and Hickman, 1966; Loganathan and Thompson, 1968 and Miller, 1973), and then slowly decline. The decline in milk fat per cent with age was progressive, but appeared to be non significant (Gravir and Hickman, 1966; Blanchard *et al.*, 1966 and Loganathan and Thompson, 1968).

A gradual, though irregular, decrease in solids- not- fat content was also noted with age (Wilcox *et al.*, 1959) and accounted for approximately 12 to 14 per cent of the total variation in Holsteins (Gacula *et al.*, 1968 and Loganathan and Thompson, 1968). The decline in SNF content was largely due to a decrease in lactose. The change in total protein content was small.

The decline in solids- not- fat percentage with age was approximately twice the magnitude of the decline in fat percentage. As cows grew older, the fat content of their milk decrease by about 0.02 percentage units per lactation while the fall in SNF content was about 0.04 percentage units. Both fat and SNF contents could be reduced

by disease, particularly mastitis. SNF in the milk also decreases. The fat and SNF content of milk were found to reach a low level in the first 30-60 days of lactation and then gradually increased during the remainder of the lactation (Ragsdale and Turner, 1922; Becker and Arnold, 1935; Davis and Harland, 1947). Decline in solids-not-fat ranging from 0.21 to 0.45 per cent during the first 7 years of lactation have been reported (Legates, 1960). The increase of SNF in advanced lactation became less pronounced as the cow aged at the ninth lactation SNF was 94.5% of that of the first lactation.

2.2.2.5 Feeding regime

Feeding has a profound effect on milk composition (Van Soest, 1983; Rook, 1961; Legates, 1960 and McCarthy, 1962) but to date no easy or universally profitable means of changing milk composition through feeding have been found.

Feed is one of the major dairy inputs accounting for 45 to 60 per cent of the cost of milk production. Feed cost in the dairy ration can be minimized either by reducing unit costs, by increasing forage quality which may result higher production of milk or reducing protein supplement, or by feeding more forage. Several reviews have been published concerning various aspects of widely varying levels of forage and concentrate feeding for dairy cows (Huffman, 1961; Kesler and Spahr, 1964; Coppock, 1969; Hillman, 1969; Miller and O'Dell, 1969 and Broster, 1972), and of the interrelationship between feeding and milk composition (Legates, 1960; Rook, 1961; Laben, 1963; Van Sorst, 1963; Huber and Boman, 1966 and Storry, 1970). Halley and Dougall (1962) noticed that higher milk yield, lower fat per cent and slightly higher SNF per cent were associated with cows which received concentrate supplement rather than cows just on pasture alone. The transfer of cows from winter feeding to spring grazing was usually associated with a rise in SNF content and a

slight fall in fat content (Waite *et al.*, 1959 and Rook *et al.*, 1960). Murdock and Rook (1963) compared cows fed hay or silage free choice, indicating certain silages could depress SNF content. Varied ration of roughage - to - concentrate have varying effects on milk protein and SNF. Olson *et al.* (1966) and Swanson *et al.* (1967) reported that while fat depression was associated with cows fed liberal concentrates, SNF content was not significantly affected. In general, reduction of energy intake below the recommended standard caused a reduction in milk SNF content (Flux and Patchell, 1957). Small increases in SNF have resulted from increased energy intake well above the standard (Burt, 1957; Holmes *et al.*, 1957; Castle *et al.*, 1959; Bishop *et al.*, 1963; Huber and Boman, 1966 and Yousef *et al.*, 1970). Increases in SNF percentage at high energy intake levels have generally occurred in the protein fraction, mainly α -casein and β -lactoglobulin fraction (Yousef *et al.*, 1970). Changing the feed of cows from full to half production ration has been shown to cause a reduction in yield of milk and a decrease of 0.3 to 0.5 in the percentage of solids- not- fat, but had no consistent effect on the percentage of fat (Riddet *et al.*, 1942).

Feeding more than the normal amount of feed, or feeding additional concentrates, has been reported to increase the solids- not- fat slightly (Webb and Johnson, 1974). The percentage of solids- not- fat returned to normal when the full ration was restored. Mature cows well fed before calving gave milk which averaged 0.28% higher in fat and 0.11% higher in solid- not- fat during first 3 months of lactation than cows poorly fed before calving. Underfeeding reduced both the fat and the SNF content of milk, although SNF content was more sensitive to feeding level. Fat content and fat composition were influenced more by roughage (fiber) intake. Underfeeding cows after calving caused an increase the percentage of fat and a decrease in the per cent of solids- not- fat (O'Connor, 1959). The SNF content may

fall if the cow was fed a low-energy diet, but was not greatly influenced by protein deficiency, unless the deficiency is acute. Underfeeding both before and after calving had a severe effect on the percentage of solids- not- fat in milk; it was lowered by as much as 0.5 or 0.6 per cent in some instances (Webb and Johnson, 1974).

2.2.2.6 Completeness of milking

The first milk drawn from the udder contains about 1.4% fat while the last milk (or stripping) contains about 8.7% fat. Thus, it is essential to milk the cow completely. It follows from these considerations that at an incomplete milking the fat content of the milk will be lower than normal, but if the udder is subsequently milked normally the fat content will be higher than normal. Jacobson (1952) verified this and also found that if incomplete milking is practiced for several successive days, the fat percentage is markedly decreased only on the first day of incomplete milking.

The interval between milking influences the fat content of milk, but has no effect on the solids-not-fat. When the intervals are unequal, the milk yield is greater and the fat content is lower following the longer interval. Since, under usual management practices, the night interval is longer than the day, milk obtain at the morning milking contains less fat than evening milk. Same tendency has been observed for morning milk to be lower in fat contain than evening milk, even when the intervals between milking are equal, but this effect does not seem to be entirely substantiated.

The variations due to milking procedure undoubtedly account for some of the variations in fat content of an individual pateron’s milk as delivered at the dairy plant. Unusual excitement of the cow at milking time may impede the “let down” of milk and thus alter the fat content of milk obtained (Jeness and Patton, 1959).

2.2.2.7 Disease effects

✈.....*Review of Literature*

Disease or environmental temperature and humidity conditions that caused a rise above the normal body temperature of the lactating cow affected milk yield and composition (Rook, 1961). Yields of milk, SNF and proteins were depressed from 10 to 12 per cent during mastitis infection (O'Donovan *et al.*, 1960). Mastitis milk generally has been characterized by lowered protein and lactose content, but with a notable increase in chlorides. Alexander and Leech (1960) reported a reduction of 0.15 per cent in SNF associated with leucocyte counts above 600,000 per ml of milk.

Waite and Blackburn (1957) had also found that SNF and lactose decreased by 0.25 and 0.38 percentage respectively, as the total leucocyte count increased to 5, 00,000 per ml. Casein content declined when the cell counts approached 1, 00,000 per ml. Milk samples studied did not include those containing clots associated with clinical mastitis. The rise in body temperatures accompanying certain disease conditions was associated with an increase in fat per cent and a decrease in milk yield and SNF content (King, 1955). The compositional changes in milk constituents associated with elevated somatic cell counts (a measure of severity of disease) have been given in Table 2.16.

Table 2.16 Change in milk constituents associated with elevated somatic cell counts

Constituent	Normal Milk, Per cent	High SCC Milk, Per cent	Per cent of Normal
Milk solids not fat	8.9	8.8	99
Fat	3.5	3.2	91
Lactose	4.9	4.4	90
Total protein	3.6	3.6	99
Total casein	2.8	2.3	82
Whey protein	0.8	1.3	162
Sodium	0.05	0.10	184
Chloride	0.09	0.15	161
Potassium	0.17	0.16	91
Calcium	0.12	0.04	33

(Harmon, 1994)

2.3 Pricing plan

Review of Literature

Milk is valued commercially for its two important parameters: (I) Milk fat (II) Solids- not- Fat (SNF). The SNF largely consists of proteins, lactose and minerals. These solids are also referred to as ‘serum solids’. These two parameters are usually forming the basis of payment to milk producers in India. The term Total Solids’ (TS) refers to the quantity of SNF plus fat present in milk. It may range from 12 to 16 per cent, depending on its source (Aneja and Mathur, 2002). Considering these facts, it can be said that the overall situation is not favorable for healthy progress of the fluid milk industry. A rational pricing policy can, however, go a long way in improving the situation. In the dairy industry, SNF of milk plays an important role. SNF is the second important component of milk, after fat. It is extensively used while receiving, dispatching and in- process standardization of milk etc. Farmers should get due price for their milk as they are paid correctly on fat and SNF basis (Sandhu, 2003). Ultimately, these factors may bring forth a greater effort on the part of dairy cattle breeders, to increase the SNF content of milk, along with a more realistic milk pricing plan designed to recognize the real value of SNF. Such plans, in varied versions, are being employed presently in a few manufacturing areas. Despite the apparent selling points, it is realized that such pricing schemes have little merit in a fluid milk market. However, it should also be stated here that the present situation of surplus and subsidy is not conducive to a change in the pricing structure. Judicious payment of milk to producers requires quick methods for estimation of both fat and SNF in milk. Fat can be easily determined by the Gerber and Babcock methods fairly accurately (Pruthi and Datt, 1977). Different dairies using different methods of SNF determination, when they get into contract of purchase and sale of milk in large quantities, it is quite likely that shortages in SNF contents will create big disputes.

The close relationship existing between specific gravity, fat and total solids of

milk has successfully been exploited for the estimation of SNF content in milk (Pruthi and Datt, 1977). It is necessary to modify the above price formula in such a way that the legitimate interests of milk producers, contractors, dairy plants and consumers are safeguarded.

2.4 Physical Properties related to TS and SNF of milk

Milk is a dilute emulsion consisting of an oil/fat dispersed phase and an aqueous colloidal continuous phase. The physical properties of milk are similar to those of water but are modified by the presence of various solutes (proteins, lactose and salts) in the continuous phase and by the degree of dispersion of the emulsified and colloidal components.

2.4.1 Viscosity

Viscosity is an important physical property of food systems. It is related to the flow properties of fluids. The viscosity of the fluid is a measure of the resistance to flow due to internal frictional forces. The viscosity of milk and cream gives an impression of “richness” to the consumer. From an organoleptic standpoint, viscosity contributes to mouth feel and flavour. Viscosity of milk and dairy products depends on temperature, concentration and state of casein micelles and fat globules. As the percentage of total solids is more in buffalo whole milk, its viscosity is also more (Aneja and Mathur, 2002). Milk except cooled raw milk exhibits Newtonian behavior, in which the viscosity is independent of the rate of shear. The viscosity of milk depends on temperature and pH (Webb and Johnson, 1974).

2.4.2 Freezing point

The freezing point of a liquid is the temperature at which the solid, liquid and vapour phase exists in equilibrium with each other. A solution freezes at a lower temperature than the pure solvent, and the depression of the freezing point depends

upon the concentration of the dissolved substances. The major components affecting the freezing point of milk are lactose and soluble salts. The freezing point of milk is raised due to more water in it. Freezing point depression is inversely proportional to amount of water added (Mathur *et al.*, 1952).

2.4.3 Electrical conductivity

The ability of electrolyte to conduct a current is measured in terms of specific resistance, which is defined as the resistance in ohms of a column of solution 1 cm long and 1 sq. cm in cross section. The electrical conductivity increases due to an increase in the dissociation of electrolytes and decreases in viscosity with the increase in temperature. The electrical conductivity decreases with the increase in fat content because the fat globules impede the mobility of ions and the fat phase constitute an inert dilutant (Mathur *et al.*, 1952).

2.4.4 Milk density or specific gravity

Density of milk is the resultant of the densities of its constituents, their concentration and state of being at a particular temperature. The density of milk averages 1.032 g/ cm³. Accordingly, the weight of one liter of milk is 1.03 Kg. The density of milk decreases from maximum at 5.2 C to a minimum at 40 C. Above 40 C, change in density is erratic. Specific gravity of milk, which is the ratio of density of milk to that of water at the temperature, is reported at 15.5 C. The specific gravity of fresh whole milk lies in the range 1.030-1.035, with an average of 1.032. Milk fat, milk SNF, skim milk and evaporated whole milk at 15.5 C have specific gravity of 0.93, 1.614, 1.036 and 1.066, respectively. Although buffalo milk contains more fat than cow milk, it has higher specific gravity because it contains more SNF as well (Aneja and Mathur, 2002). Addition of extraneous fat decreases specific gravity and also water.

Density of a substance at a specific temperature is defined as the mass divided by volume at that temperature. It is expressed in kg/m³ in the SI units. According to the c.g.s. unit density measurements are expressed in gram of mass per cubic centimeter (g/cm³). However, this absolute density is seldom used. In order to avoid various unit expressions, it has been found convenient to express the density in reference to some standard substance. The less dimension constant thus obtained is known as specific gravity. The density of milk is the summary result of the densities of its various components. Specific gravity of milk, the resultant of the values of specific gravities of all its constituents present in milk has been shown in Table 2.17. It is dependent on the amount of dissolved or suspended matter, changes in chemical composition of the constituents, and variations in physical states of components. Thus, milk density is influenced by various factors such as temperature history of samples, biological differences of milk, and processing of milk. Among the various constituents, the variation of fat content is known to be the main cause in milk density variation (Davies, 1936 and Walstra and Jenness 1984). However, according to Sherborn (1988), variations in the composition of fat and in the proportions of water, lactose, proteins, and salts may influence the milk density much less than variations due to the physical state of fat.

Table 2.17 Specific gravity of various milk constituents

Milk constituents	Sp.Gravity at 15 C
Fat	0.930
Protein	1.346
Lactose	1.666
Salts	4.120
Ash	5.500
SNF	1.616
Water	1.000

(Mathur *et al.*, 1952)

2.4.5 Factors affecting density or sp. gravity

2.4.5.1 Temperature

Milk should be either heated to liquid the fat or held sufficiently long to allow attainment of maximum density. The former method, first suggested by Sharp and Hart (1936), is carried out by warming milk samples to 40-45 C for one-half to five minutes to ensure that all the fats are in liquid state, followed by cooling to the temperature of density measurement (Vanstone and Dougall, 1960). Hilker (1961) investigated the change in the specific gravity of milk fat with various holding times and found that the samples that had been held at a desired temperature (32-50 F or 40 C) more than 4 hours showed the maximum values. As seen in the previous works, controlled temperature history is necessary to secure high precision and accuracy with density determination (Davies, 1936).

2.4.5.2 Recknagel's phenomenon

Increased density of cold stored milk has been known for a long time. Recknagel (1883) was the first researcher to determine some of the conditions under which the increase in specific gravity occurred (Sharp and Hart, 1936). Thus, this increase in density during storage was named Recknagel's phenomenon. He showed that the escape of air bubbles was not the factor but attributed to an increase in the hydration of the casein at the low temperatures. Sharp and Hart (1936) confirmed that the fluctuation of the value of specific gravity was due to the variation in physical states of fat. Solid fat has greater sp. gravity than liquid fat at the same temperature.

Fat solidification is a slow process and that the degree of solidification depends not only on the temperature, but also a previous temperature history of the sample.

2.4.5.3 Richness of milk

A milk low in fat has lower sp. gravity is not the case, but SNF content should also be taken into consideration to explain the variation in sp. gravity. Variations in sp. gravity with fat and SNF have been given in Table 2.18.

Table 2.18 Variations in sp. gravity with fat and SNF

Breed	Sp.Gravity at 20 C	Fat per cent	SNF per cent
Holstein	1.0324	3.55	8.95
Brown Swiss	1.0318	4.01	9.40
Ayreshire	1.0317	4.14	8.97
Jersey	1.0330	5.18	9.51
Guerensey	1.0336	5.19	9.68

(Webb and Johnson, 1974)

2.4.5.4 Addition of water

Addition of water will lower the sp. gravity of milk. Water is lighter than milk, and therefore a given volume of milk weighs less if it contains some extraneous water (Jenness and Patton, 1959).

2.5 Methods of sp. gravity measurement

The relation between the contents of fat and solids - not - fat (SNF) in milk is of paramount importance in the establishment of plans for pricing milk (Jenness and Patton, 1959). Two types of total solids tests for fresh whole milk are in current use. Gravimetric tests, in which the water is removed under controlled conditions, are capable of considerable accuracy but are generally slow and require skilled analysts. Specific gravity tests are quick and inexpensive, but not very accurate (Herrington, 1946; Lampert *et al.*, 1954; Heinemann *et al.*, 1954; Watson, 1957; Brunner, 1958). The SNF of milk purchased by different dairies can precisely be determined only through gravimetric method which is considered as standard method. But in practices,

when hundreds of samples are brought to the dairy for testing purpose, and for determination of value of milk supplied by hundred of milk cooperative societies the gravimetric test is not practical. Under these circumstances a volumetric physical method of lactometer reading is used for quick results.

The sp. gravity of a substance is the ratio of its weight to the weight of an equal volume of another substance taken as a standard at the same temperature. It has no units. Two temperatures are needed to define its value.

In milk and food analysis, sp. gravity determination is generally performed only on liquid products. The density and sp. gravity may be measured in a number of ways.

- a) By measuring the weight of a known volume either with a pycnometer or with a hydrostatic balance.
- b) By measuring the volume of a known weight with the help of a hydrometer or lactometer (Davis and Macdonald, 1963).

The measurement performed either with pycnometer or hydrostatic balance or hydrometer is based on a well- known Archimedes's principle "that buoyed up by a force equal to the weight. In other words, a floating object sinks until it has displaced a weight of fluid equal to its own weight. Pycnometer method is a very accurate means of measuring the sp. gravity. Hydrostatic balance is a simple and convenient method where sufficient samples are available. Westphal balance is a special type of sp. gravity balance and operates on the basis of Archimedes's principle. Hydrometer or Lactometric method is rapid but less accurate means of determining sp. gravity. A special form of hydrometer used for taking the sp. gravity of milk is called Lactometer (Jenness and Patton, 1959).

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Determination of Solid- Not- Fat in milk is still an important test for assessing the chemical quality of milk for a rapid and routine estimation of SNF. Under field or commercial condition, a method using a lactometer or a hydrometer is adopted and then applying a formula to calculate SNF from the lactometer reading and the fat content of milk. Divergent view are held about the type of lactometers to be used (sp. gravity type or density type), the proper temperature correction to be applied and the constants to be used in the Richmond formula for a sp. gravity lactometer of Quevenne type standardized at 15.6 C (60 F). The Richmond formula commonly uses a constant factor of 0.14 to calculate TS and SNF. There are, however, instances of using other constant factor such as 0.66 and 0.72 for the density hydrometer standardized for 20 C with fat in the liquid state (BIS, 1960 and 1962) , where the studies are limited to fat content of milk not exceeding 6 per cent and only standard temperature of 20 C being taken into consideration. The Bureau of Indian Standards in its revised specification for density hydrometer calibrated at 27 C (Sebastian and Rao, 1974). Mostly, lactometer calibrated at 84 C is available, and many dairies are using such lactometers for determination of SNF content of milk. Theoretically, the specific gravity of milk is to be determined at 60 F. In India lactometer calibrated at 60 F temperature is not normally available and whatever indigenously manufactured lactometers are available calibrated at 60 F is not showing correct reading (Patel and Gandhi, 1980). The different samples of milk showed considerable variation in fat content. The fat content varied from 5.6 per cent to 11.0 per cent (Aggarwala and Sharma, 1961). Table 2.19 shows a very intense linear relationship between fat and total solids per cent by gravimetric method and lactometric reading.

Table 2.19 Relationship between total solids and lactometric reading at 84 F

Fat level per cent	Relationship	Standard error of estimate
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2	TS = 0.284L+ 1.642	0.20
4	TS = 0.282L+ 4.339	0.20
6	TS = 0.274L+ 6.946	0.22
8	TS = 0.275L+ 9.443	0.34
10	TS = 0.297L+ 11.072	0.38

(Sebastian and Rao, 1974)

The urgent need is for using a uniform lactometer and formula throughout the country without much debating on issues like whether to use a lactometer or a hydrometer and whether it should be calibrated at 20 C or 27 C. It is suggested that all the dairies in India should adopt only one standard in this regard so that disputes and difficulties between them should be avoided (Rama Murthy, 1980). In the dairy industry, Richmond formula for calculation of S.N.F of milk plays an important role. SNF is the second important component of milk, after fat. It is extensively used while receiving, dispatching and in-process standardization of milk etc (Patel and Gandhi, 1977).

Rapid lactometric estimation of solids- not-fat in milk with reasonable accuracy is of paramount importance in procurement and payment of milk. Complexity in composition of milk, lactometric measurements and mathematical formulae for estimating SNF, contribute to error under different situations. Every investigator has proposed new constant or correction in the basic equation (Muralidhar and Prasad, 1993).

2.6 Basic equation for TS or SNF estimation in milk

The relationship between milk density or specific gravity and composition of milk, especially fat and solids-not-fat (SNF) content, has been investigated for more than a century. The use of formulas for computing the percentage of total solids or SNF in milk has been common. These formulas are based upon sp. gravity and the percentage of fat in the milk (Overman *et al.*, 1945). The idea that a relation

exists between specific gravity, fat and solids in milk occurred first to Behrend and Morgen in 1879.

Various equations were proposed to determine the fat content of milk from the specific gravity and total solids content because at that time no simple method for determination of fat in milk was available (Sharp and Hart, 1936). The development of the Babcock and Gerber methods for the determination of fat shifted the use of the equation to the determination of total solids or SNF from the fat content and the sp. gravity (Sharp and Hart, 1936). Formulae are of great use in laboratories where large numbers of routine examination and milk samples are involved. Total solids in milk are of great use in detecting skimming, watering and assessing the quantity of different milk products as dried milk powder, condensed milk, khova etc. therefore, it is essential that formula or total solids estimation should be simple, less time consuming and should give correct value within the statistical limits (Parekh and Gangwar, 1968).

Fleischmann (1885) appears to be the first individual to present a formula relating fat percentage, sp. gravity and total solids that was sufficiently accurate to be generally accepted.

Babcock (1891) and Richmond et al. (1942) advanced formulae most commonly employed in the United States and England. Toyonaga (1898) was credited by Fleischmann and Wiegner (1913) as the individual who first recognized the importance of the physical condition of the fat in the lactometric determination of total solids.

The original method had equation established in 1895 by Richmond which related the milk's total solids content to its fat content and sp. gravity (measured at 15.5 C with the fat in the solid state). Richmond's equation was modified to allow for

substitution of density at 20 C for sp. gravity at 15.5 C. No allowance was made for the change in state of the fat, although the density of milk is less when the fat is in the liquid state than when in the solid state. This omission was deliberate, since it was known that when Richmond's equation was applied to density readings obtained with the fat in the solid state, it gave higher figures for total solids than those obtained by modern gravimetric methods. However, subsequent investigations showed that the use of the modified equation with the fat in the liquid state over-compensated for the high figures obtained by Richmond's method, and usually gave lower results for total solids than those obtained gravimetrically. Other investigations have been carried out in which the density was determined with fat in the solid state.

This standard method measures the density of milk when the fat is in the liquid state and the equation for calculating solids-not-fat is only for use with such density readings and not for density measurements when the fat is solid. The equation gives values that are, on average, in close agreement with those obtained by gravimetric methods.

Sharp and Hart (1936) studied the factors influencing the estimation of total milk solids in milk from measurements of sp. gravity and fat content. As a result of their studies, they derived the equations:

$$\text{Total solids} = 1.2648 \text{ Fat} + 0.2586 \text{ Lactometer} \quad (\text{I})$$

$$\text{Total solids} = 1.2537 \text{ Fat} + 0.2680 \frac{\text{Lactometer}}{\text{sp.gr. milk}} \quad (\text{II})$$

The first equation is theoretically less accurate but more convenient to use. However, there were several reports concerning the values calculated by Sharp and Hart's equation were too low. Sharp and Hart did not use a lactometer for their measurements. Their data were obtained by means of a modified Wesphal balance and

they recorded the specific gravity of milk as the ratio of weights of equal volumes of milk and water both were at 30 C.

It is obvious that the sp. gravity of milk is resultant of the sp. gravity of its constituents, if

S= Sp. gravity of milk

N= Sp. gravity/ density of mixture of SNF (Protein, lactose, minerals).

M= Sp. gravity/ density of fat.

T= Percentage of TS by weight.

F= Percentage of fat by weight.

T – F = Percentage of SNF by weight.

100- T = Percentage of water by weight.

Sp. gravity of milk = Sp. gravity of fat + Sp. gravity of SNF + Sp. gravity of water

$$S = \frac{F}{M} + \frac{(T-F)}{N} + \frac{(100-T)}{1}$$

$$S = \frac{F + T - F + 100 -}{FN + MT - MF + 100MN -}$$

$$= \frac{100 MN}{FN + MT - MF + 100MN -} \quad (1)$$

The equation 1 is general which can be solved for any one of these factors, sp. gravity, fat or TS, if the other two are known and if values for M and N are known and constant. It is the basis for number of equations for calculating the TS from the fat contains and the sp. gravity. When rearranged and solved for T, it becomes;

$$FN + MT - MF + 100 MN - \frac{100 MN}{S}$$

$$MT - MNT - \frac{100 M}{S} - FN + MF - 100$$

$$T(M - MN) = \frac{100 MN}{S} - FN + MF - 100 MN$$

$$T = \frac{1}{M - MN} \left(\frac{100 MN}{S} - FN + MF - 100 MN \right)$$

$$= \frac{1}{M - MN} \times F(M - N) + MN \left(\frac{100}{S} - 100 \right)$$

$$= \frac{M - N}{M - MN} F + \frac{MN}{M - MN} \left(\frac{100}{S} - 100 \right)$$

$$= \frac{M - N}{M(1 - N)} F + \frac{MN}{M(1 - N)} \left(\frac{100}{S} - 100 \right)$$

$$= \frac{M - N}{M(1 - N)} F + \frac{N}{(1 - N)} \left(\frac{100}{S} - 100 \right)$$

By taking negative sign

$$\frac{-M - N}{\quad} \quad \frac{-N}{\quad} \quad \frac{100}{\quad}$$

$$= \frac{M - N}{M(1 - N)} F + \frac{N}{(1 - N)} \left(\frac{S}{100} - 100 \right)$$

$$T = \frac{M - N}{M(1 - N)} F + \frac{N}{(1 - N)} \left(\frac{100}{S} - 100 \right)$$

Fleishmann (1885) appeared to be the first individual to present a formula relating fat percentage, sp. gravity and total solids that was sufficiently accurate to be generally accepted equation.

$$T = 1.2 F + 0.2665 G/D$$

Where, T= Total solids of milk,

F = Fat content of milk,

G = Sp. gravity of Milk * 1000 or lactometer reading of milk,

D = Sp. gravity of milk (Pruthi and Dutt, 1977)

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

$$T = 0.265 GD + 1.2 F$$

Where, D= LR

G = Sp. gravity of milk

Babcock (1897) simplified this equation still further and wrote the following very well- known equation.

$$T = 1.2 F + 0.25 LR + 0.14$$

An algebraic equation was derived from the theoretical equation of the calculation of the solids from the lactometer and the Babcock fat determinations.

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The constant (0.31) of the original formula was increased to 0.4 to compensate for a change in the calibration of the lactometers, which was made later by the national bureau of standard

$$\text{Per cent TS} = 1.33F + \frac{273L}{L+1000} - 0.40$$

F= Babcock fat per cent, L = Lactometer reading (Whittier, 1954).

Pruthi and Bhalero (1973) proposed following modification of the existing ISI formula for buffalo milk.

$$T = 0.25 D + 1.22F + 0.87$$

British Standard Institution recommended the following formula which mathematically derived from Richmond formula from the knowledge of the coefficient of cubical expansion of milk and density of water at 60 F.

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

The same formula was also adopted by Indian standard Institution. Later, it was observed that British Standards Institution (BSI) formula slightly under estimates the total solids. BSI made the first amendment. The BIS also made a similar amendment.

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

The Bureau of Indian Standards has recommended the same formula for both cow and buffalo milk as BSI. This does not appear in order for buffalo milk. The values of sp. gravity, fat and SNF may be different and different relationship may exist for buffalo milk. In fact Richmond had prescribed a separate formula for buffalo milk which quite different from the formula mean for cow milk.

$$T = 0.27G/D + 1.191F \text{ (Buffalo milk)}$$

$$T = 0.2625G/D + 1.2F \text{ (Cow milk)}$$

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The present BIS and ISI formulae are modifications of original Richmond's formula for cow milk and hence cannot be expected give a true estimate of SNF or the total solids for buffalo milk.

From the foregoing discussion, it emerged out that lactometer should be calibrated for its accuracy at a particular temperature, otherwise deferent readings will be observed for the same sample of milk using same lactometer but at different temperature. Hence, it is essential that milk should have temperature of 60 F to get correct sp. gravity reading if the lactometer calibrated at 60 F is used.

Many dairies in India are using lactometers calibrated at 84 F but the temperature of milk being tested by them is kept at 60 F. Obviously the reading would be more than what it should be. This resulted in to more than 0.5 per cent increase in SNF per cent obtained. Theoretically this is not a correct method of obtaining sp. gravity and hence it is absolutely inappropriate.

Moreover, such mistreated milk if marketed by the dairy and the sample sent to public analyst by health laboratories be subjected to gravimetric test then the sample thus tested by public analyst will be found deficient in SNF and below standard also. This may result into the dairy being drawn to court of law under the PFA Act and possibility of conviction also gets increased.

Different dairies have different formula for SNF determination. It was observed that the same sample of milk subjected to them individually gave different SNF percentage. Hence, it is imperative that only a formula which gave closest results to the gravimetric method should be adopted universally.

In past, the determination of either density or sp. gravity of milk was made according to the convenience of the individual worker for the calculation of TS on the basis of Richmond formula. The determination of density has the advantage of giving

results in terms of absolute units at one specified temperature and is not subject to the confusion which has arisen in many countries through the use of numerous convention for indicating sp. gravity under a variety of conditions. In India there are as many as 20 varieties of Richmond formula for SNF estimation by volumetric method. Therefore the present day international practice is to favour the use of density hydrometer only.

Secondly a question arose whether the density hydrometers should be calibrated at 20 C or 27 C on account of the tropical conditions prevailing in India. Research work in progress on this fact would take some more time to alter the modified Richmond formula to be applied to density reading taken at 27 C directly. For the present, it has been decided to calibrate density hydrometers at 20 C and to change the calibration to 20 C as soon as the necessary correction factors have been worked out with suitable Richmond formula.

The fat contain of milk obtained in India varies considerably from that in other countries and because of existence in India of milk obtained both from buffalos and cows with varying fat contents, it has been decided that the density hydrometers should be calibrated with the liquid (Na_2CO_3 solution) having surface tension of 50 dynes/cm by the drop method.

In the latest equations, the corrected lactometer reading coupled with the fat content of milk as determined by Gerber test provides data for application of Richmond formula by which either the TS or SNF of milk tested could be calculated. However, experience has proved that the Richmond formula suggested for sp. gravity lactometers was not justifiable when applied to lactometers described above and erroneous results were obtained. This error in calculation would also affect payment

related to the quality of milk in which the producer, the procurer, the processor and the consumer are affected (Sebastian and Rao, 1974).

Therefore, it was imperative to undertake the investigation to provide a suitable modified formula using Zeal lactometer at 29 C and for milks of varying fat contents from cows, buffalos and mixed milk.

CHAPTER 3

MATERIALS AND METHODS

The present experiment was designed and carried out to study the appraisal of modification of Richmond formula for calculation of SNF/Total Solids in cows, buffaloes and mixed milk from some well-known dairy plants of Gujarat state. The names of the Dairy Plants are not mentioned for obvious reasons. These are defined as Dairy Plant A to E. Fifty samples of each milk (cows, buffaloes and mixed milk) were taken from the above dairies for analyses. In all 150 samples were taken for a period of study from each dairy plant. The study was phased out in a manner by collecting morning and evening milk and in rotation of dairy plant. Five milk samples each of cows, buffaloes and mixed in morning and evening supplies were collected in a day for a specific Dairy Plant. Three day period was allotted to a specific Dairy Plant for 15 sample analysis. After three days the Dairy Plant was changed for collection of another 15 samples. Fifteen days were required to complete one rotation for 5 dairy plants.

3.1 Calibration of instrument

3.1.1 Calibration of lactometer

Zeal lactometer was used for measuring the lactometer reading of milk. The calibration was conveniently done as per the procedure recommended by BIS (1981). Suitable salt solutions (3.863 per cent and 4.415 per cent) of pure sodium chloride in distilled water were prepared. That temperature of these solutions was brought to 15 C using ice bath. A measuring cylinder was filled with 3.863% salt solution at 15 C, lactometer was inserted into the solution. Lactometer reading at 15.5 C was noted immediately as soon as the lactometer becomes stable. Similarly lactometer reading was taken into another solution. The lactometer showed 28 and 32 lactometer

reading, respectively 3.863 per cent and 4.415 per cent in salt solution (IS: 1183-1965). This calibrated lactometer was used throughout the study.

3.1.2 Calibration of thermometer

The floating dairy thermometer conforming to the standards IS: 1672-1967 was used for measuring the temperature of milk. The thermometer was previously calibrated or tested in a bath of melting crushed pure ice for determining correct zero mark on the scale where as steam bath from boiling of glass distilled water was employed for correct 100 scale on the thermometer. The accuracy of intermediate marks was checked by comparison of test thermometer with reference thermometer using glass distilled water bath at different temperatures.

3.2 Method of sampling of milk

The raw milk samples of cows, buffaloes and mixed milk were taken as per procedure described in BIS (BIS, 1981). About 250 ml of raw milk from different cows, buffaloes and mixed was drawn for the purpose. These samples were then subjected to fat, total solids (gravimetric method) and lactometer reading analysis.

3.2.1 Milk fat

The fat content was determined by Gerber method as described in Indian standard IS: 1224 (Part I) - 1977.

3.2.2 Total solids (Gravimetric method)

The total solids in milk by gravimetric method was estimated as per procedure described in IS: 1479 (Part II) - 1961. Duplicate determinations on single sample of milk were conducted by this method.

3.2.3 Total solids (Lactometric or Lactometer method)

The total solids in milk by lactometer method was estimated as per procedure described in IS: 9585 - 1980. The raw milk samples before taking the lactometer

reading were kept in constant temperature water bath at 45 C for 2-3 minute. The samples were then brought to the temperature 29 C one by one. The calibrated Zeal lactometer was also kept in constant temperature water bath at 29 C throughout the analysis. The prerequisite quantity of milk was filled in glass cylinder large enough to let the lactometer float freely. The lactometer was inserted in the milk samples at 29 C slowly and as soon as the lactometer comes to rest, the division at the top of the meniscus was read. The reading was taken with as little delay as possible because the fat globules soon rise. The lactometer reading was subsequently then put in the two equations of either TS or SNF determination as given below.

$$TS = \frac{CLR}{4} + 1.22 F + \text{Correction factor} \text{ ----- (M1)}$$

$$TS = \frac{CLR}{4} + 1.25 F + \text{Correction factor} \text{ ----- (M2)}$$

3.3 Statistical analysis

The data obtained for each of the attribute under study were subjected to statistical analysis in t- test and normality test.

3.3.1 t- Test

Studentized 't' test was used to compare the different methods (gravimetric and volumetric) of total solids (Agrawal, 2009).

3.3.2 Normality test

Testing the normality of the data, Kolmogorov-Smirnov test was used by using SAS 9.3, 2011 software.

RESULTS AND DISCUSSION

Milk is a unique biological secretion of mammary gland, endowed by nature with nutrients to fulfill the nutritional needs of the offspring. Milk is a very variable biological fluid. Milk differs widely in composition, the greatest differences between among milks of different species of mammals. The variations in milks within a species depend on so many factors difficult to determine accurately the relationship between a specific factor and composition (Webb and Johnson, 1974). Milk is in a quantitative sense, fairly constant in composition and properties; there is a considerable quantitative variation. Chemical composition, size and stability of structural elements, and physical properties may all differ among lots of milk. In recent years the solids-not-fat content of milk has come to be regarded as of equal or of greater importance, than the fat per cent. This change is the result of an increased awareness of the nutritive value of milk protein and the other non-fatty constituents, in particular calcium and vitamins (Waite *et al.*, 1956). The increased emphasis now being placed on the solids-not-fat (SNF) and total solids portion of milk makes it essential that the dairy breeder and the producer know more about factors that cause variation in these constituents in the milk of individual cows (Johnson *et al.*, 1959).

The solid constituent of milk, other than fat, is often grouped as solid-not-fat, the percentage of which is calculated as the difference between the total solids and fat content (Jenness and Patton, 1959). Recently interest in the solids-not-fat content of the milk has been stimulated, the current surplus of fats, calorie-conscious milk consumers, and a recognition of the presence of high quality proteins in this portion of the milk. Ultimately, these factors may bring forth a greater effort on the part of dairy cattle breeders, to increase the SNF content of milk, along with a more realistic milk

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pricing plan designed to recognize the real value of SNF. Such plans, in varied versions, are being employed presently in a few manufacturing areas. Judicious payment of milk to producers requires quick methods for estimation of both fat and Solid- Not- Fat (SNF) in milk. Fat can easily be determined by the Gerber and Babcock method fairly accurately. The close relationship existing between specific gravity, fat and total solids of milk has successfully been exploited for the estimation of SNF content in milk (Pruthi and Dutt, 1977). The SNF of milk purchased by different dairy can precisely be determined only through gravimetric method. But in practices, when hundreds and thousands of samples are brought to the dairy for testing purpose and for determination of value of the milk supplied by milk co-operative societies, the gravimetric test has not been found practical. Under such circumstances, a physical method, lactometer reading method is being used for quick and accurate determination of total solids.

While different dairies using different methods of SNF determination, it is observed that the same sample of milk subjected individually would give different SNF per cent results. Hence it is imperative that only a formula which gives closest results to gravimetric method should be adopted. In India there are 20 varieties of Richmond formula for SNF estimation by volumetric method (Ganguly and Kuchroo, 1980). Therefore there is an urgent need for using a uniform Richmond formula for all dairies or otherwise a constant is implicated in basic Richmond equation to have computed value for large number of samples agreeable to gravimetric method.

Based on this available information and data, this study was carried out to develop the modified Richmond formula. The results of this study are discussed in this chapter.

Under study, 5 well-known dairy plants of big capacity of Gujarat state were selected. Fifty samples, each in raw form from cows, buffaloes and mixed milk

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supplies were collected. In all 150 samples were taken for a period of study from each dairy plant. These samples were subjected to milk fat, total solids (gravimetric) and TS/SNF (lactometer) estimations. The data collected were analysed statistically and the results of the study are discussed in this chapter.

4.1 Dairy Plant A

Total of 150 samples each of cows, buffaloes and mixed milk were analyzed for milk fat, TS (gravimetric) and TS/SNF (lactometer) methods.

4.1.1 Buffaloes milk

The results for milk fat, TS (gravimetric) and TS (lactometer) for buffaloes milk of Dairy Plant A are given in Table 4.1.1.1.

Table 4.1.1.1 Milk fat, TS (gravimetric) and TS (lactometer) of buffaloes milk from Dairy Plant A

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
	I	II	Average			
1	18.08	18.10	18.09	26.00	8.40	16.58
2	17.35	17.36	17.36	26.50	7.75	15.93
3	18.54	18.55	18.55	25.00	8.90	16.93
4	19.00	18.98	18.99	27.50	8.80	17.44
5	18.95	18.96	18.96	25.50	9.00	17.18
6	18.10	18.14	18.12	28.00	8.00	16.60
7	18.09	18.10	18.10	26.50	8.30	16.59
8	18.50	18.48	18.49	28.00	8.55	17.26
9	19.45	19.47	19.46	26.00	9.50	17.90
10	18.09	18.07	18.08	27.00	8.25	16.65
11	17.20	17.20	17.20	26.00	7.70	15.74
12	17.60	17.61	17.61	27.50	7.70	16.12
13	18.25	18.24	18.25	25.50	8.55	16.64
14	18.80	18.84	18.82	28.00	8.50	17.20
15	17.65	17.66	17.66	26.50	7.80	15.99
16	18.00	17.98	17.99	27.00	8.00	16.35
17	17.42	17.43	17.43	27.00	7.65	15.93
18	17.01	17.00	17.01	25.50	7.60	15.50
19	17.42	17.40	17.41	26.00	7.90	15.98

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20	18.50	18.47	18.49	30.00	7.50	16.50
21	19.32	19.31	19.32	28.00	8.90	17.68
22	19.25	19.24	19.25	27.00	9.05	17.61
23	17.74	17.76	17.75	26.00	8.15	16.28
24	17.92	17.93	17.93	26.00	8.25	16.40
25	17.24	17.25	17.25	29.50	7.10	15.90
26	17.95	17.96	17.96	28.50	7.85	16.55
27	18.64	18.62	18.63	27.50	8.50	17.08
28	19.05	19.03	19.04	29.50	8.55	17.64
29	18.79	18.81	18.80	29.50	8.25	17.28
30	17.53	17.55	17.54	28.00	7.75	16.30
31	17.15	17.18	17.17	26.50	7.80	15.99
32	17.57	17.56	17.57	26.00	7.95	16.04
33	18.71	18.73	18.72	28.00	8.45	17.14
34	18.00	18.00	18.00	26.50	8.15	16.41
35	17.78	17.80	17.79	29.00	7.45	16.19
36	17.84	17.85	17.85	28.00	7.85	16.42
37	18.14	18.12	18.13	28.50	8.05	16.79
38	17.33	17.31	17.32	27.50	7.35	15.70
39	18.07	18.08	18.08	28.50	8.05	16.79
40	17.80	17.82	17.81	29.00	7.60	16.37
41	19.00	19.01	19.01	28.00	8.80	17.56
42	16.55	16.56	16.56	28.00	7.00	15.40
43	18.25	18.28	18.27	28.00	8.25	16.90
44	18.35	18.33	18.34	26.50	8.65	17.01
45	17.00	16.98	16.99	25.00	7.90	15.73
46	17.88	17.87	17.88	28.00	8.00	16.60
47	17.15	17.16	17.16	27.00	7.65	15.93
48	17.25	17.24	17.25	27.00	7.80	16.11
49	18.10	18.08	18.09	29.00	8.00	16.85
50	17.50	17.51	17.51	27.50	7.95	16.42

The minimum, maximum and average TS content in buffaloes milk measured by gravimetric method and lactometric method with or without correction factor and by using M_1 and M_2 formulae have been presented in Table 4.1.1.2.

Table 4.1.1.2 Total solids of buffaloes milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant A

	Total solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M_1	M_2	M_1	M_2
	$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+1.30}{4}$	$\frac{CLR+1.25F+1.05}{4}$	
Minimum	16.55	15.54	15.75	16.83	16.80

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Maximum	19.46	18.09	18.37	19.38	19.42
Average	18.02	16.72	16.96	18.02	18.02
t-test					
t value	-	9.94	7.99	0	1.6182X 10-13
Result	-	S	S	NS	NS

S= Significant NS = Non Significant

In volumetric method using M₁ formula without correction factor, the minimum, maximum and average values of total solids were 15.54, 18.09 and 16.72 respectively, while using M₂ formula, these values were 15.75, 18.37 and 16.96, respectively. While addition of 1.30 correction factor in M₁ formula, the minimum, maximum and average values of total solids were 16.83, 19.38 and 18.02 respectively, and addition of 1.05 correction factor in M₂ formula, these values were 16.80, 19.42 and 18.02, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 16.55, 19.46 and 18.02, respectively.

It indicated that volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M₁ and M₂ formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as comparable to gravimetric method.

The values of two sample t-test of Dairy Plant A as presented in Table 4.1.1.2, no significant difference was found between gravimetric mean and volumetric mean by M₁ and M₂ formulae with correction factor. Thus, it could be said that the TS by gravimetric method and volumetric method were almost same for buffaloes milk of Dairy Plant A.

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Table 4.1.1.3 Frequency distribution of total solids of buffaloes milk from Dairy Plant

A by M₁ formula

Sr. No	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	16.50-17.00	2	4.00	2	4.00
2	17.00-17.50	11	22.00	13	26.00
3	17.50-18.00	13	26.00	26	52.00
4	18.00-18.50	12	24.00	38	76.00
5	18.50-19.00	7	14.00	45	90.00
6	19.00-19.50	5	10.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		18.0182	
Std Dev		Sigma		0.623027	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.08051781	Pr > D	>0.150

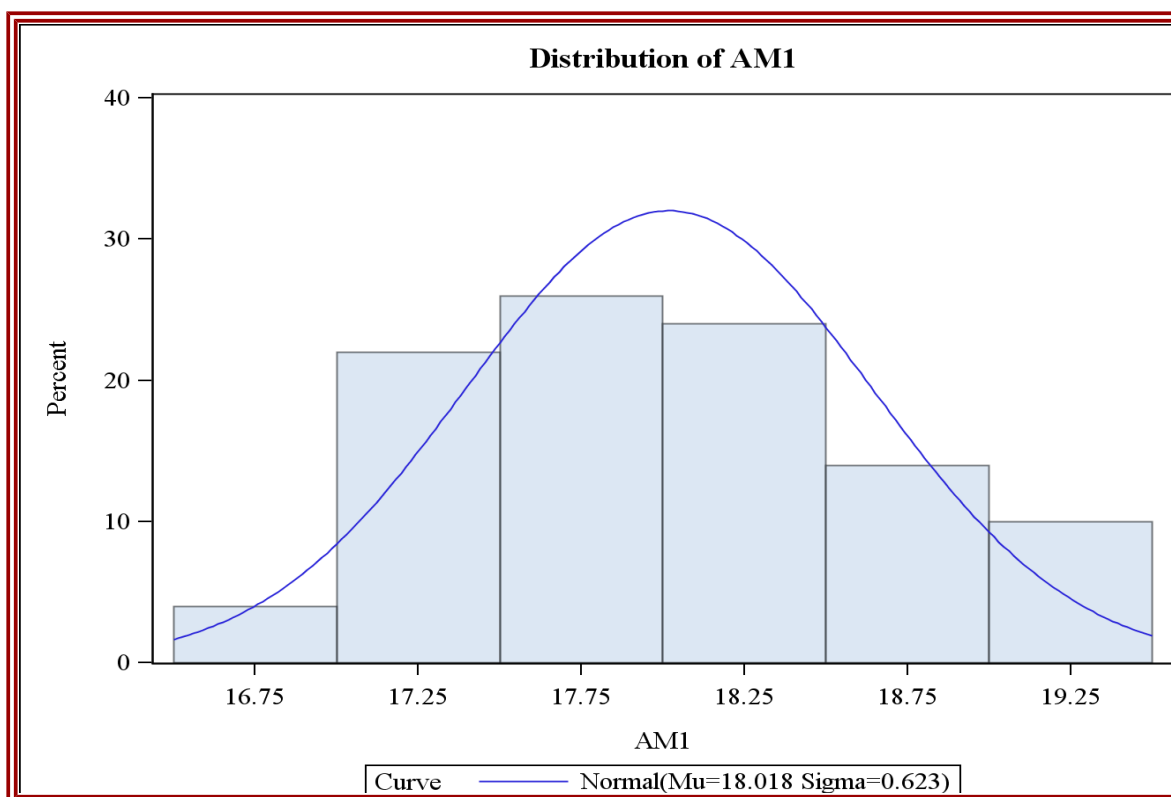


Fig. 4.1.1.1 The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant A by M₁ formula

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Table 4.1.1.4 Frequency distribution of total solids of buffaloes milk from Dairy Plant A by M₂ formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	16.50-17.00	2	4.00	2	4.00
2	17.00-17.50	11	22.00	13	26.00
3	17.50-18.00	13	26.00	26	52.00
4	18.00-18.50	12	24.00	38	76.00
5	18.50-19.00	7	14.00	45	90.00
6	19.00-19.50	5	10.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		18.0182	
Std Dev		Sigma		0.636647	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.0791	Pr > D	>0.150

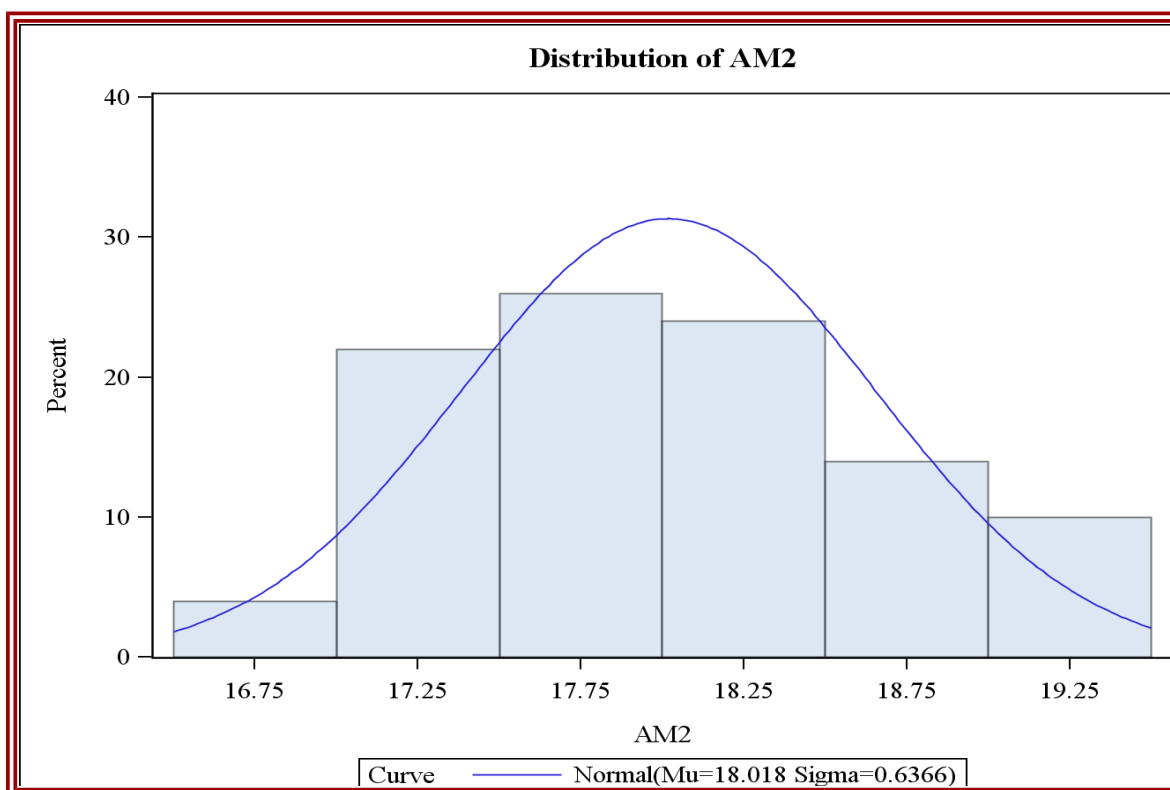


Fig. 4.1.1.2 The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant A by M₂ formula

The frequency distribution was worked out for total solids of buffaloes milk by M_1 and M_2 formulae and is presented in Table 4.1.1.3 and 4.1.1.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The same is also depicted in Figure 4.1.1.1 and 4.1.1.2, respectively. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

It is inferred that the values for TS obtained either by M_1 and M_2 formulae without correction factor were very low indicating implication of correction factors for both the equations is required.

The Richmond's formula has been found to be fairly satisfactory for normal milk samples in United States. While Desai and Patel (1945) reported that Richmond's formula yielded results higher than the values obtained by gravimetric method for cows and buffaloes milk. MacMohan *et al.* (1932) concluded that Richmond's formula was not applicable in tropical countries.

A separate Richmond's formula ($TS = 0.27 G/D + 1.191 F$) gave less satisfactory results (Ramchandra *et al.*, 1953) for buffalo milk. Next modification to Richmond's formula for buffalo milk suggested by British standard institution ($TS = 0.25 G + 1.21 F + 0.66$) gave better results. Mudaliar (1956) suggested a separate formula ($TS = 0.25 G + 1.21F + 0.88$) for milk samples from buffaloes and southern cattle of India.

Parekh and Gangwar (1968) observed that Richmond's formula commonly used was not suitable for buffalo milk. They studied four equations ($G/3 + 0.9F$; $0.25G + 1.21F + 0.88$; $0.25G + 1.21F + 0.66$ and $0.25G + 1.21F + 0.14$) and showed that the calculated values for TS in buffalo milk was lower than the

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gravimetric method by an average mean difference of 1.20. They suggested a modified formula for SNF = G/3 – 0.1F in case of buffalo milk.

Pruthi and Bhalerao (1973) had proposed the modification of existing ISI formula for buffalo milk as TS= 0.25D+ 1.22F + 0.87. However, some investigators (Desai and Patel, 1945; ICAR, 1951; EL-Sokkary and Hasasn, 1953) had given contradictory reports and observed Richmond’s formula to give higher SNF values than the gravimetric procedure.

Basic Richmond formula is taken as a basis for calculation of TS/SNF in milk and it was applied by various worker after modification for the calculation of TS/SNF in different countries. The formula is based on interrelationship among TS/SNF, milk fat and sp. gravity of milk. However the composition of milk, its variability due to several factors and sample size all might have contributed to differences in a variety of equation by different workers.

Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant A, two probable equations derived statistically are given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 1.30$$

$$TS = \frac{CLR}{4} + 1.25 F + 1.05$$

4.1.2 Cows milk

The results for milk fat, TS (gravimetric) and TS (lactometer) for cows milk from Dairy Plant A are given in Table 4.1.2.1.

Table 4.1.2.1 Milk fat, TS (gravimetric) and TS (lactometer) for cows milk from Dairy Plant A

Sr.	Methods	
	Gravimetric method	Volumetric method

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No.	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
	I	II	Average			
1	13.00	13.01	13.01	28.50	4.10	12.05
2	12.67	12.70	12.69	26.50	4.30	11.79
3	13.35	13.38	13.37	26.50	4.70	12.27
4	12.81	12.83	12.82	28.00	4.10	11.92
5	13.20	13.22	13.21	28.50	4.30	12.29
6	13.86	13.87	13.87	26.50	5.15	12.81
7	12.01	12.04	12.03	27.00	3.70	11.19
8	12.53	12.55	12.54	27.00	4.20	11.79
9	12.50	12.52	12.51	26.50	4.25	11.73
10	12.10	12.12	12.11	26.00	3.90	11.18
11	12.09	12.11	12.10	28.50	3.35	11.15
12	12.10	12.08	12.09	26.00	3.95	11.24
13	12.55	12.54	12.55	26.00	4.30	11.66
14	12.87	12.88	12.88	26.50	4.35	11.85
15	12.78	12.80	12.79	26.00	4.40	11.78
16	13.35	13.38	13.37	27.50	4.60	12.40
17	11.82	11.84	11.83	28.50	3.15	10.91
18	14.55	14.55	14.55	27.50	5.60	13.60
19	14.21	14.22	14.22	27.50	5.25	13.18
20	13.80	13.83	13.82	27.00	5.00	12.75
21	13.24	13.26	13.25	28.00	4.30	12.16
22	11.90	11.93	11.92	27.80	3.55	11.21
23	12.04	12.02	12.03	28.00	3.35	11.02
24	12.18	12.17	12.18	27.50	3.60	11.20
25	13.06	13.03	13.05	28.00	4.30	12.16
26	12.30	12.32	12.31	29.00	3.60	11.57
27	12.56	12.55	12.56	26.00	4.30	11.66
28	13.33	13.35	13.34	25.50	5.00	12.38
29	13.10	13.08	13.09	27.00	4.50	12.15
30	12.45	12.44	12.45	29.50	3.60	11.70
31	13.26	13.24	13.25	27.50	4.45	12.22
32	12.32	12.33	12.33	27.50	3.85	11.50
33	12.37	12.35	12.36	27.00	3.95	11.49
34	12.75	12.76	12.76	25.50	4.40	11.66
35	12.45	12.47	12.46	26.00	4.10	11.42
36	13.24	13.25	13.25	27.00	4.60	12.27
37	12.46	12.47	12.47	27.00	4.05	11.61
38	13.20	13.21	13.21	26.00	4.80	12.26
39	12.70	12.72	12.71	27.00	4.15	11.73
40	13.88	13.86	13.87	25.00	5.15	12.43
41	12.96	12.95	12.96	27.00	4.35	11.97
42	14.39	14.40	14.40	26.50	5.55	13.29
43	14.53	14.53	14.53	26.50	5.50	13.23

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44	13.06	13.07	13.07	27.00	4.65	12.33
45	14.32	14.34	14.33	26.00	5.75	13.40
46	13.49	13.50	13.50	28.00	4.65	12.58
47	14.40	14.40	14.40	25.00	5.75	13.15
48	12.80	12.82	12.81	27.50	4.20	11.92
49	12.80	12.81	12.81	27.00	4.40	12.03
50	13.63	13.62	13.63	27.50	5.05	12.94

The minimum, maximum and average TS content in cows milk by both gravimetric method, by lactometric methods with and without correction factor for M₁ and M₂ formulae have been presented in Table 4.1.2.2.

Table 4.1.2.2 Total solids of cows milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant A

	Total solid, per cent				
	Gravimetric method	Volumetric method			
		Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
	$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.86}{4}$	$\frac{CLR+1.25F+0.73}{4}$	
Minimum	11.83	10.96	11.06	11.82	11.79
Maximum	14.55	13.70	13.87	14.56	14.60
Average	12.99	12.13	12.26	12.99	12.99
t-test					
t value	-	6.092	5.095	1.30 X 10 ⁻¹⁴	1.24 X 10 ⁻¹⁴
Result	-	S	S	NS	NS

S= Significant NS= Non significant

In volumetric method using M₁ formula without correction factor, the minimum, maximum and average values of total solids were 10.96, 13.70 and 12.13 respectively, while using M₂ formula, these values were 11.06, 13.87 and 12.26, respectively. Addition of 0.86 correction factor in M₁ formula, the minimum, maximum and average values of total solids changed to 11.82, 14.56 and 12.99 respectively, while addition of 0.73 correction factor in M₂ formula these values were 11.79, 14.60 and 12.99, respectively.

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By using gravimetric method the minimum, maximum and average values of total solids were 11.83, 14.55 and 12.99, respectively.

It indicated that both of the formula M1 and M2 for volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M₁ and M₂ formulae with correction factor, the values for TS showed statistically a non significant difference indicating almost similar values for TS as compared to gravimetric method.

The values of two sample t-test of Dairy Plant A as presented in Table 4.1.2.2, no significant difference was seen between TS obtained by gravimetric mean and volumetric mean either by M₁ and M₂ formulae. Thus, it could be said that the TS by gravimetric method and volumetric method were almost same for cows milk from Dairy Plant A.

Table 4.1.2.3 Frequency distribution of total solids of cows milk from Dairy Plant A

by M₁ formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	11.50-12.00	2	4.00	2	4.00
2	12.00-12.50	9	18.00	11	22.00
3	12.50-13.00	17	34.00	28	56.00
4	13.00-13.50	12	24.00	40	80.00
5	13.50-14.00	4	8.00	44	88.00
6	14.00-14.50	5	10.00	49	98.00
7	14.50-15.00	1	2.00	50	100.00
Parameters for Normal Distribution					

Results and Discussion

Parameter	Symbol	Estimate
Mean	Mu	12.99
Std Dev	Sigma	0.677
Goodness-of-Fit Tests for Normal Distribution		
Test	Statistic	p Value
Kolmogorov-Smirnov	D	0.08922632
	Pr > D	>0.150

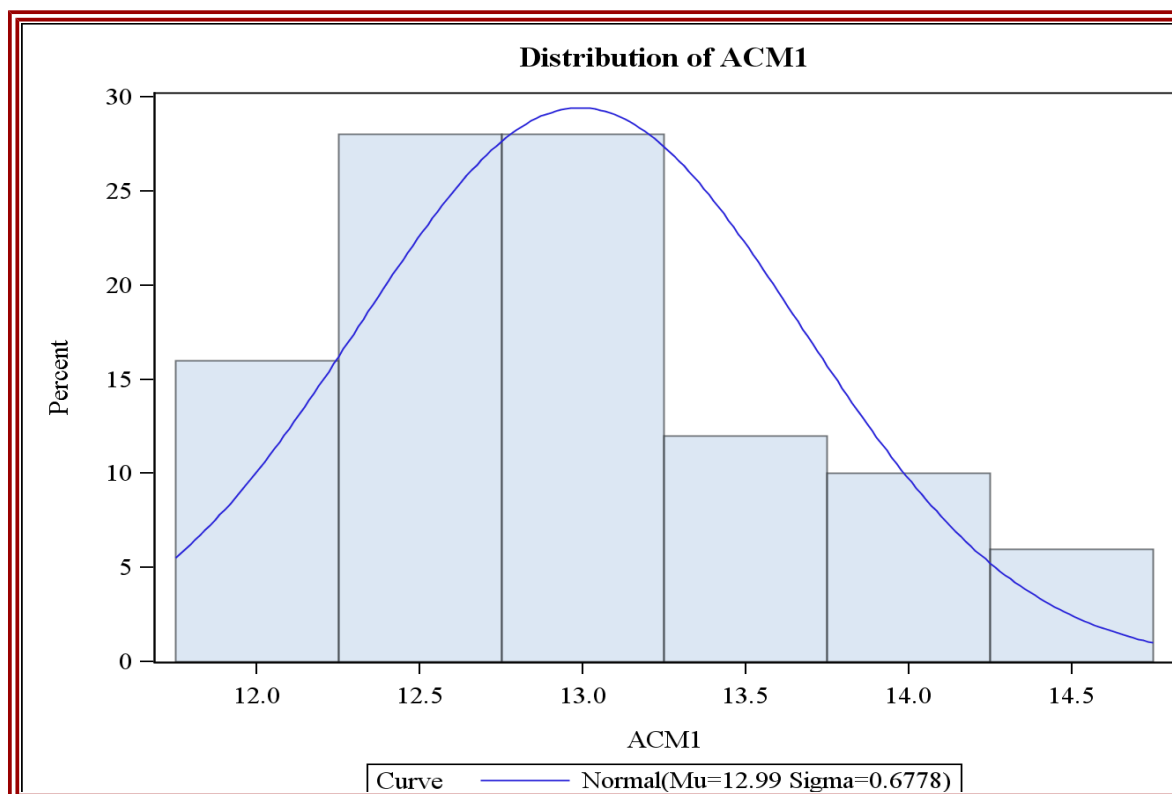


Fig. 4.1.2.1 The grouped frequency distribution curve of total solids of cows milk from Dairy Plant A by M_1 formula

Table 4.1.2.4 Frequency distribution of total solids of cows milk from Dairy Plant A by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	11.50-12.00	2	4.00	2	4.00
2	12.00-12.50	10	20.00	12	24.00
3	12.50-13.00	16	32.00	28	56.00
4	13.00-13.50	12	24.00	40	80.00
5	13.50-14.00	4	8.00	44	88.00
6	14.00-14.50	5	10.00	49	98.00

Results and Discussion

7	14.50-15.00	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		12.99	
Std Dev		Sigma		0.695	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.08692783	Pr > D	>0.150

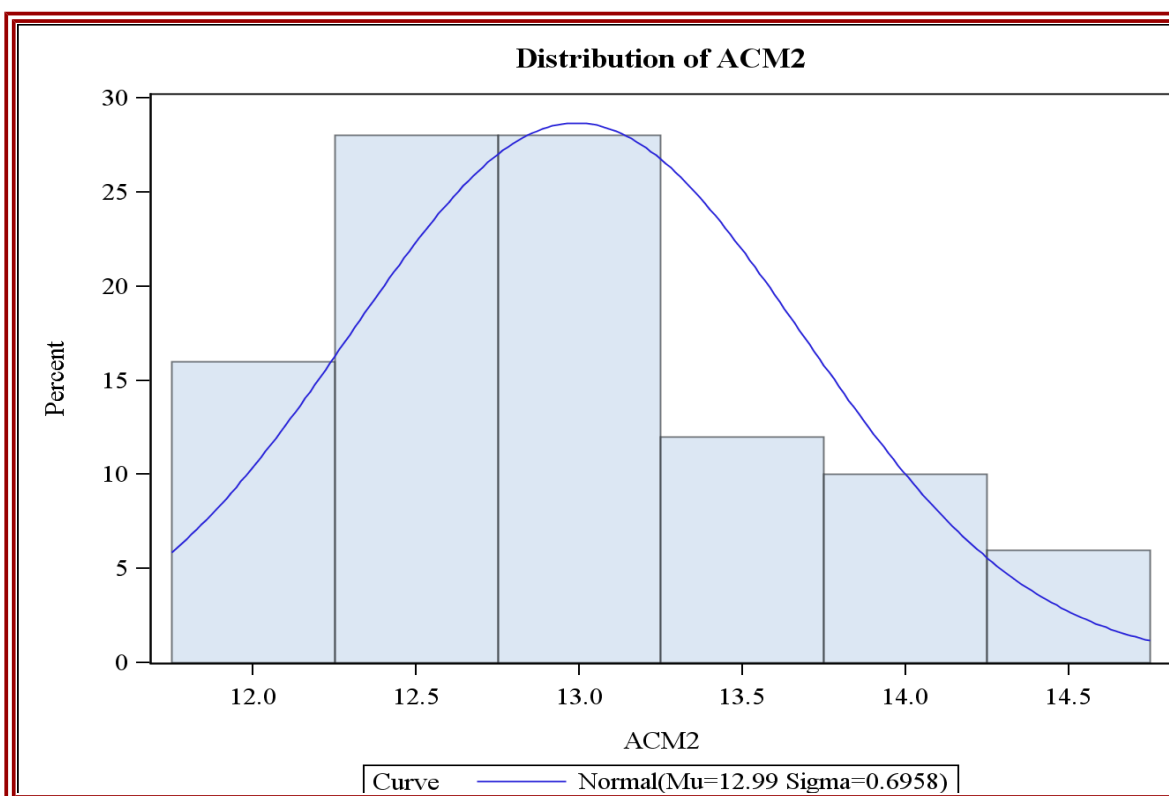


Fig. 4.1.2.2 The grouped frequency distribution curve of total solids of cows milk from Dairy Plant A by M₂ formula

The frequency distribution was worked out for total solids of cows milk by M₁ and M₂ formulae and is presented in Table 4.1.2.3 and 4.1.2.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The same is also depicted in Figure 4.1.2.1 and 4.1.2.2, respectively. All the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range.

.....Results and Discussion

Overman *et al.* (1945) studied the relation of TS and sp. gravity by taking 1158 individual, 134 random and 40 vat samples of cow's milk. They found that the standard deviation of the difference for the three groups of samples were 0.340, 0.242 and 0.100 per cent, respectively. The standard deviation is a measure of variability, as the number of cows contributing to the milk sample was increased; the variability in the difference between the TS by weight and their corresponding percentage of TS by formula was markedly decreased. They suggested that formula $TS = L/4 + 1.2F + 0.173$ in computing the percentage of TS in milk from individual cow is accurate but the variability within the results was too great to make it of any practical use. Rao and Bector (1980) reported that modified Richmond's formula ($SNF = 0.25 D + 0.2F + 0.50$) using Zeal lactometer and BSI formula ($SNF = 0.25D + 0.22F + 0.72$) using density hydrometer along with fat estimated by Gerber method gave higher and lower SNF values than the gravimetric values indicating that these methods did not give a true estimate of SNF in cow or buffalo milk.

It seemed that different workers applied only the correction factor to the formula to obtain the close values to the estimated by gravimetric method. This resulted in more complication of the formula for estimating TS/SNF. The probable errors might also be assumed that the samples derived may not be representative of the general populations of the respective types as well as a number of factors affecting composition of milk.

Based on analysis of 50 samples of cows milk collected from Dairy Plant A, two probable equations derived statistically are given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 0.86$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.73$$

Results and Discussion

4.1.3 Mixed milk

The values for milk fat, TS (gravimetric) and TS/SNF (lactometer) for mixed milk from Dairy Plant A are given in Table 4.1.3.1.

Table 4.1.3.1 Milk fat, TS (gravimetric) and TS (lactometer) for mixed milk from Dairy Plant A

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
	I	II	Average			
1	14.36	14.37	14.37	25.00	5.65	13.03
2	16.00	16.01	16.01	25.00	6.90	14.53
3	14.40	14.41	14.41	25.00	5.65	13.03
4	15.01	14.99	15.00	27.00	6.15	14.13
5	15.90	15.92	15.91	26.00	6.80	14.66
6	14.65	14.66	14.66	25.50	5.95	13.52
7	15.98	15.99	15.99	26.50	6.75	14.73
8	14.58	14.60	14.59	26.00	5.80	13.46
9	15.25	15.27	15.26	25.50	6.35	14.00
10	14.84	14.85	14.85	26.00	5.90	13.58
11	14.50	14.48	14.49	26.50	5.70	13.47
12	14.34	14.32	14.33	26.50	5.50	13.23
13	15.20	15.21	15.21	25.50	6.20	13.82
14	13.90	13.92	13.91	26.00	5.25	12.80
15	15.15	15.16	15.16	26.00	6.15	13.88
16	16.00	16.01	16.01	25.50	6.80	14.54
17	14.87	14.86	14.87	25.50	6.10	13.70
18	15.51	15.50	15.51	25.00	6.55	14.11
19	16.01	15.98	16.00	26.50	6.85	14.85
20	14.56	14.58	14.57	26.00	5.75	13.40
21	14.41	14.43	14.42	26.00	5.70	13.34
22	13.29	13.30	13.30	26.00	4.80	12.26
23	15.10	15.08	15.09	26.00	6.10	13.82
24	14.15	14.14	14.15	26.50	5.40	13.11
25	14.80	14.78	14.79	25.00	6.10	13.57
26	13.50	13.51	13.51	25.50	5.05	12.44
27	15.43	15.41	15.42	26.50	6.35	14.25

Results and Discussion

28	16.44	16.47	16.46	27.00	6.95	15.09
29	15.55	15.53	15.54	26.50	6.50	14.43
30	15.05	15.03	15.04	26.00	6.15	13.88
31	15.65	15.65	15.65	26.00	6.60	14.42
32	15.80	15.78	15.79	25.50	6.80	14.54
33	14.10	14.11	14.11	26.00	5.40	12.98
34	14.70	14.72	14.71	26.00	5.90	13.58
35	14.35	14.36	14.36	26.00	5.65	13.28
36	14.03	14.04	14.04	26.00	5.40	12.98
37	14.85	14.86	14.86	26.50	5.95	13.77
38	15.81	15.78	15.80	27.00	6.65	14.73
39	13.28	13.29	13.29	27.00	4.55	12.21
40	15.81	15.77	15.79	27.50	6.40	14.56
41	14.39	14.40	14.40	26.50	5.60	13.35
42	15.64	15.62	15.63	27.00	6.45	14.49
43	14.68	14.66	14.67	26.50	5.75	13.53
44	13.71	13.70	13.71	27.00	5.05	12.81
45	15.90	15.88	15.89	27.00	6.60	14.67
46	15.83	15.81	15.82	26.50	6.70	14.67
47	14.92	14.90	14.91	26.00	6.10	13.82
48	15.28	15.29	15.29	27.00	6.30	14.31
49	14.28	14.26	14.27	27.00	5.55	13.41
50	14.85	14.86	14.86	27.00	5.95	13.89

The minimum, maximum and average TS content in mixed milk by gravimetric and lactometric method without correction factor and by using M_1 and M_2 formulae have been presented in Table 4.1.3.2.

Table 4.1.3.2 Total solids of mixed milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant A

	Total solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M_1	M_2	M_1	M_2
	$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+1.04}{4}$	$\frac{CLR+1.25F+0.86}{4}$	
Minimum	13.28	12.30	12.43	13.34	13.29
Maximum	16.45	15.22	15.43	16.26	16.29
Average	14.92	13.88	14.06	14.92	14.92
t-test					
t value	-	6.97	5.69	1.20×10^{-14}	7.10×10^{-14}
Result	-	S	S	NS	NS

.....Results and Discussion

S= Significant NS = Non Significant

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids in milk were 12.30, 15.22 and 13.88 respectively, while using M_2 formula, these values were 12.43, 15.43 and 14.06, respectively. Addition of 1.04 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.34, 16.26 and 14.92 respectively, while addition of 0.86 correction factor in M_2 formula, these values were 13.29, 16.29 and 14.92, respectively. The minimum, maximum and average values of total solids by using gravimetric method were 13.28, 16.45 and 14.92, respectively.

It indicated that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS showed a non significant difference indicating almost similar values for TS as comparable with gravimetric method.

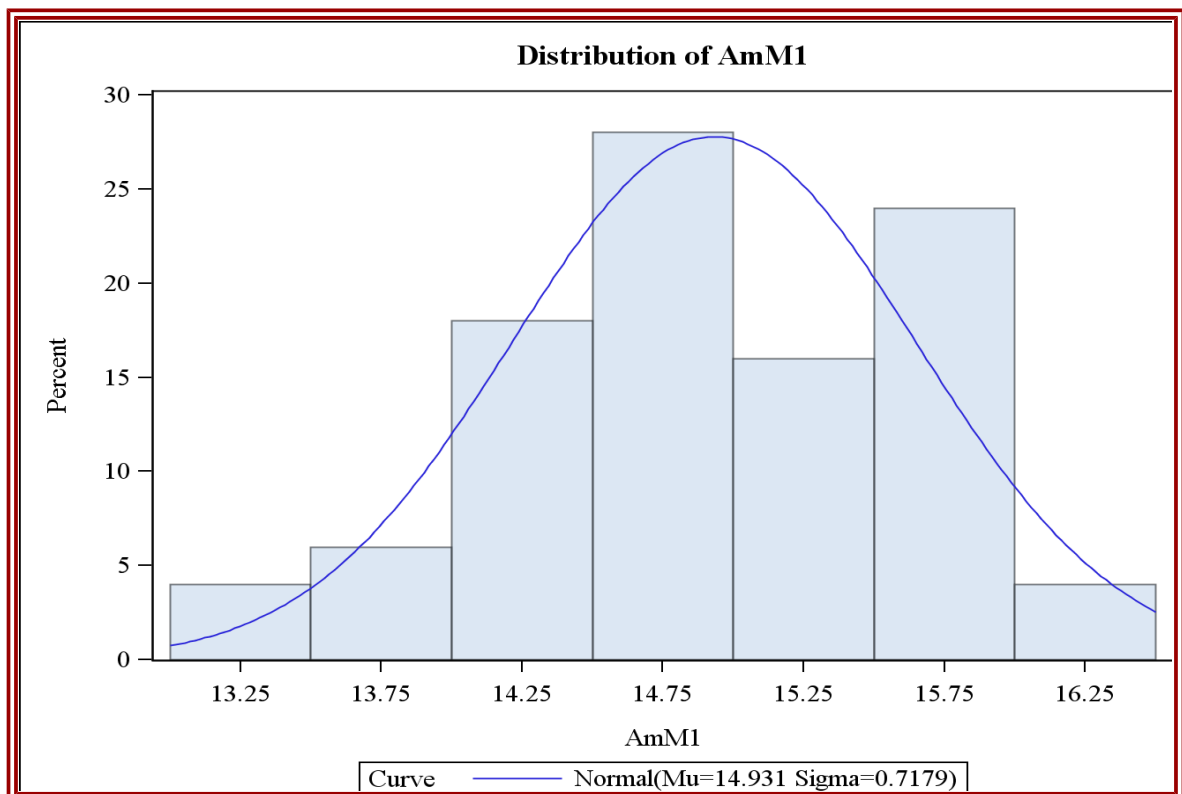
For the values of two sample t-test of Dairy Plant A as presented in Table 4.1.3.2, there was no statistical significant difference between gravimetric mean and volumetric mean by M_1 and M_2 formulae. Thus, it could be inferred that the TS by gravimetric and volumetric method were almost same for mixed milk from Dairy Plant A.

Table 4.1.3.3 Frequency distribution of total solids of mixed milk from Dairy Plant A by M_1 formula

Sr. No	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.00-13.50	2	4.00	2	4.00

Results and Discussion

2	13.50-14.00	3	6.00	5	10.00
3	14.00-14.50	9	18.00	14	28.00
4	14.50-15.00	14	28.00	28	56.00
5	15.00-15.50	8	16.00	36	72.00
6	15.50-16.00	12	24.00	48	96.00
7	16.00-16.50	2	4.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		14.93	
Std Dev		Sigma		0.7179	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.1011	Pr > D	>0.150

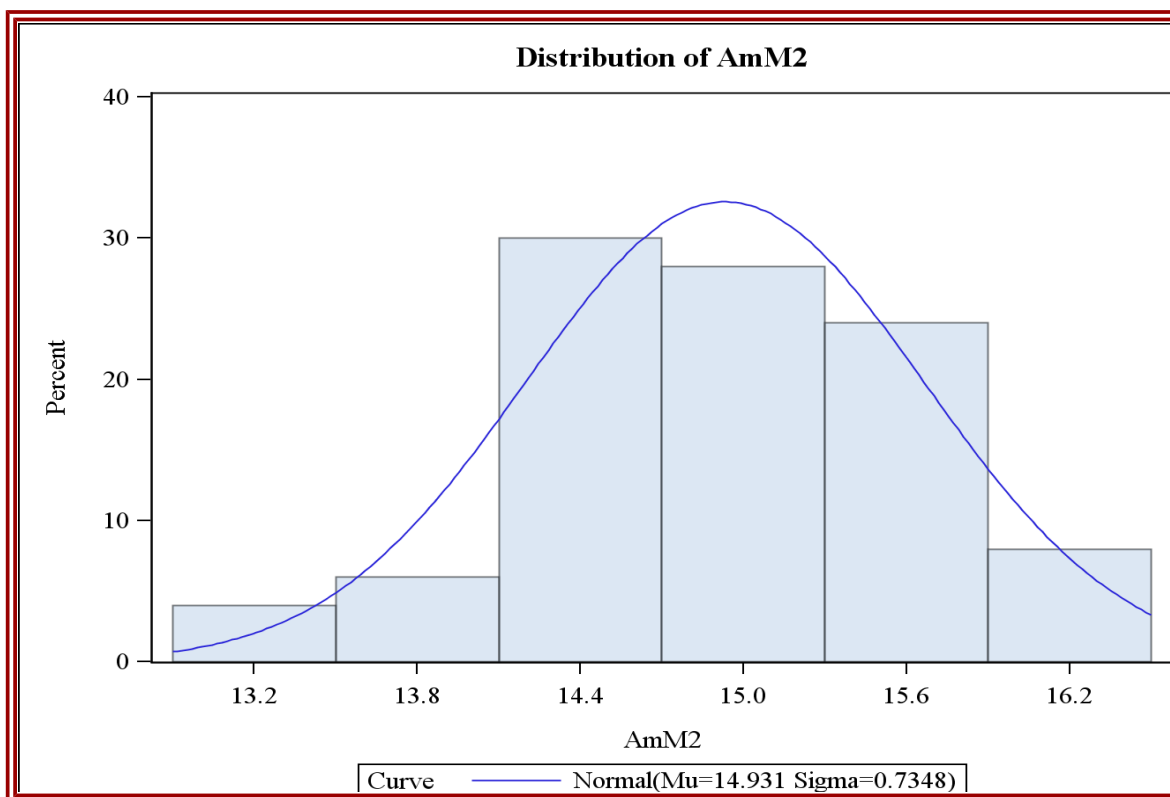


Results and Discussion

Fig. 4.1.3.1 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant A by M_1 formula

Table 4.1.3.4 Frequency distribution of total solids of mixed milk from Dairy Plant A by M_2 formula

Sr. No	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.00-13.50	2	4.00	2	4.00
2	13.50-14.00	3	6.00	5	10.00
3	14.00-14.50	9	18.00	14	28.00
4	14.50-15.00	14	28.00	28	56.00
5	15.00-15.50	8	16.00	36	72.00
6	15.50-16.00	12	24.00	48	96.00
7	16.00-16.50	2	4.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		14.93	
Std Dev		Sigma		0.7347	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.1017	Pr > D	>0.150



.....Results and Discussion

Fig. 4.1.3.2 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant A by M₂ formula

The frequency distribution as calculated for total solids of mixed milk by M₁ and M₂ formulae is presented in Table 4.1.3.3 and 4.1.3.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis indicated that the data followed the normal distribution. The same is also shown graphically in Figure 4.1.3.1 and 4.1.3.2, respectively. All the data for TS contents of mixed milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant A, two probable equations were derived statistically and are given as below.

$$TS = \frac{CLR}{4} + 1.22 F + 1.04$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.86$$

4.2 Dairy Plant B

Total of 150 samples each of cows, buffaloes and mixed milk were analyzed for milk fat and total solids by gravimetric and lactometer method.

4.2.1 Buffaloes milk

The results for milk fat, TS (gravimetric) and TS (lactometer) for buffaloes milk from Dairy Plant B are given in Table 4.2.1.1.

Table 4.2.1.1 Milk fat, TS (gravimetric) and TS (lactometer) for buffaloes milk from Dairy Plant B

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent $\frac{(CLR + 1.2F)}{4}$
I	II	Average				
1	19.06	19.14	19.10	28.50	9.30	18.29

Results and Discussion

2	19.44	19.51	19.47	30.00	9.30	18.66
3	18.81	18.86	18.83	29.50	8.85	18.00
4	17.98	18.00	17.99	28.00	8.30	16.96
5	19.76	19.86	19.81	26.50	10.20	18.87
6	19.51	19.52	19.51	26.50	9.70	18.27
7	17.71	17.74	17.72	28.50	8.10	16.85
8	20.06	20.13	20.10	29.50	9.65	18.96
9	16.79	16.77	16.78	30.50	6.70	15.67
10	19.56	19.57	19.57	27.50	9.75	18.58
11	19.15	19.20	19.18	27.50	9.40	18.16
12	17.52	17.58	17.55	27.00	8.20	16.59
13	16.97	16.96	16.96	27.00	8.00	16.35
14	20.78	20.81	20.80	25.50	10.60	19.10
15	19.37	19.23	19.30	29.50	9.20	18.42
16	18.02	18.00	18.01	31.00	7.60	16.87
17	19.78	19.80	19.79	28.00	9.65	18.58
18	19.10	19.11	19.11	28.00	9.05	17.86
19	17.95	17.93	17.94	27.00	8.50	16.95
20	15.21	15.36	15.29	35.00	5.00	14.75
21	16.85	17.45	17.15	25.00	8.70	16.69
22	15.36	15.23	15.29	28.00	6.35	14.62
23	17.55	17.49	17.52	25.00	8.70	16.69
24	17.45	17.23	17.34	30.00	7.50	16.50
25	15.36	15.23	15.29	28.00	6.35	14.62
26	18.13	18.18	18.16	31.50	7.70	17.12
27	17.14	17.14	17.14	32.00	6.60	15.92
28	19.39	19.41	19.40	32.00	8.60	18.32
29	22.18	22.28	22.23	26.00	12.10	21.02
30	16.82	16.88	16.85	34.00	6.05	15.76
31	21.33	21.28	21.30	29.00	10.80	20.21
32	18.65	18.73	18.69	29.00	8.75	17.75
33	18.07	18.05	18.06	27.50	8.50	17.08
34	19.14	19.18	19.16	29.00	9.10	18.17
35	17.79	17.80	17.80	28.00	7.75	16.30
36	15.16	15.17	15.16	33.00	4.90	14.13
37	16.13	16.13	16.13	29.50	6.50	15.18
38	17.95	18.02	17.98	26.00	8.65	16.88
39	17.76	17.83	17.80	30.50	7.40	16.51
40	19.78	19.78	19.78	27.50	9.80	18.64
41	17.51	17.51	17.51	29.00	7.50	16.25
42	16.76	16.81	16.78	28.50	7.00	15.53
43	17.13	17.18	17.16	29.50	7.25	16.08
44	17.29	17.32	17.31	29.50	7.35	16.20
45	17.44	17.52	17.48	29.00	7.45	16.19
46	16.91	16.99	16.95	27.50	7.40	15.76
47	15.10	15.19	15.14	32.50	5.00	14.13
48	18.55	18.49	18.52	29.00	8.40	17.33
49	18.67	18.66	18.66	28.00	8.80	17.56

Results and Discussion

50	16.01	16.02	16.02	31.50	6.15	15.26
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The minimum, maximum and average TS content in buffaloes milk by gravimetric and lactometric method without correction factor and by using correction factor (M_1 and M_2 formula) have been presented in Table 4.2.1.2.

Table 4.2.1.2: Total solids of buffaloes milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant B

	Total solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M_1	M_2	M_1	M_2
		$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.86}{4}$	$\frac{CLR+1.25F+0.61}{4}$
Minimum	15.14	14.22	14.37	15.09	14.99
Maximum	22.22	21.26	21.62	22.12	22.24
Average	18.07	17.20	17.45	18.07	18.07
t-test					
t value	-	2.76	1.95	1.6191×10^{-13}	1.13×10^{-14}
Result	-	S	S	NS	NS

S= Significant NS = Non Significant

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids were 14.22, 21.26 and 17.20 respectively, while using M_2 formula, these values were 14.37, 21.62 and 17.45, respectively. While addition of 0.86 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 15.09, 22.12 and 18.07 respectively, and addition of 0.61 correction factor in M_2 formula, these values were 14.99, 22.24 and 18.07, respectively. The minimum, maximum and average values of total solids by using gravimetric method were 15.14, 22.22 and 18.07, respectively.

It indicated that volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS quite comparable with gravimetric method.

.....Results and Discussion

The values of two sample t-test of Dairy Plant B are presented in Table 4.2.1.2, and no significant difference was found in mean values of TS of buffaloes milk for gravimetric and volumetric method by using M_1 and M_2 formulae. Thus, it could be said that the TS by both the methods were almost same for buffaloes milk from Dairy Plant B.

Table 4.2.1.3 Frequency distribution of total solids of buffaloes milk from Dairy Plant B by M_1 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	15.00-15.50	2	4.00	2	4.00
2	15.50-16.00	3	6.00	5	10.00
3	16.00-16.50	2	4.00	7	14.00
4	16.50-17.00	5	10.00	12	24.00
5	17.00-17.50	6	12.00	18	36.00
6	17.50-18.00	10	20.00	28	56.00
7	18.00-18.50	3	6.00	31	62.00
8	18.50-19.00	3	6.00	34	68.00
9	19.00-19.50	7	14.00	41	82.00
10	19.50-20.00	5	10.00	46	92.00
11	20.00-20.50	2	4.00	48	96.00
12	20.50-21.00	0	0.00	48	96.00
13	21.00-21.50	1	2.00	49	98.00
14	21.50-22.00	0	0.00	49	98.00
15	22.00-22.50	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		18.051	
Std Dev		Sigma		1.547	

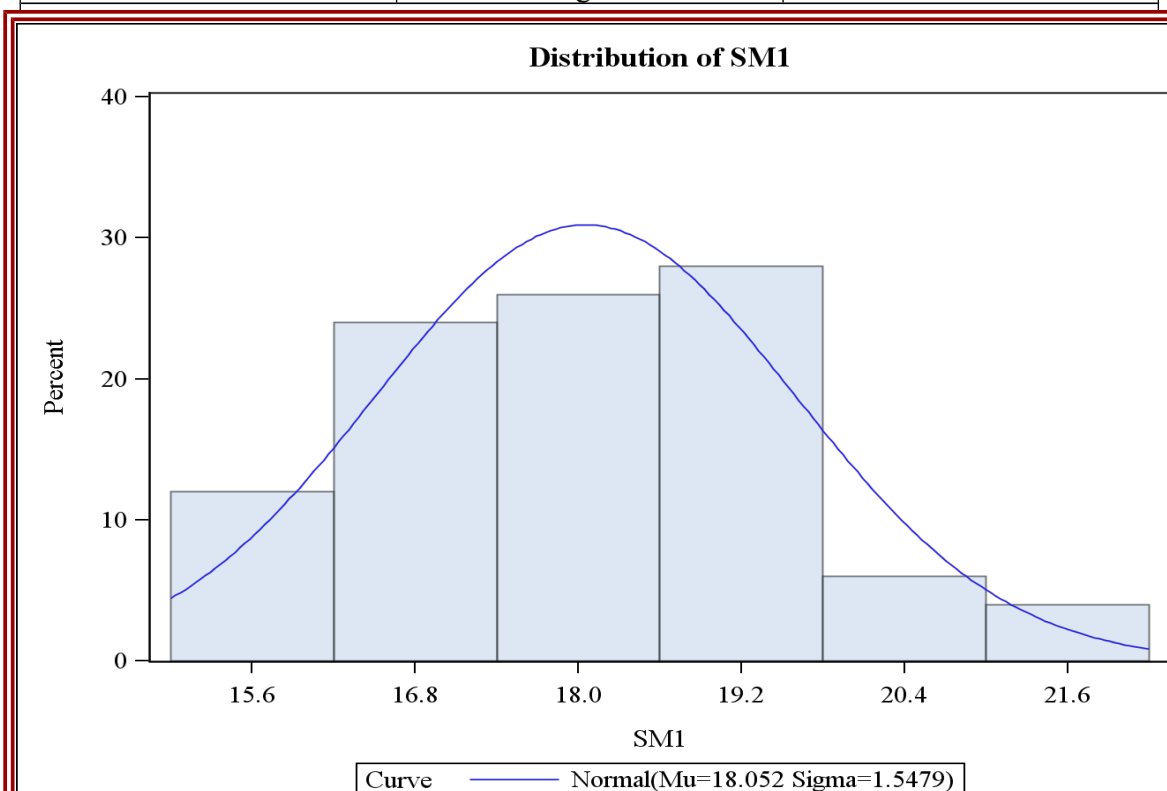


Fig. 4.2.1.1 The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant B by M_1 formula

Table 4.2.1.4 Frequency distribution of total solids of buffaloes milk from Dairy Plant B by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	14.50-15.00	2	4.00	2	4.00
2	15.00-15.50	0	0.00	2	4.00
3	15.50-16.00	3	6.00	5	10.00
4	16.00-16.50	3	6.00	8	16.00
5	16.50-17.00	4	8.00	12	24.00
6	17.00-17.50	8	16.00	20	40.00
7	17.50-18.00	8	16.00	28	56.00
8	18.00-18.50	3	6.00	31	62.00
9	18.50-19.00	3	6.00	34	68.00
10	19.00-19.50	7	14.00	41	82.00
11	19.50-20.00	5	10.00	46	92.00
12	20.00-20.50	2	4.00	48	96.00
13	20.50-21.00	0	0.00	48	96.00

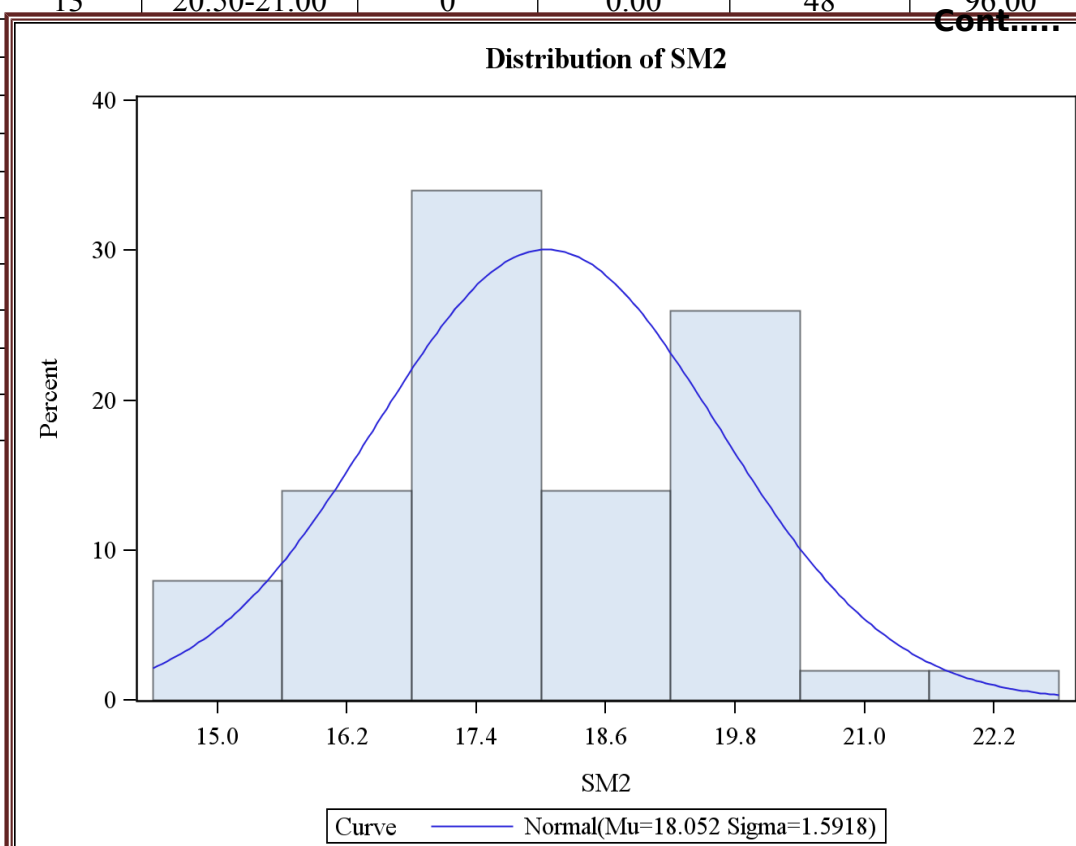


Fig. 4.2.1.2 The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant B by M₂ formula

The frequency distribution was worked out for total solids of buffaloes milk by M₁ and M₂ formulae are presented in Table 4.2.1.3 and 4.2.1.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The same is also depicted graphically in Figure 4.2.1.1 and 4.2.1.2, respectively. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant B for TS content by comparison of lactometer method with gravimetric method, two probable equations have been derived statistically given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 0.86$$

$$TS = CLR + 1.25 F + 0.61$$

4.2.2 Cows milk

The average values for TS by gravimetric method, milk fat by Gerber method, LR at 29 C and TS per cent calculated by Richmond equation for cows milk from Dairy Plant B are given in Table 4.2.2.1.

Table 4.2.2.1 Milk fat, TS (gravimetric) and TS (lactometer) for cows milk from Dairy Plant B

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
	I	II	Average			
1	13.40	13.41	13.40	28.50	4.80	12.89
2	13.18	13.20	13.19	29.00	4.40	12.53
3	14.24	14.24	14.24	29.00	5.30	13.61
4	14.06	14.04	14.05	29.00	5.20	13.49
5	12.14	12.04	12.09	29.00	3.85	11.87
6	12.67	12.62	12.65	27.50	4.25	11.98
7	13.44	13.49	13.46	29.00	4.50	Cont. 12.65
8	11.52	11.58	11.55	27.50	3.50	11.08
9	17.02	17.02	17.02	27.50	7.65	16.06
10	15.21	15.23	15.22	28.50	6.00	14.33
11	12.05	12.11	12.08	25.00	4.50	11.65
12	14.54	14.51	14.52	29.00	5.50	13.85
13	13.05	13.01	13.03	29.00	4.30	12.41
14	13.17	13.20	13.18	28.00	4.65	12.58
15	13.98	14.05	14.01	30.50	4.80	13.39
16	13.11	13.08	13.09	30.50	4.00	12.43
17	13.87	13.91	13.89	29.00	5.00	13.25
18	13.76	13.78	13.77	30.50	4.50	13.03
19	13.25	13.27	13.26	28.50	4.50	12.53
20	13.87	13.90	13.89	30.00	4.85	13.32
21	13.02	12.99	13.00	25.00	5.00	12.25
22	13.66	13.73	13.69	29.00	4.85	13.07
23	14.75	14.74	14.74	28.00	6.00	14.20
24	13.02	12.99	13.01	25.50	5.05	12.44
25	13.66	13.73	13.69	29.00	4.85	13.07
26	12.97	13.02	13.00	31.00	3.90	12.43
27	13.34	13.45	13.40	28.00	4.80	12.76
28	13.22	13.23	13.22	28.50	4.40	12.41

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29	10.70	10.68	10.69	24.00	3.50	10.20
30	12.82	12.81	12.81	28.00	4.50	12.40
31	13.64	13.67	13.65	27.00	5.35	13.17
32	12.89	12.83	12.86	27.50	4.45	12.22
33	13.82	13.79	13.80	29.00	4.90	13.13
34	13.88	13.90	13.89	28.50	5.15	13.31
35	12.92	12.88	12.90	27.00	4.50	12.15
36	13.16	13.10	13.13	28.50	4.50	12.53
37	13.23	13.28	13.26	29.00	4.30	12.41
38	12.55	12.53	12.54	29.50	3.80	11.94
39	12.52	12.57	12.54	29.50	3.55	11.64
40	15.88	15.85	15.87	29.00	6.45	14.99
41	12.44	12.49	12.46	27.50	4.05	11.74
42	12.96	12.97	12.96	28.00	4.45	12.34
43	13.16	13.24	13.20	28.00	4.45	12.34
44	12.70	12.80	12.75	28.50	4.10	12.05
45	13.08	13.07	13.07	28.50	4.20	12.17
46	12.88	12.89	12.89	28.50	4.20	12.17
47	12.43	12.53	12.48	28.00	4.10	11.92
48	13.10	13.06	13.08	28.50	4.40	12.41
49	13.26	13.25	13.26	30.50	3.90	12.31
50	13.30	13.32	13.31	29.00	4.55	12.71

The minimum, maximum and average TS content in cows milk by gravimetric method, by lactometric method without correction factor and by using correction factor (M_1 and M_2 formula) have been presented in Table 4.2.2.2.

Table 4.2.2.2 Total solids of cows milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant B

	Total solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M_1	M_2	M_1	M_2
	$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.57}{4}$	$\frac{CLR+1.25F+0.42}{4}$	
Minimum	10.69	10.27	10.37	10.83	10.80
Maximum	17.01	16.20	16.43	16.77	16.86
Average	13.35	12.78	12.92	13.35	13.35
t-test					
t value	-	2.89	2.16	9.10×10^{-15}	9.00×10^{-15}
Result	-	S	S	NS	NS

S= Significant NS= Non significant

Results and Discussion

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids from cows milk were 10.27, 16.20 and 12.78 respectively, while using M_2 formula, these values were 10.37, 16.43 and 12.92, respectively. While addition of 0.57 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 10.83, 16.77 and 13.35 respectively, and addition of 0.42 correction factor in M_2 formula, these values were 10.80, 16.86 and 13.35, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 10.69, 17.01 and 13.35, respectively.

It indicated that the volumetric method without correction factor gave lower values of TS, which were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS almost in consonance with gravimetric method.

The values of two sample t-test of Dairy Plant B as presented in Table 4.2.2.2, showed no significant difference between gravimetric and volumetric mean by M_1 and M_2 formulae. Thus, the TS by gravimetric and volumetric method were almost same for cows milk from Dairy Plant B.

Table 4.2.2.3 Frequency distribution of total solids of cows milk from Dairy Plant B by M_1 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	10.50-11.00	1	2.00	1	2.00
2	11.00-11.50	0	0.00	1	2.00
3	11.50-12.00	1	2.00	2	4.00
4	12.00-12.50	3	6.00	5	10.00
5	12.50-13.00	13	26.00	18	36.00
6	13.00-13.50	15	30.00	33	66.00

Results and Discussion

7	13.50-14.00	9	18.00	42	84.00
8	14.00-14.50	3	6.00	45	90.00
9	14.50-15.00	2	4.00	47	94.00
10	15.00-15.50	1	2.00	48	96.00
11	15.50-16.00	1	2.00	49	98.00
12	16.00-16.50	0	0.00	49	98.00
13	16.50-17.00	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		13.33537	
Std Dev		Sigma		0.960103	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.14162385	Pr > D	0.013

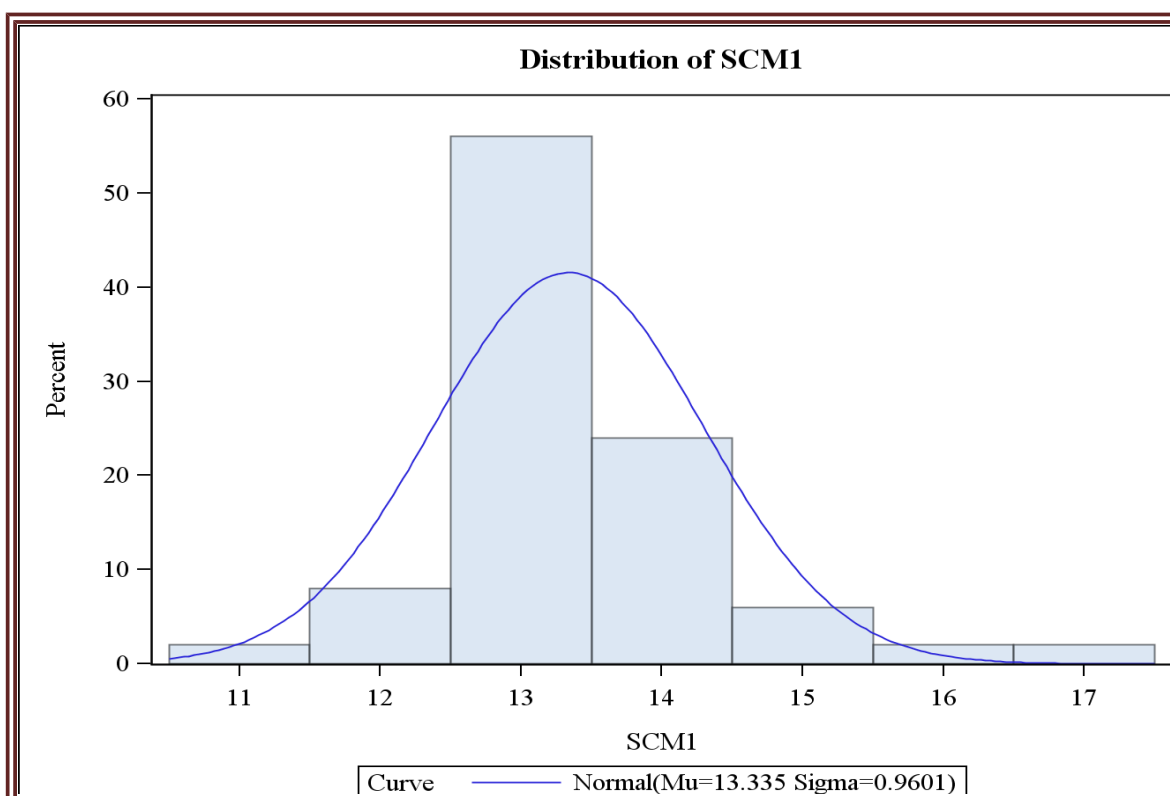


Fig. 4.2.2.1 The grouped frequency distribution curve of total solids of cows milk from Dairy Plant B by M_1 formula

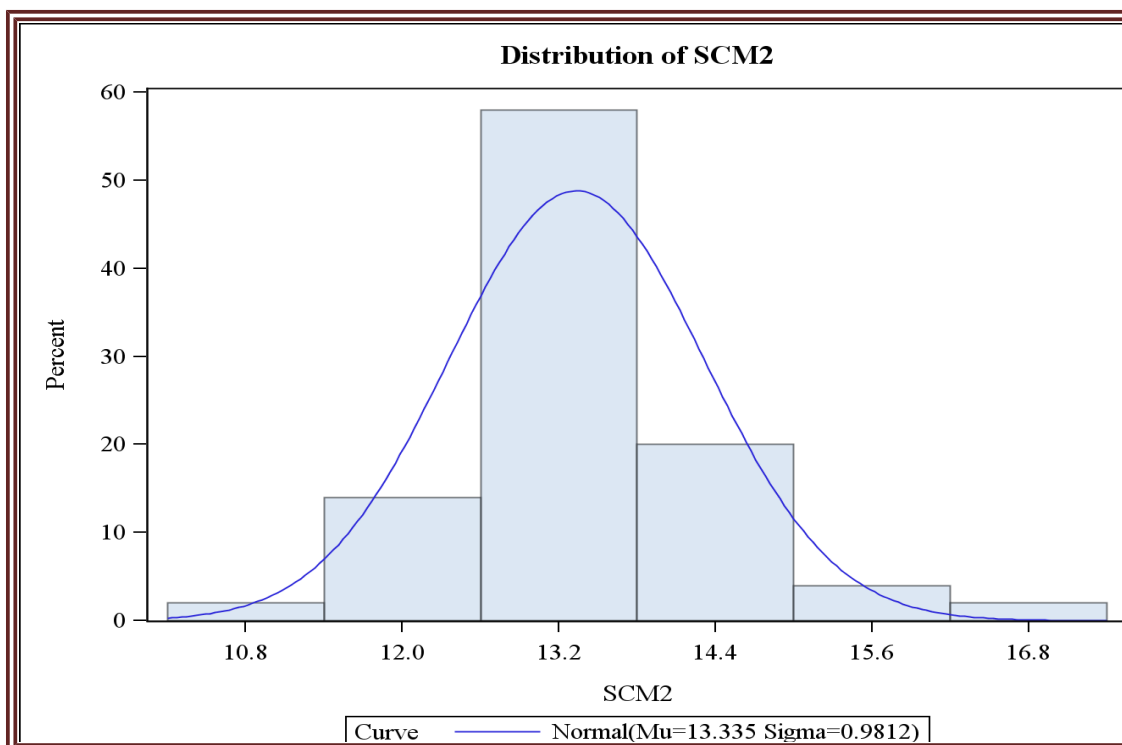
Table 4.2.2.4 Frequency distribution of total solids of cows milk from Dairy Plant B by M_2 formula

Results and Discussion

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	10.50-11.00	1	2.00	1	2.00
2	11.00-11.50	0	0.00	1	2.00
3	11.50-12.00	1	2.00	2	4.00
4	12.00-12.50	4	8.00	6	12.00
5	12.50-13.00	12	24.00	18	36.00
6	13.00-13.50	15	30.00	33	66.00
7	13.50-14.00	9	18.00	42	84.00
8	14.00-14.50	3	6.00	45	90.00
9	14.50-15.00	2	4.00	47	94.00
10	15.00-15.50	1	2.00	48	96.00
11	15.50-16.00	1	2.00	49	98.00
12	16.00-16.50	0	0.00	49	98.00
13	16.50-17.00	1	2.00	50	100.00

Parameters for Normal Distribution		
Parameter	Symbol	Estimate
Mean	Mu	13.33537
Std Dev	Sigma	0.981189

Goodness-of-Fit Tests for Normal Distribution				
Test	Statistic		p Value	
Kolmogorov-Smirnov	D	0.14326232	Pr > D	0.011



Results and Discussion

Fig. 4.2.2.2 The grouped frequency distribution curve of total solids of cows milk from Dairy Plant B by M₂ formula

The frequency distribution for total solids of cows milk by M₁ and M₂ formulae are presented in Table 4.2.2.3 and 4.2.2.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The same is also depicted graphically in Figure 4.2.2.1 and 4.2.2.2, respectively. All the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of cows milk collected from Dairy Plant B, two probable equations are derived statistically given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 0.57$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.42$$

4.2.3 Mixed milk

The results for milk fat, TS (gravimetric), LR at 29 C and corresponding TS (lactometer) for mixed milk from Dairy Plant B are given in Table 4.2.3.1.

Table 4.2.3.1 Milk fat, TS (gravimetric) and TS (lactometer) for mixed milk from Dairy Plant B

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent $\frac{(CLR+1.2F)}{4}$
	I	II	Average			
1	15.87	15.87	15.87	28.50	6.70	15.17
2	17.25	17.22	17.23	30.00	7.45	16.44
3	17.04	16.90	16.97	29.50	7.50	16.38
4	16.43	16.54	16.48	28.50	7.20	15.77
5	14.11	14.06	14.08	28.50	5.40	13.61
6	14.91	14.85	14.88	28.00	5.70	13.84
7	15.08	15.11	15.09	28.50	5.00	13.13
8	15.93	15.90	15.92	28.00	6.70	15.04
9	16.85	16.95	16.90	30.00	7.00	15.90
10	16.03	16.09	16.06	29.00	6.65	15.23

Results and Discussion

11	14.88	14.85	14.87	26.00	6.45	14.24
12	16.40	16.33	16.37	28.00	7.15	15.58
13	14.47	14.43	14.45	29.50	5.30	13.74
14	16.10	16.11	16.11	27.50	6.95	15.22
15	15.82	15.82	15.82	30.00	6.30	15.06
16	14.90	14.99	14.95	30.50	5.35	14.05
17	16.20	16.20	16.20	29.00	6.60	15.17
18	17.39	17.36	17.37	28.50	7.70	16.37
19	14.85	14.87	14.86	28.00	5.80	13.96
20	14.41	14.46	14.44	32.00	5.00	14.00
21	15.90	15.90	15.90	26.00	7.70	15.74
22	14.99	15.01	15.00	28.50	6.00	14.33
23	16.47	16.47	16.47	26.00	7.70	15.74
24	15.90	15.90	15.90	28.50	6.65	15.11
25	14.99	15.01	15.00	28.50	6.00	14.33
26	15.22	15.15	15.18	31.00	5.50	14.35
27	15.03	15.07	15.05	29.50	5.70	14.22
28	16.19	16.26	16.22	30.00	6.50	15.30
29	14.40	14.31	14.36	25.00	6.15	13.63
30	15.58	15.49	15.54	32.00	5.50	14.60
31	16.32	16.39	16.36	27.50	7.20	15.52
32	15.36	15.33	15.34	28.50	6.50	14.93
33	16.04	15.99	16.02	28.00	6.70	15.04
34	16.10	16.11	16.11	28.50	6.80	15.29
35	14.85	14.77	14.81	27.50	5.80	13.84
36	14.43	14.49	14.46	31.50	4.80	13.64
37	14.49	14.56	14.52	27.00	6.00	13.95
38	14.95	14.96	14.96	28.00	5.90	14.08
39	14.63	14.67	14.65	29.50	5.25	13.68
40	18.27	18.13	18.20	27.50	8.60	17.20
41	15.49	15.44	15.46	28.00	6.25	14.50
42	15.46	15.50	15.48	28.00	6.20	14.44
43	14.65	14.67	14.66	29.00	5.45	13.79
44	15.51	15.54	15.52	29.00	6.00	14.45
45	15.59	15.54	15.56	28.00	6.20	14.44
46	14.45	14.45	14.45	28.00	5.45	13.54
47	14.32	14.21	14.27	29.00	5.20	13.49
48	15.49	15.37	15.43	29.00	6.15	14.63
49	15.66	15.59	15.62	29.50	6.10	14.70
50	14.66	14.57	14.62	30.00	5.15	13.68

The minimum, maximum and average TS content in mixed milk by gravimetric method, by lactometric method without correction factor and by using correction factor (M_1 and M_2 formula) have been presented in Table 4.2.3.2.

Table 4.2.3.2 Total solids of mixed milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant B

Results and Discussion

	Total Solid, per cent				
	Gravimetric Method	Volumetric method			
		Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
		$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.75}{4}$	$\frac{CLR+1.25F+0.58}{4}$
Minimum	14.08	13.22	13.37	13.94	13.90
Maximum	18.20	17.36	17.62	18.08	18.15
Average	15.54	14.82	15.01	15.53	15.54
t-test					
t value	-	2.89	2.16	9.10X10 ⁻¹⁵	9.00X10 ⁻¹⁵
Result	-	S	S	NS	NS

In volumetric method using M₁ formula without correction factor, the minimum, maximum and average values of total solids of mixed milk were 13.22, 17.36 and 14.82 respectively, while using M₂ formula, these values were 13.37, 17.62 and 15.01, respectively. While addition of 0.75 correction factor in M₁ formula, the minimum, maximum and average values of total solids were 13.94, 18.08 and 15.53 respectively, and addition of 0.58 correction factor in M₂ formula, these values were 13.90, 18.15 and 15.54, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 14.04, 18.20 and 15.54, respectively.

It indicated that the volumetric method without correction factor gave lower values of TS. This was also evidenced by statistical significant difference. While using M₁ and M₂ formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as compared to gravimetric method.

The values of two sample t-test for mixed milk from Dairy Plant B as presented in Table 4.2.3.2, no significant difference was found between gravimetric

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and volumetric mean values of TS calculated by M_1 and M_2 formulae. Thus, it could be said that the TS by gravimetric method and volumetric method were almost same for mixed milk from Dairy Plant B.

Table 4.2.3.3 Frequency distribution of total solids of mixed milk from Dairy Plant B by M_1 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.50-14.00	1	2.00	1	2.00
2	14.00-14.50	7	14.00	8	16.00
3	14.50-15.00	9	18.00	17	34.00
4	15.00-15.50	11	22.00	28	56.00
5	15.50-16.00	6	12.00	34	68.00
6	16.00-16.50	8	16.00	42	84.00
7	16.50-17.00	4	8.00	46	92.00
8	17.00-17.50	3	6.00	49	98.00
9	17.50-18.00	0	0.00	49	98.00
10	18.00-18.50	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		15.52048	
Std Dev		Sigma		0.929085	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.09971680	Pr > D	>0.150

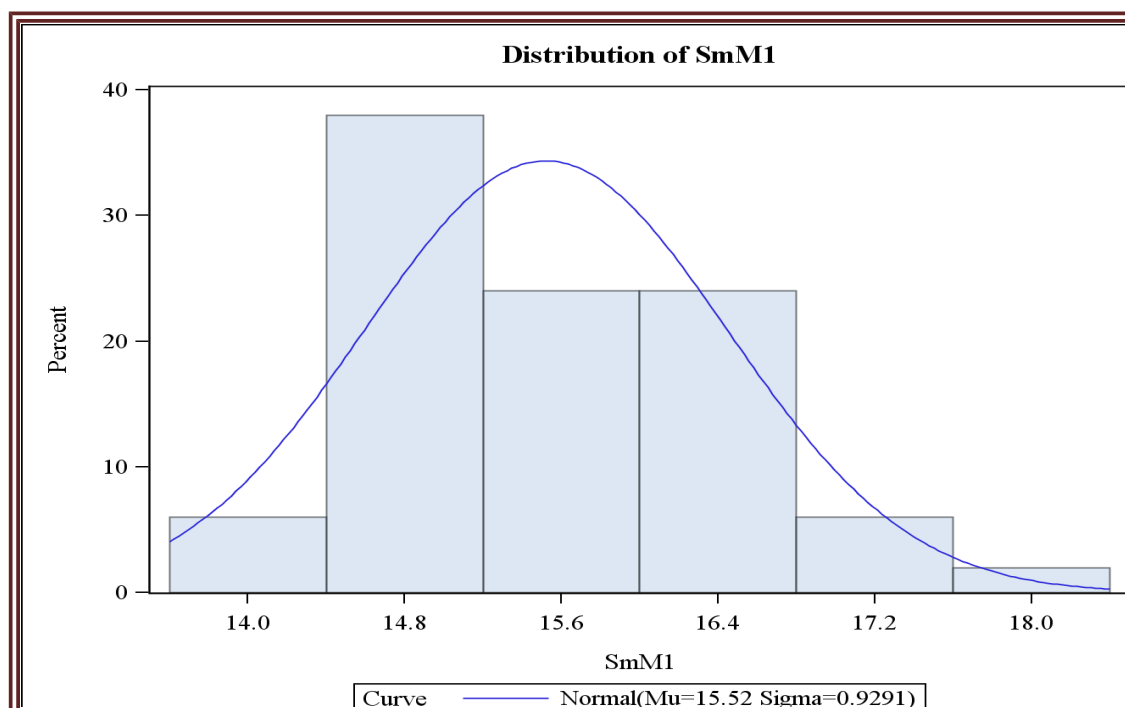


Fig. 4.2.3.1 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant B by M_1 formula

Table 4.2.3.4 Frequency distribution of total solids of mixed milk from Dairy Plant B by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.50-14.00	1	2.00	1	2.00
2	14.00-14.50	7	14.00	8	16.00
3	14.50-15.00	9	18.00	17	34.00
4	15.00-15.50	11	22.00	28	56.00
5	15.50-16.00	6	12.00	34	68.00
6	16.00-16.50	8	16.00	42	84.00
7	16.50-17.00	4	8.00	46	92.00
8	17.00-17.50	3	6.00	49	98.00
9	17.50-18.00	0	0.00	49	98.00
10	18.00-18.50	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		15.52	
Std Dev		Sigma		0.952	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.1004	Pr > D	>0.150

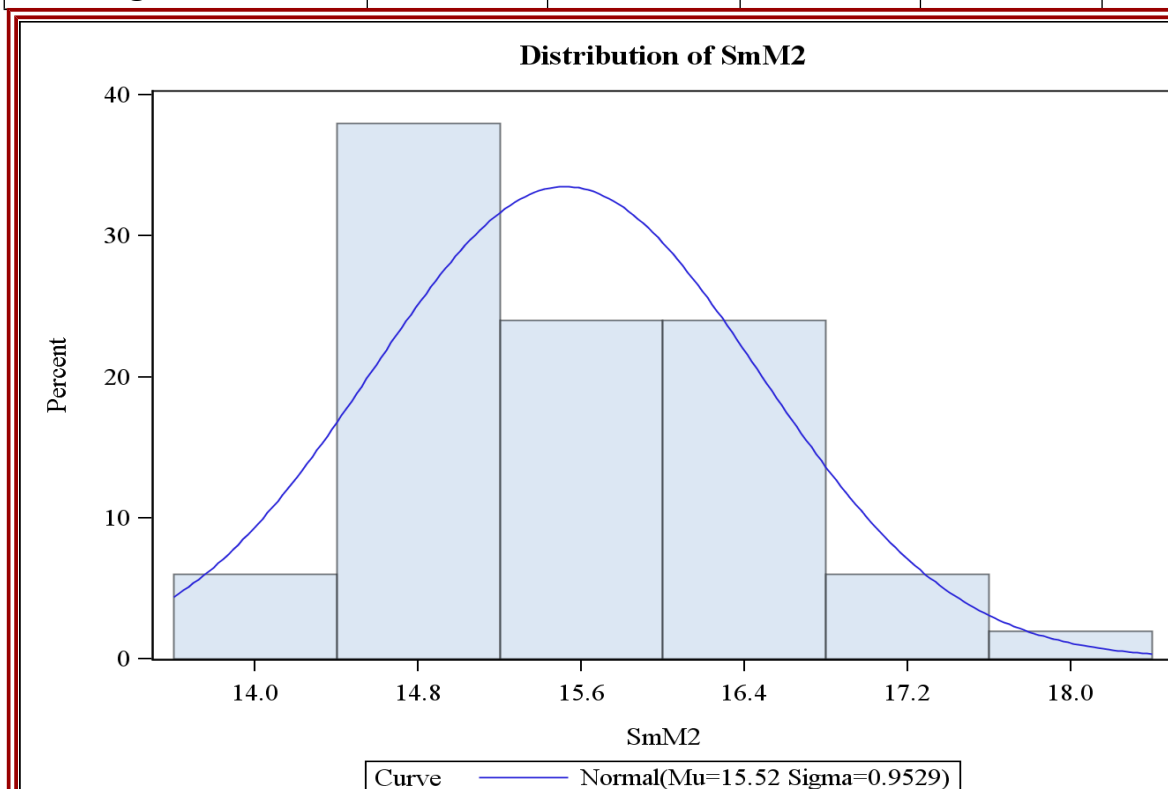


Fig. 4.2.3.2 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant B by M₂ formula

The frequency distribution as worked out for total solids of mixed milk by M₁ and M₂ formulae are presented in Table 4.2.3.3 and 4.2.3.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The same is also presented graphically in Figure 4.2.3.1 and 4.2.3.2, respectively. All the data for TS contents of mixed milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant B, two probable equations have been derived statistically and are given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 0.75$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.58$$

4.3 Dairy Plant C

Total of 150 samples each of cows, buffaloes and mixed milk were analyzed for milk fat, total solids by gravimetric method, LR at 29 C and corresponding TS by lactometer method.

4.3.1 Buffaloes milk

The results for milk fat, TS (gravimetric) and TS (lactometer), for buffaloes milk from Dairy Plant C are given in Table 4.3.1.1.

Results and Discussion

Table 4.3.1.1 Milk fat, TS (gravimetric) and TS (lactometer) for buffaloes milk from Dairy Plant C

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
I	II	Average				
1	16.88	17.03	16.96	28.00	6.75	15.10
2	17.29	16.99	17.14	28.50	7.25	15.83
3	16.41	16.37	16.39	26.50	7.20	15.27
4	17.58	17.51	17.55	27.50	7.85	16.30
5	16.88	16.84	16.86	26.00	7.58	15.60
6	17.45	17.48	17.47	27.00	7.90	16.23
7	17.07	17.17	17.12	27.00	7.65	15.93
8	17.39	17.38	17.39	28.00	7.73	16.28
9	17.09	17.15	17.12	27.00	7.75	16.05
10	15.99	15.88	15.94	26.50	6.80	14.79
11	16.77	16.74	16.76	26.50	7.50	15.63
12	16.39	16.27	16.33	27.00	6.85	14.97
13	16.82	16.88	16.85	26.50	7.63	15.78
14	16.87	16.78	16.83	27.50	7.23	15.55
15	16.67	16.78	16.73	27.50	7.40	15.76
16	15.85	15.81	15.83	27.00	6.75	14.85
17	17.39	17.38	17.39	28.00	7.70	16.24
18	16.34	16.31	16.33	27.00	7.00	15.15
19	16.44	16.42	16.43	28.50	6.98	15.50
20	17.99	17.90	17.95	28.00	8.03	16.64
21	16.44	16.47	16.46	28.50	6.75	15.23
22	16.82	16.80	16.81	27.50	7.23	15.55
23	16.88	16.83	16.86	26.50	7.60	15.75
24	16.14	16.19	16.17	26.50	7.20	15.27
25	16.81	16.79	16.80	27.50	7.38	15.73
26	16.51	16.52	16.52	27.50	7.25	15.58
27	16.73	16.70	16.72	26.50	7.65	15.81
28	18.16	18.10	18.13	27.50	8.35	16.90
29	17.11	17.12	17.12	28.50	7.50	16.13
30	17.17	17.05	17.11	28.00	7.38	15.86
31	16.95	16.89	16.92	28.00	7.43	15.92
32	16.66	16.56	16.61	28.00	7.08	15.50
33	16.91	16.93	16.92	28.00	7.35	15.82
34	15.44	15.33	15.39	26.50	6.60	14.55
35	16.01	15.95	15.98	28.00	6.73	15.08
36	16.45	16.38	16.42	27.50	6.95	15.22
37	17.65	17.66	17.66	28.50	7.88	16.58
38	17.20	17.18	17.19	27.00	7.63	15.91
39	17.23	17.18	17.21	27.50	7.35	15.70

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40	16.26	16.14	16.20	27.50	6.80	15.04
41	17.45	17.40	17.43	28.00	7.68	16.22
42	17.20	17.13	17.17	29.00	7.80	16.61
43	16.61	16.60	16.61	27.50	7.30	15.64
44	17.13	17.08	17.11	28.00	7.53	16.04
45	15.52	15.78	15.65	27.00	6.83	14.95
46	16.97	17.02	17.00	28.50	7.25	15.83
47	15.91	15.88	15.90	27.00	6.85	14.97
48	16.50	16.50	16.50	27.50	7.15	15.46
49	16.45	16.45	16.45	27.50	7.10	15.40
50	16.68	16.97	16.83	28.00	7.40	15.88

The minimum, maximum and average TS content in buffaloes milk by gravimetric and lactometric method without correction factor and by using M₁ and M₂ formulae have been presented in Table 4.3.1.2.

Table 4.3.1.2 Total solids of buffaloes milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant C

	Total Solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
		$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.97}{4}$	$\frac{CLR+1.25F+0.75}{4}$
Minimum	15.38	14.67	14.87	15.64	15.62
Maximum	18.13	17.06	17.31	18.02	18.05
Average	16.78	15.81	16.03	16.78	16.78
t-test					
t value	-	8.83	6.75	3.22X10 ⁻¹⁴	3.22X10 ⁻¹⁴
Result	-	S	S	NS	NS

S= Significant NS= Non Significant

The minimum, maximum and average values of total solids were 14.67, 17.06 and 15.81, respectively in volumetric method using M₁ formula without correction factor, while these values were 14.87, 17.31 and 16.03, respectively using M₂ formula. By addition of 0.97 correction factor in M₁ formula, the minimum, maximum and average values of total solids in buffaloes milk were 15.64, 18.02 and 16.78, respectively, and addition of 0.75 correction factor in M₂ formula, these values were

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15.62, 18.05 and 16.78, respectively. The minimum, maximum and average values of total solids were 15.38, 18.13 and 16.7,8 respectively by using gravimetric method.

It indicated that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as compared to gravimetric method.

The values of two sample t-test for milk samples collected from Dairy Plant C as presented in Table 4.3.1.2, showed no statistical significant difference between gravimetric and volumetric mean in TS by M_1 and M_2 formulae. Thus, it could said that the TS by gravimetric method and volumetric method were almost same for buffaloes milk of Dairy Plant C.

Table 4.3.1.3 Frequency distribution of total solids of buffaloes milk from Dairy Plant C by M_1 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	15.50-16.00	3	6.00	3	6.00
2	16.00-16.50	11	22.00	14	28.00
3	16.50-17.00	21	42.00	35	70.00
4	17.00-17.50	11	22.00	46	92.00
5	17.50-18.00	3	6.00	49	98.00

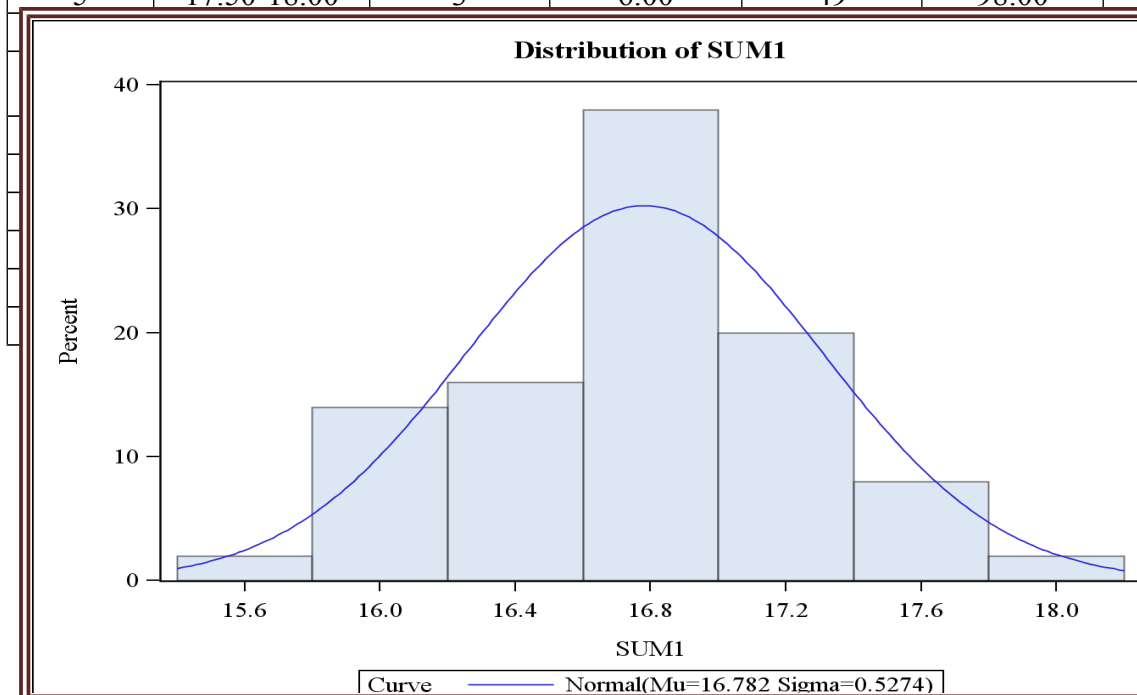


Fig. 4.3.1.1 The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant C by M_1 formula

Table 4.3.1.4. Frequency distribution of total solids of buffaloes milk from Dairy Plant C by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	15.50-16.00	3	6.00	3	6.00
2	16.00-16.50	12	24.00	15	30.00
3	16.50-17.00	20	40.00	35	70.00
4	17.00-17.50	11	22.00	46	92.00
5	17.50-18.00	3	6.00	49	98.00
6	18.00-18.50	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	

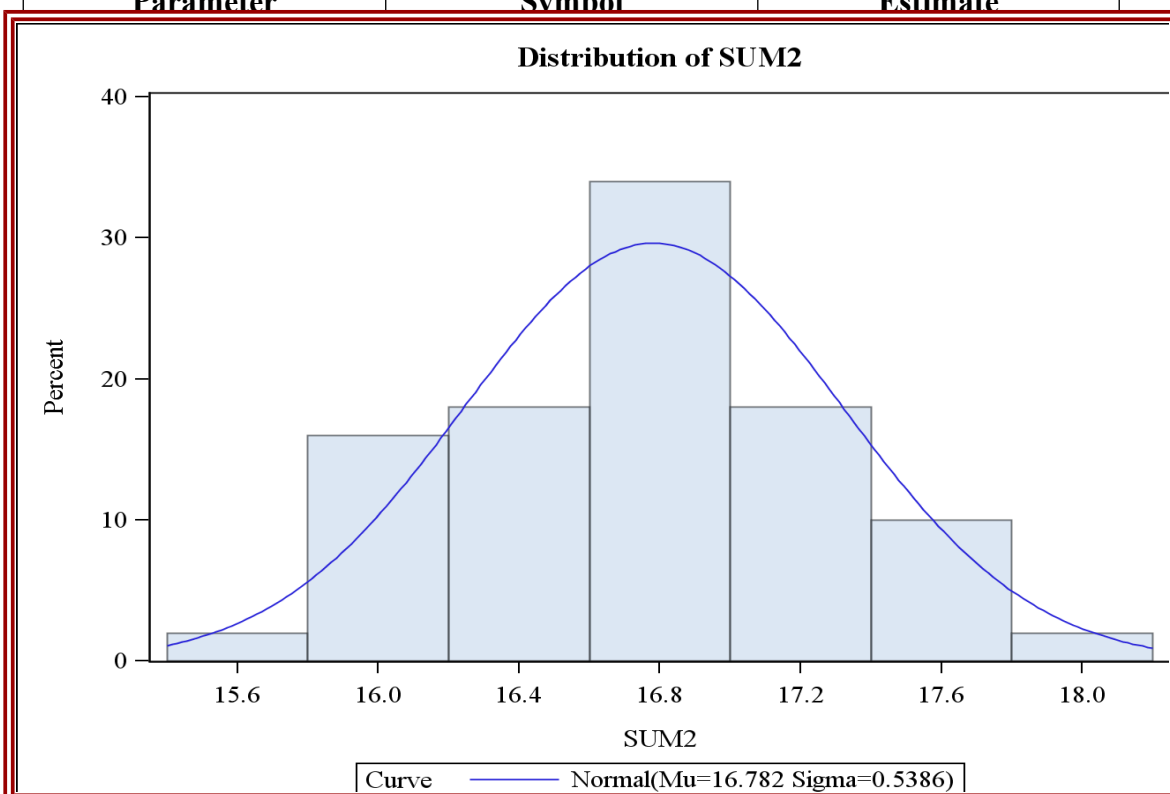


Fig. 4.3.1.2 The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant C by M₂ formula

The frequency distribution was worked out for total solids of buffaloes milk by M₁ and M₂ formulae and are presented in Table 4.3.1.3 and 4.3.1.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis revealed that the data followed the normal distribution. The same is also shown graphically in Figure 4.3.1.1 and 4.3.1.2, respectively. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant C, two probable equations derived statistically have been given as below.

$$TS = \frac{CLR}{4} + 1.22 F + 0.97$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.75$$

4.3.2 Cows Milk

The values for milk fat, TS by gravimetric method, Lactometer Reading at 29 C and TS by putting LR in Richmond equation for cows milk from Dairy Plant C are given in Table 4.3.2.1.

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Table 4.3.2.1 Milk fat, TS (gravimetric) and TS (lactometer) for cows milk for Dairy Plant C

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	(TS per cent)					
	I	II	Average	LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
1	13.11	13.12	13.12	26.50	4.73	12.30
2	13.87	13.83	13.85	27.00	5.50	13.35
3	12.61	12.68	12.65	27.50	4.30	12.04
4	12.94	12.92	12.93	26.50	4.65	12.21
5	13.57	13.53	13.55	26.50	5.03	12.66
6	13.29	13.26	13.28	27.50	4.58	12.37
7	13.02	12.98	13.00	27.00	4.65	12.33
8	13.14	13.14	13.14	27.00	4.73	12.43
9	12.54	12.52	12.53	26.50	4.43	11.94
10	13.51	13.46	13.49	27.50	4.85	12.70
11	13.70	13.69	13.70	27.00	5.30	13.11
12	14.20	14.17	14.19	27.50	5.40	13.36
13	12.81	12.81	12.81	27.00	4.45	12.09
14	13.15	13.12	13.14	26.50	4.68	12.24
15	12.85	12.86	12.86	27.50	4.45	12.22
16	13.36	13.34	13.35	27.50	4.68	12.49
17	13.00	13.00	13.00	26.50	4.75	12.33
18	14.24	14.16	14.20	28.50	5.18	13.34
19	13.19	13.18	13.19	27.50	4.63	12.43
20	13.01	13.01	13.01	27.00	4.38	12.01
21	12.94	12.93	12.94	26.50	4.75	Cont.....
22	13.08	13.04	13.06	25.50	4.75	12.08
23	12.89	12.91	12.90	27.00	4.70	12.39
24	13.08	13.04	13.06	27.00	4.60	12.27
25	12.87	12.86	12.87	26.50	4.60	12.15
26	14.20	14.21	14.21	27.50	5.28	13.21
27	13.49	13.48	13.49	28.00	4.83	12.80
28	13.33	13.26	13.30	27.00	4.70	12.39
29	12.63	12.61	12.62	25.50	4.60	11.90
30	13.27	13.24	13.26	28.50	4.55	12.59
31	12.70	12.68	12.69	27.00	4.33	11.95
32	12.48	12.49	12.49	27.00	4.18	11.77
33	13.27	13.31	13.29	27.00	4.73	12.43
34	13.27	13.27	13.27	27.50	4.75	12.58
35	12.82	12.72	12.77	27.50	4.33	12.07
36	12.50	12.47	12.49	27.00	4.15	11.73
37	13.35	13.28	13.32	27.50	4.65	12.46
38	13.14	13.09	13.12	27.50	4.65	12.46

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39	13.28	13.28	13.28	27.00	4.75	12.45
40	13.36	13.31	13.34	27.50	4.70	12.52
41	12.90	12.90	12.90	27.00	4.75	12.45
42	13.64	13.66	13.65	27.00	5.08	12.85
43	12.89	12.94	12.92	27.00	4.68	12.37
44	12.35	12.43	12.39	26.50	4.28	11.76
45	13.04	13.04	13.04	27.00	4.80	12.51
46	13.31	13.32	13.32	26.50	5.00	12.63
47	12.77	12.78	12.78	26.50	4.60	12.15
48	13.36	13.37	13.37	26.50	4.83	12.42
49	13.28	13.28	13.28	26.00	4.75	12.20
50	13.48	13.47	13.48	26.00	5.00	12.50

The minimum, maximum and average TS content in cows milk by gravimetric method, by lactometric method without correction factor and by using M₁ and M₂ formulae have been presented in Table 4.3.2.2.

Table 4.3.2.2 Total solids of cows milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant C

	Total Solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
		$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.66}{4}$	$\frac{CLR+1.25F+0.52}{4}$
Minimum	12.39	11.81	11.93	12.46	12.45
Maximum	14.20	13.46	13.62	14.11	14.14
Average	13.16	12.50	12.64	13.16	13.16
t-test					
t value	-	8.06	6.27	0	1.3X10-13
Result	-	S	S	NS	NS

S= Significance NS= Non significance

In volumetric method using M₁ formula without correction factor, the minimum, maximum and average values of total solids in cows milk were 11.81, 13.46 and 12.50 respectively, while using M₂ formula, these values for TS were 11.93, 13.62 and 12.64, respectively. Addition of 0.66 correction factor in M₁ formula gave minimum, maximum and average values of 12.46, 14.11 and 13.16, per cent total solids respectively and addition of 0.52 correction factor in M₂ formula these

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values were 12.45, 14.14 and 13.16, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 12.39, 14.20 and 13.16, respectively.

The results indicated that volumetric method using basic Richmond formula without correction factor gave lower values of TS in cows milk and the difference between the TS were statistically significant. While using M₁ and M₂ formulae with correction factor, the values for TS were quite comparable with gravimetric method and these values also showed a non significant difference.

The values of two sample t-test of TS of milk collected from Dairy Plant C as presented in Table 4.3.2.2 revealed no significant difference between gravimetric and volumetric mean by M₁ and M₂ formulae. Thus, it could be inferred that the TS by both the methods were almost alike for cows milk from Dairy Plant C.

Table 4.3.2.4. Frequency distribution of total solids of cows milk from Dairy Plant C by M₁ formula

Sr. No	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	12.00-12.50	1	2.00	1	2.00
2	12.50-13.00	16	32.00	17	34.00
3	13.00-13.50	26	52.00	43	86.00
4	13.50-14.00	4	8.00	47	94.00
5	14.00-14.50	3	6.00	50	100.00

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Parameters for Normal Distribution				
Parameter	Symbol		Estimate	
Mean	Mu		13.1553	
Std Dev	Sigma		0.393621	
Goodness-of-Fit Tests for Normal Distribution				
Test	Statistic		p Value	
Kolmogorov-Smirnov	D	0.14953778	Pr > D	<0.010

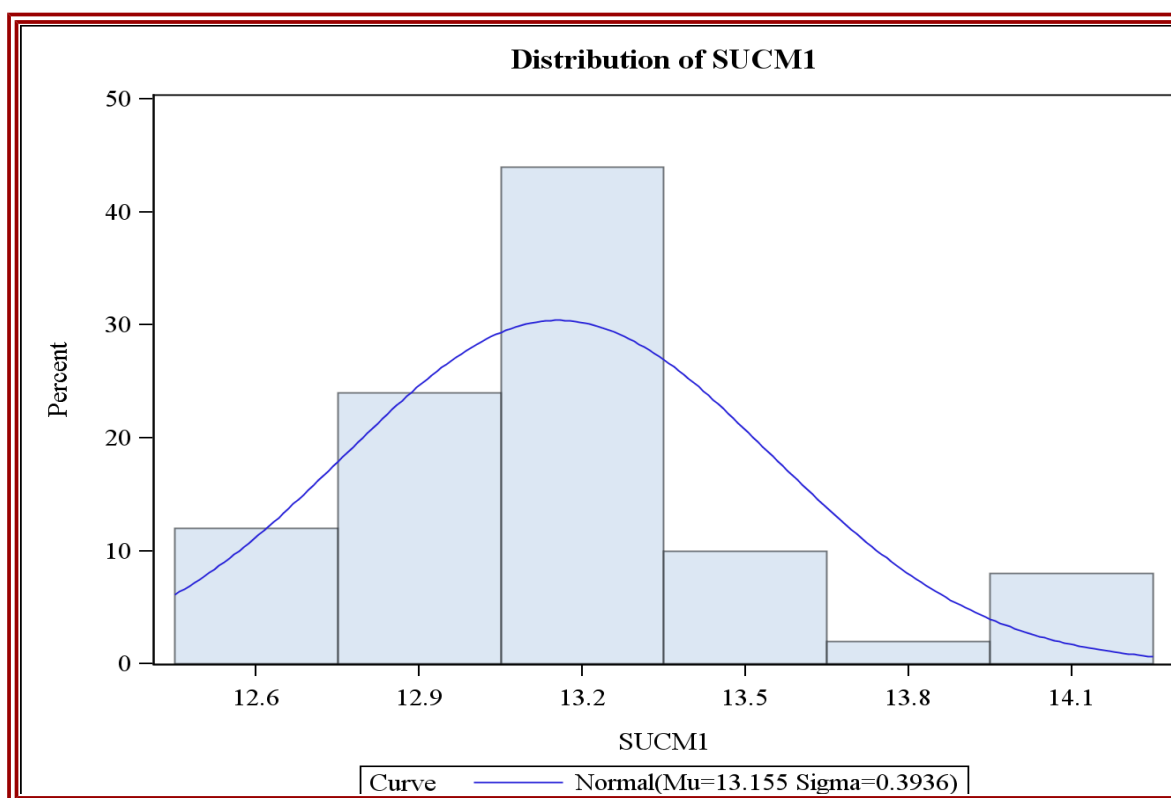


Fig. 4.3.2.1 The grouped frequency distribution curve of total solids of Cows milk from Dairy Plant C by M_1 formula

Table 4.3.2.4 Frequency distribution of total solids of cows milk from Dairy Plant C by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	12.00-12.50	3	6.00	3	6.00

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2	12.50-13.00	14	28.00	17	34.00
3	13.00-13.50	26	52.00	43	86.00
4	13.50-14.00	4	8.00	47	94.00
5	14.00-14.50	3	6.000	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		13.1553	
Std Dev		Sigma		0.401679	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.15209964	Pr > D	<0.010

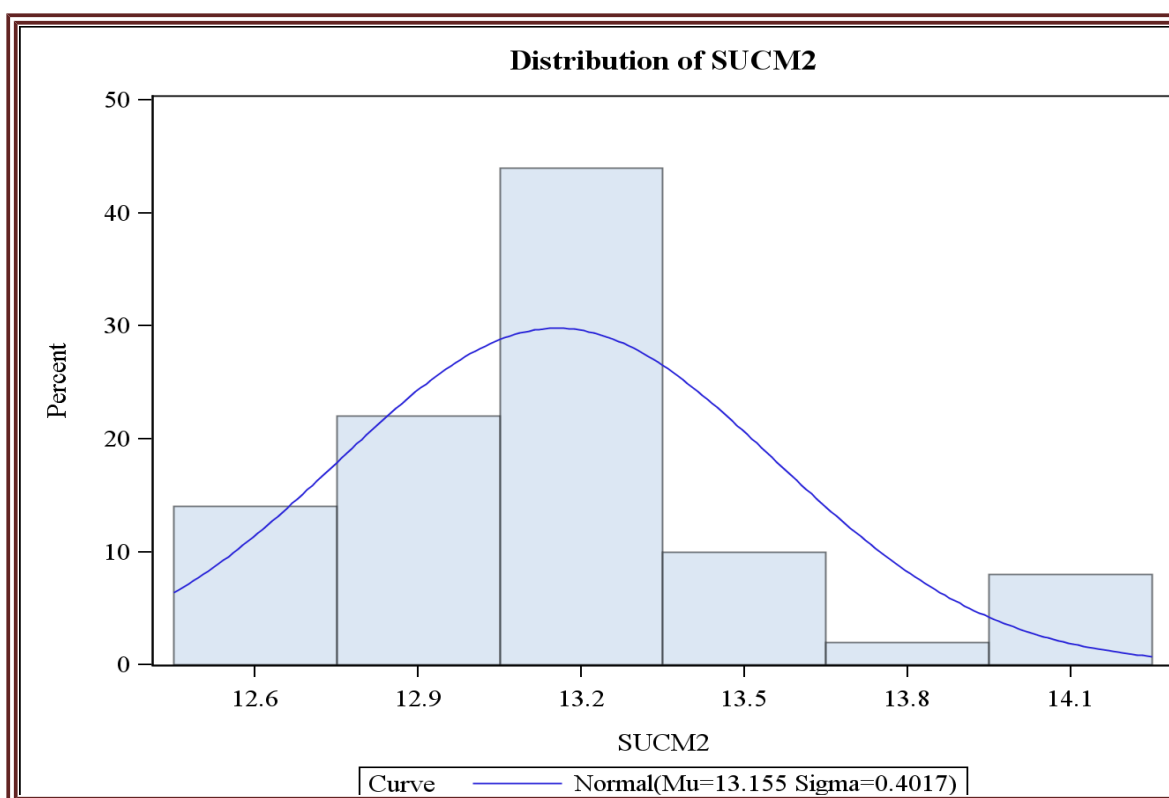


Fig. 4.3.2.2 The grouped frequency distribution curve of total solids of cows milk from Dairy Plant C by M_2 formula

The frequency distribution was derived for total solids of cows milk by M_1 and M_2 formulae and is presented in Table 4.3.2.3 and 4.3.2.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The graphical distribution is

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also shown in Figure 4.3.2.1 and 4.3.2.2, respectively. All the data for TS contents of cows milk followed the $\mu \pm 3 \sigma$ range.

Based on analysis of 50 samples of cows milk collected from Dairy Plant C, two probable equations are derived statistically and are given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 0.66$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.52$$

4.3.3 Mixed milk

The results for average TS (gravimetric), LR at 29 C, milk fat, and TS calculated using lactometer reading in basic Richmond equation for mixed milk from Dairy Plant C are given in Table 4.3.3.1.

Table 4.3.3.1 Milk fat, TS (gravimetric) and TS (lactometer) for mixed milk from Dairy Plant C

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent $\frac{(CLR+1.2F)}{4}$
	I	II	Average			
1	13.91	13.84	13.88	26.50	5.35	13.05
2	14.08	14.05	14.07	27.00	5.40	13.23
3	14.61	14.52	14.57	27.00	5.80	13.71
4	14.02	13.95	13.99	27.00	5.38	13.21
5	13.46	13.37	13.42	26.50	4.98	12.60
6	14.37	14.24	14.31	27.00	5.50	13.35
7	14.84	14.81	14.83	27.00	5.83	13.75
8	14.16	14.09	14.13	27.00	5.30	13.11
9	14.01	13.96	13.99	27.00	5.20	12.99
10	14.83	14.77	14.80	27.00	5.90	13.83
11	14.52	14.52	14.52	27.00	5.68	13.57
12	14.82	14.73	14.78	27.50	5.95	14.02
13	14.72	14.65	14.69	27.00	5.73	13.63
14	13.67	13.59	13.63	27.00	5.03	12.79

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15	14.22	14.24	14.23	27.00	5.53	13.39
16	14.35	14.36	14.36	27.00	5.65	13.53
17	14.66	14.68	14.67	27.00	5.78	13.69
18	14.60	14.59	14.60	27.00	5.73	13.63
19	14.02	14.05	14.04	27.00	5.38	13.21
20	13.78	14.77	14.28	26.50	5.40	13.11
21	14.17	14.14	14.16	26.50	5.63	13.38
22	13.74	13.73	13.74	26.50	5.30	12.99
23	14.03	14.03	14.03	26.50	5.45	13.17
24	14.66	14.70	14.68	27.00	5.95	13.89
25	14.03	14.02	14.03	26.00	5.58	13.20
26	14.74	14.71	14.73	27.50	5.85	13.90
27	15.41	15.37	15.39	28.00	6.30	14.56
28	14.71	14.74	14.73	27.50	5.80	13.84
29	15.02	15.03	15.03	27.50	6.03	14.11
30	15.38	15.39	15.39	27.50	6.30	14.44
31	15.23	15.20	15.22	27.50	6.13	14.23
32	14.09	14.14	14.12	27.00	5.48	13.33
33	15.31	15.36	15.34	28.00	6.20	14.44
34	14.81	14.88	14.85	27.00	5.98	13.93
35	14.60	14.60	14.60	27.50	5.80	13.84
36	13.89	13.87	13.88	25.50	5.50	12.98
37	14.17	14.23	14.20	27.50	5.40	13.36
38	14.68	14.68	14.68	28.00	5.68	13.82
39	14.68	14.70	14.69	28.00	5.68	13.82
40	15.34	15.32	15.33	28.50	6.15	14.51
41	14.50	14.50	14.50	28.00	5.53	13.64
42	14.57	14.58	14.58	27.00	5.78	13.69
43	15.61	15.57	15.59	28.50	6.43	14.84
44	15.17	15.15	15.16	27.50	6.20	14.32
45	14.46	14.44	14.45	27.00	5.68	13.57
46	14.52	14.49	14.51	26.00	6.10	13.82
47	14.22	14.20	14.21	25.50	5.95	13.52
48	14.18	14.15	14.17	26.50	5.48	13.20
49	14.27	14.22	14.25	28.00	5.58	13.70
50	14.86	14.82	14.84	28.00	5.88	14.06

Cont.....

The minimum, maximum and average values for TS content in mixed milk by gravimetric and lactometric method without correction factor and by using M₁ and M₂ formulae have been presented in Table 4.3.3.2.

Table 4.3.3.2 Total solids of mixed milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant C

	Total solid, per cent	
	Gravimetric	Volumetric Method

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	Method	Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
		$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.75}{4}$	$\frac{CLR+1.25F+0.58}{4}$
Minimum	13.41	12.70	12.85	13.45	13.43
Maximum	15.59	14.96	15.16	15.72	15.74
Average	14.49	13.74	13.91	14.49	14.49
t-test					
t value	-	7.64	5.84	5.41X10 ⁻¹⁴	5.41X10 ⁻¹⁴
Result	-	S	S	NS	NS

S= Significant NS= Non Significant

In volumetric method using M₁ formula without correction factor, the minimum, maximum and average values of total solids in mixed milk supplies were 12.70, 14.96 and 13.74 respectively, while using M₂ formula, these values were 12.85, 15.16 and 13.91, respectively. While addition of 0.75 correction factor in M₁ formula, the minimum, maximum and average values of total solids were 13.45, 15.72 and 14.49 respectively, and addition of 0.58 correction factor in M₂ formula, these values were 13.43, 15.74 and 14.49, respectively. The minimum, maximum and average values of total solids were 13.41, 15.59 and 14.49, respectively by using gravimetric method.

It showed that the volumetric method without correction factor gave lower values of TS with statistically significant difference. While using M₁ and M₂ formulae with correction factor, the values for TS showed a non significant difference indicating almost similar values for TS as comparable to gravimetric method.

The values of two sample t-test of TS content in mixed milk from Dairy Plant C as presented in Table 4.3.3.2, indicated no significant difference between gravimetric mean and volumetric mean by M₁ and M₂ formulae. Thus, it could be said that the TS by gravimetric method and volumetric method were almost same for mixed milk from Dairy Plant C.

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Table 4.3.3 Frequency distribution of total solids of mixed milk from Dairy Plant C by M_1 formula

Sr. No	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.00-13.50	1	2.00	1	2.00
2	13.50-14.00	7	14.00	8	16.00
3	14.00-14.50	18	36.00	26	52.00
4	14.50-15.00	17	34.00	43	86.00
5	15.00-15.50	6	12.00	49	98.00
6	15.50-16.00	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		14.4944	
Std Dev		Sigma		0.4949	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.07589900	Pr > D	>0.150

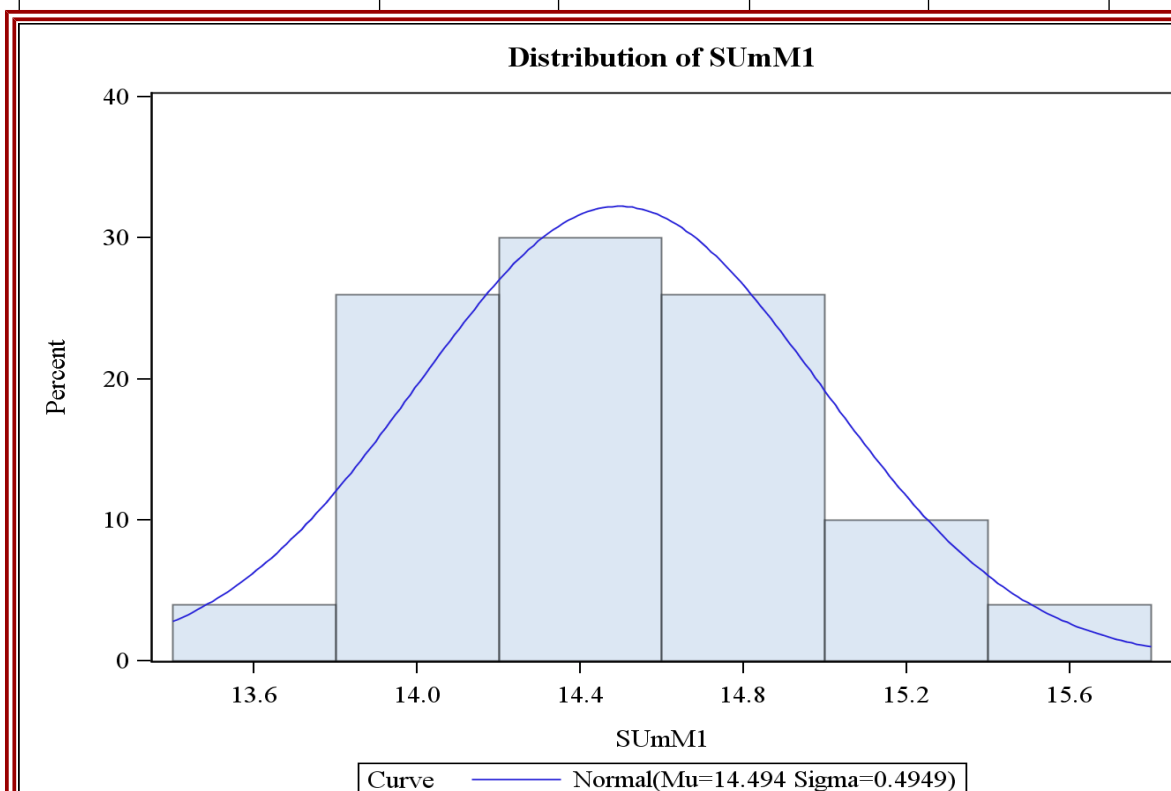


Fig . 4.3.3.1 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant C by M_1 formula

Table 4.3.3.4 Frequency distribution of total solids of mixed milk from Dairy Plant C by M_2 formula

Sr. No	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.00-13.50	1	2.00	1	2.00
2	13.50-14.00	7	14.00	8	16.00
3	14.00-14.50	18	36.00	26	52.00
4	14.50-15.00	17	34.00	43	86.00
5	15.00-15.50	6	12.00	49	98.00
6	15.50-16.00	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		14.4944	
Std Dev		Sigma		0.504318	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.07674573	Pr > D	>0.150

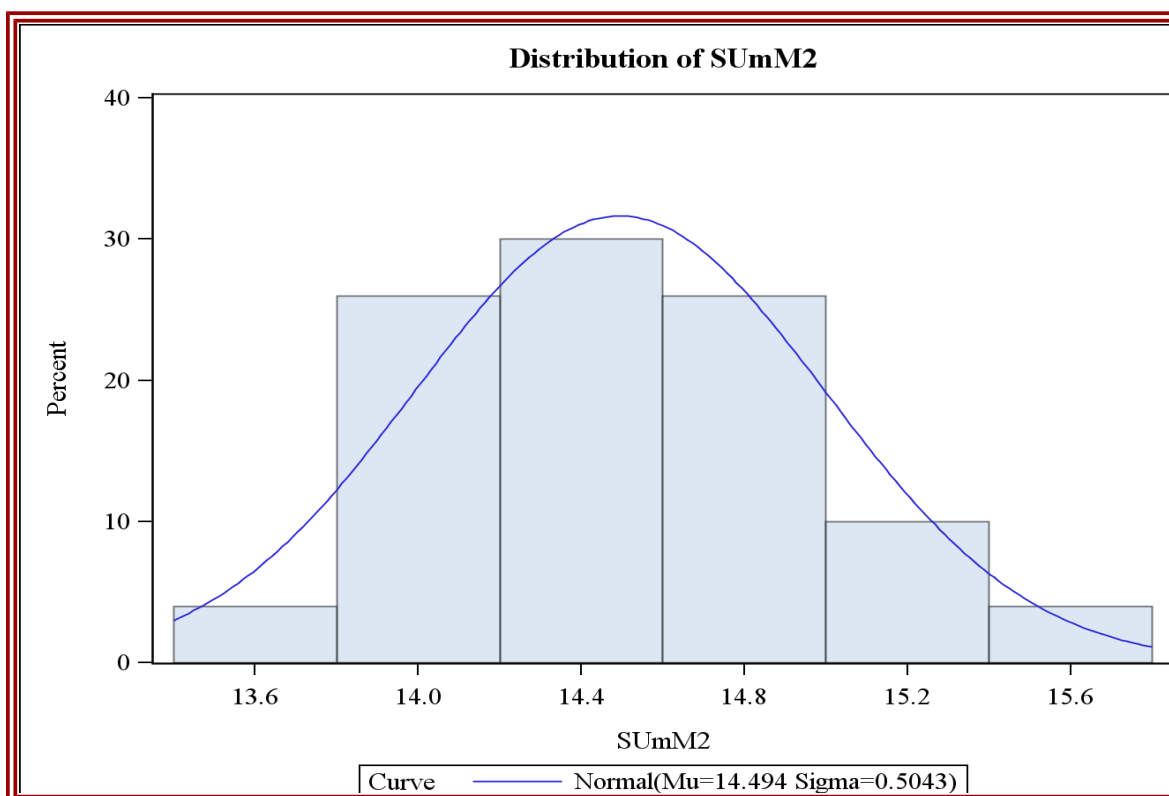


Fig. 4.3.3.2 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant C by M₂ formula

The frequency distribution was worked out for total solids of mixed milk by M₁ and M₂ formulae are presented in Table 4.3.3.3 and 4.3.3.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The same is also depicted in Figure 4.3.3.1 and 4.3.3.2, respectively. All the data for TS contents of mixed milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant C, two probable equations are derived statistically given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 0.75$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.58$$

4.4 Dairy plant D

Total of 150 samples each of cows, buffaloes and mixed milk were analyzed for milk fat, total solids (gravimetric) and TS/SNF (lactometer) methods.

4.4.1 Buffaloes milk

The results for milk fat by Gerber method, average values for TS (gravimetric), LR at 29 C and TS (lactometer) for buffaloes milk from Dairy Plant D are given in Table 4.4.1.1.

Table 4.4.1.1 Milk fat, TS (gravimetric) and TS (lactometer) for buffaloes milk from Dairy Plant D

Sr. No.	Methods
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.....Results and Discussion

	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
	I	II	Average			
1	16.03	16.10	16.07	23.00	7.10	14.27
2	15.01	15.10	15.06	28.00	5.50	13.60
3	16.65	16.71	16.68	24.50	7.20	14.77
4	16.36	16.41	16.39	22.50	7.40	14.51
5	15.67	15.70	15.69	22.50	7.00	14.03
6	16.46	16.52	16.49	28.00	7.40	15.88
7	17.92	17.99	17.96	26.00	8.00	16.10
8	15.30	15.25	15.28	25.00	6.10	13.57
9	17.52	17.56	17.54	25.00	7.90	15.73
10	17.47	17.52	17.50	25.50	7.60	15.50
11	14.11	14.16	14.14	21.00	6.10	12.57
12	13.55	13.50	13.53	22.00	5.40	11.98
13	14.46	14.52	14.49	24.00	5.80	12.96
14	16.73	16.80	16.77	23.00	7.50	14.75
15	17.03	17.10	17.07	26.00	7.00	14.90
16	17.76	17.82	17.79	27.00	7.40	15.63
17	15.03	15.09	15.06	22.50	6.40	13.31
18	17.10	17.13	17.12	26.00	7.30	15.26
19	16.83	16.90	16.87	26.50	6.90	14.91
20	18.71	18.79	18.75	28.00	8.40	17.08
21	16.76	16.76	16.76	27.00	7.40	15.63
22	17.65	17.68	17.67	27.00	7.40	15.63
23	17.20	17.28	17.24	28.00	6.80	15.16
24	17.66	17.75	17.71	27.50	7.40	15.76
25	16.97	16.91	16.94	24.50	7.30	14.89
26	16.40	16.48	16.44	25.00	7.00	14.65
27	17.88	17.86	17.87	27.00	7.60	15.87
28	16.78	16.78	16.78	27.50	7.00	15.28
29	18.18	18.19	18.19	27.00	8.00	16.35
30	17.02	17.06	17.04	26.00	7.20	15.14
31	16.89	16.85	16.87	27.00	6.80	14.91
32	16.35	16.33	16.34	25.00	6.80	14.41
33	17.06	17.09	17.08	26.00	7.20	15.14
34	14.20	14.16	14.18	21.00	6.20	12.69
35	13.80	13.89	13.85	23.00	5.40	12.23
36	15.05	15.12	15.09	24.00	6.20	13.44
37	16.82	16.88	16.85	27.00	6.80	14.91
38	16.82	16.84	16.83	26.00	7.00	14.90
39	16.82	16.90	16.86	25.00	7.20	14.89
40	19.02	18.95	18.99	27.00	8.50	16.95

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41	17.16	17.19	17.18	28.00	6.90	15.28
42	16.82	16.89	16.86	27.00	6.80	14.91
43	15.92	15.85	15.89	25.00	6.50	14.05
44	16.33	16.39	16.36	26.00	6.70	14.54
45	16.05	15.98	16.02	24.00	6.80	14.16
46	15.62	15.58	15.60	24.00	6.50	13.80
47	15.72	15.67	15.70	24.00	6.60	13.92
48	16.13	16.09	16.11	25.00	6.70	14.29
49	16.39	16.30	16.35	26.00	6.70	14.54
50	16.18	16.25	16.22	25.00	6.80	14.41

The minimum, maximum and average TS content in buffaloes milk by gravimetric and lactometric method without correction factor and by using correction factor M₁ and M₂ formulae have been presented in Table 4.4.1.2.

Table 4.4.1.2 Total solids of buffaloes milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant D

	Total Solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
		$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+1.66}{4}$	$\frac{CLR+1.25F+1.45}{4}$
Minimum	13.52	12.08	12.25	13.74	13.70
Maximum	18.98	17.24	17.5	18.90	18.95
Average	16.47	14.81	15.02	16.47	16.47
t-test					
t value	-	7.17	6.22	6.127X10 ⁻¹⁴	1.064X10 ⁻¹³
Result	-	S	S	NS	NS

S= Satisfactory NS= Non Satisfactory

The minimum, maximum and average values of total solids were 13.52, 18.98 and 16.47, respectively in gravimetric method.

In volumetric method using M₁ formula without correction factor, the minimum, maximum and average values of total solids were 12.08, 17.24 and 14.81 respectively, while using M₂ formula, these values for TS were 12.25, 17.50 and 15.02, respectively. On addition of 1.66 correction factor in M₁ formula, the minimum, maximum and average values of total solids were 13.74, 18.90 and 16.47

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respectively, and on addition of 1.45 correction factor in M_2 formula, these values were 13.70, 18.95 and 16.47, respectively.

It revealed that the volumetric method without correction factor gave lower values of TS, whose difference was statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as compared to gravimetric method.

The values of two sample t-test for TS in raw milk samples of buffaloes from Dairy Plant D is presented in Table 4.4.1.2. No significant difference was seen between gravimetric and volumetric mean by M_1 and M_2 formulae. Thus, it was concluded that the TS by gravimetric method and volumetric method were almost same for buffaloes milk from Dairy Plant D.

Table 4.4.1.3 Frequency distribution of total solids of buffaloes milk from Dairy Plant D by M_1 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.50-14.00	2	4.00	2	4.00
2	14.00-14.50	2	4.00	4	8.00
3	14.50-15.00	1	2.00	5	10.00
4	15.00-15.50	4	8.00	9	18.00
5	15.50-16.00	5	10.00	14	28.00
6	16.00-16.50	8	16.00	22	44.00
7	16.50-17.00	13	26.00	35	70.00
8	17.00-17.50	7	14.00	42	84.00
9	17.50-18.00	5	10.00	47	94.00
10	18.00-18.50	1	2.00	48	96.00
11	18.50-19.00	2	4.00	50	100.00

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Parameters for Normal Distribution				
Parameter	Symbol		Estimate	
Mean	Mu		16.4797	
Std Dev	Sigma		1.117122	
Goodness-of-Fit Tests for Normal Distribution				
Test	Statistic		p Value	
Kolmogorov-Smirnov	D	0.09527770	Pr > D	>0.150

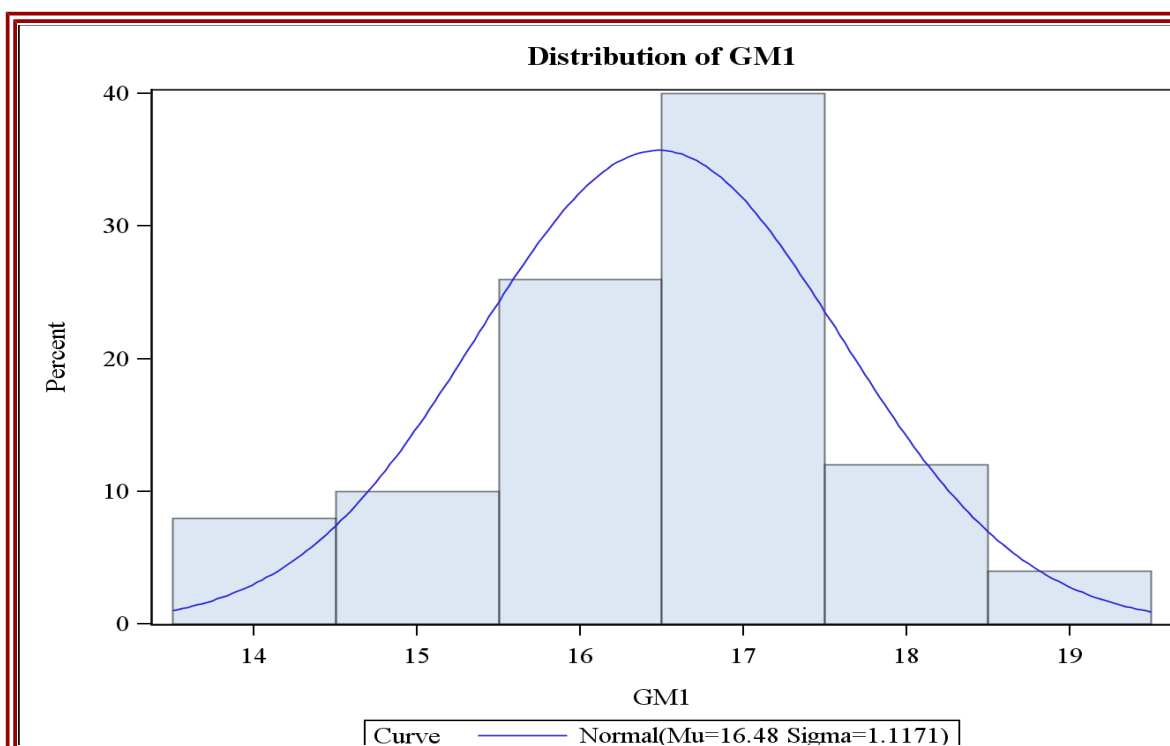


Fig. 4.4.4.1. The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant D by M_1 formula

Table 4.4.1.4 Frequency distribution of total solids of buffaloes milk from Dairy Plant D by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.50-14.00	2	4.00	2	4.00
2	14.00-14.50	2	4.00	4	8.00
3	14.50-15.00	1	2.00	5	10.00
4	15.00-15.50	4	8.00	9	18.00
5	15.50-16.00	5	10.00	14	28.00
6	16.00-16.50	8	16.00	22	44.00
7	16.50-17.00	13	26.00	35	70.00
8	17.00-17.50	7	14.00	42	84.00

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9	17.50-18.00	5	10.00	47	94.00
10	18.00-18.50	1	2.00	48	96.00
11	18.50-19.00	2	4.00	50	100.00
Parameters for Normal Distribution					
Parameter	Symbol			Estimate	
Mean	Mu			16.4797	
Std Dev	Sigma			1.135942	
Goodness-of-Fit Tests for Normal Distribution					
Test	Statistic			p Value	
Kolmogorov-Smirnov	D	0.09764511	Pr > D	>0.150	

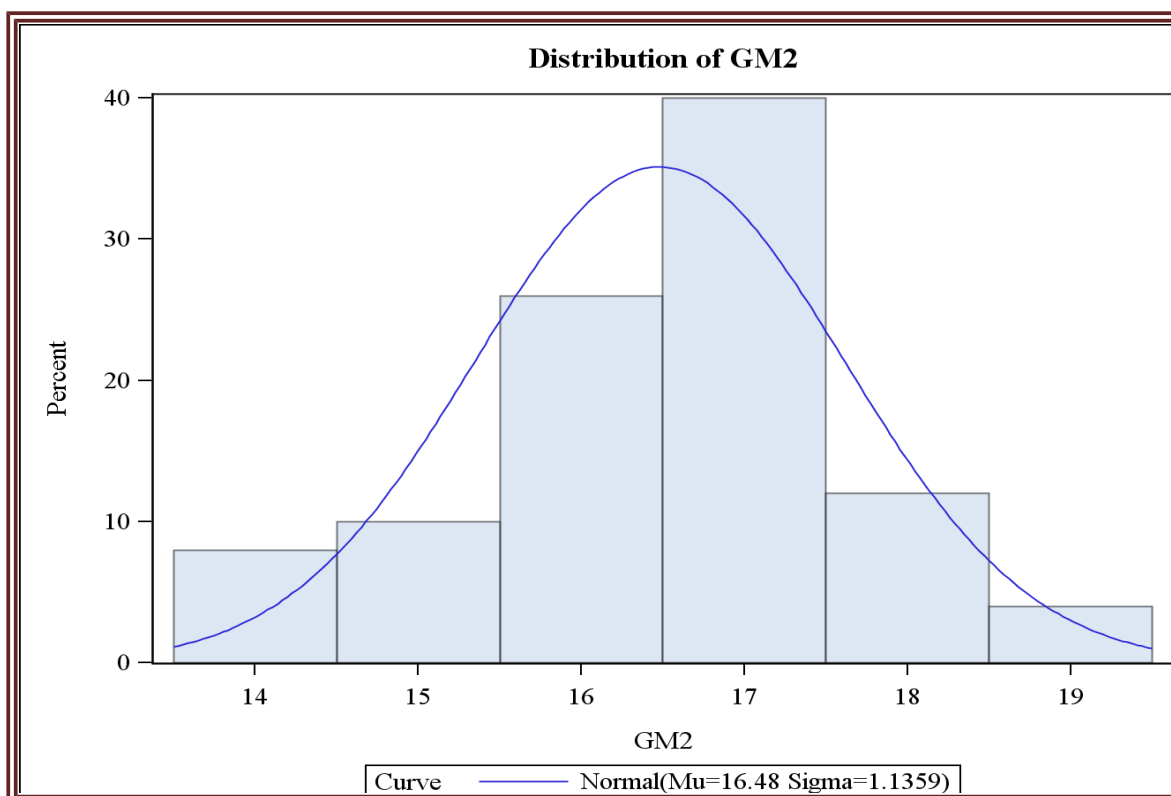


Fig. 4.4.1.2 The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant D by M₂ formula

The frequency distribution was calculated for total solids of buffaloes milk by M₁ and M₂ formulae are presented in Table 4.4.1.3 and 4.4.1.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution as is also evident from graphical presentation in Figure 4.4.1.1 and 4.4.1.2, respectively. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

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Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant

D, two probable equations are derived statistically which are given below.

$$TS = \frac{CLR}{4} + 1.22 F + 1.66$$

$$TS = \frac{CLR}{4} + 1.25 F + 1.45$$

4.4.2 Cows Milk

The results for values for TS (gravimetric), LR at 29 C and corresponding TS using LR in basic equation for cows milk from Dairy Plant D are given in Table 4.4.2.1.

Table 4.4.2.1 Milk fat, TS (gravimetric) and TS (lactometer) for cows milk from Dairy Plant D

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent $\frac{(CLR+1.2F)}{4}$
I	II	Average				
1	12.31	12.32	12.32	26	4	11.30
2	13.27	13.28	13.28	26	4.8	12.26
3	13.33	13.3	13.32	25.5	4.9	12.26
4	12.59	12.6	12.60	24	4.6	11.52
5	12.39	12.37	12.38	25	4.2	11.29
6	12.7	12.65	12.68	22	4.7	11.14
7	12.73	12.72	12.73	28	3.7	11.44
8	12.36	12.39	12.38	24	4.3	11.16
9	12.49	12.5	12.50	24	4.3	11.16
10	14.67	14.65	14.66	27	5.4	13.23
11	12.96	13	12.98	24	4.6	11.52
12	12.37	12.37	12.37	24	4.2	11.04
13	12.12	12.13	12.13	24	4	10.80
14	12.03	12.01	12.02	24.5	3.8	10.69
15	13.43	13.46	13.45	25	4.7	11.89
16	12.83	12.95	12.89	23	4.5	11.15
17	13.27	13.28	13.28	24	4.9	11.88

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18	12.71	12.9	12.81	24	4.5	11.40
19	13.42	13.43	13.43	25.5	4.9	12.26
20	12.96	12.95	12.96	25	4.5	11.65
21	14.3	14.35	14.33	24	5.7	12.84
22	13.17	13.27	13.22	25	4.8	Conti...
23	14.62	14.65	14.64	27	5.4	13.23
24	13.36	13.33	13.35	23	5.3	12.11
25	13.09	13.04	13.07	24	4.7	11.64
26	12.03	12.12	12.08	23	4.1	10.67
27	13.4	13.3	13.35	26	4.6	12.02
28	12.83	12.73	12.78	24	4.7	11.64
29	11.64	11.68	11.66	23	3.8	10.31
30	14.25	14.29	14.27	27	5.1	12.87
31	13.08	13.12	13.10	24	4.7	11.64
32	13.73	13.75	13.74	25	4.9	12.13
33	13.71	13.75	13.73	27.5	4.4	12.16
34	11.17	11.2	11.19	21	3.9	9.93
35	12.06	12.1	12.08	24	3.9	10.68
36	12.96	12.92	12.94	26	4.3	11.66
37	12.85	12.9	12.88	24	4.5	11.40
38	11.84	11.89	11.87	22	4.1	10.42
39	8.95	8.96	8.96	18	2.8	7.86
40	12.56	12.51	12.54	24.5	4.4	11.41
41	14.3	14.36	14.33	25	5.3	12.61
42	11.86	11.8	11.83	29	2.6	10.37
43	11.02	11.08	11.05	24	3.3	9.96
44	12.35	12.4	12.38	25	4	11.05
45	12.86	12.9	12.88	26	4.2	11.54
46	12.65	12.65	12.65	25	4.2	11.29
47	12.68	12.7	12.69	22	4.8	11.26
48	13.04	13.04	13.04	25	4.6	11.77
49	12.3	12.25	12.28	23	4.5	11.15
50	12.22	12.29	12.26	24	4.3	11.16

The minimum, maximum and average TS content in cows milk by gravimetric and lactometric method without correction factor and by using correction factor in M_1 and M_2 formulae have been presented in Table 4.4.2.2. In gravimetric method the minimum, maximum and average values of total solids were 8.95, 14.66 and 12.72, respectively.

4.4.2.2 Total solids of Cows milk obtained by gravimetric and volumetric method by different formulae for Dairy plant D

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	Total Solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
		$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+1.24}{4}$	$\frac{CLR+1.25F+1.11}{4}$
Minimum	8.95	7.91	8.00	9.15	9.10
Maximum	14.66	13.33	13.50	14.57	14.60
Average	12.72	11.49	11.62	12.72	12.72
t-test					
t value	-	6.58	5.83	0.00	9.36X10 ⁻¹⁵
Result	-	S	S	NS	NS

S= Satisfactory NS= Non Satisfactory

The minimum, maximum and average values of total solids were 7.91, 13.33 and 11.49, respectively for M₁ formula while these values were 8.00, 13.50 and 11.62, respectively for M₂ formula without correction factor in volumetric method. On addition of 1.24 correction factor in M₁ formula, the minimum, maximum and average values of total solids were 9.15, 14.57 and 12.72, respectively and on addition of 1.11 correction factor in M₂ formula, these values were 9.10, 14.60 and 12.72, respectively.

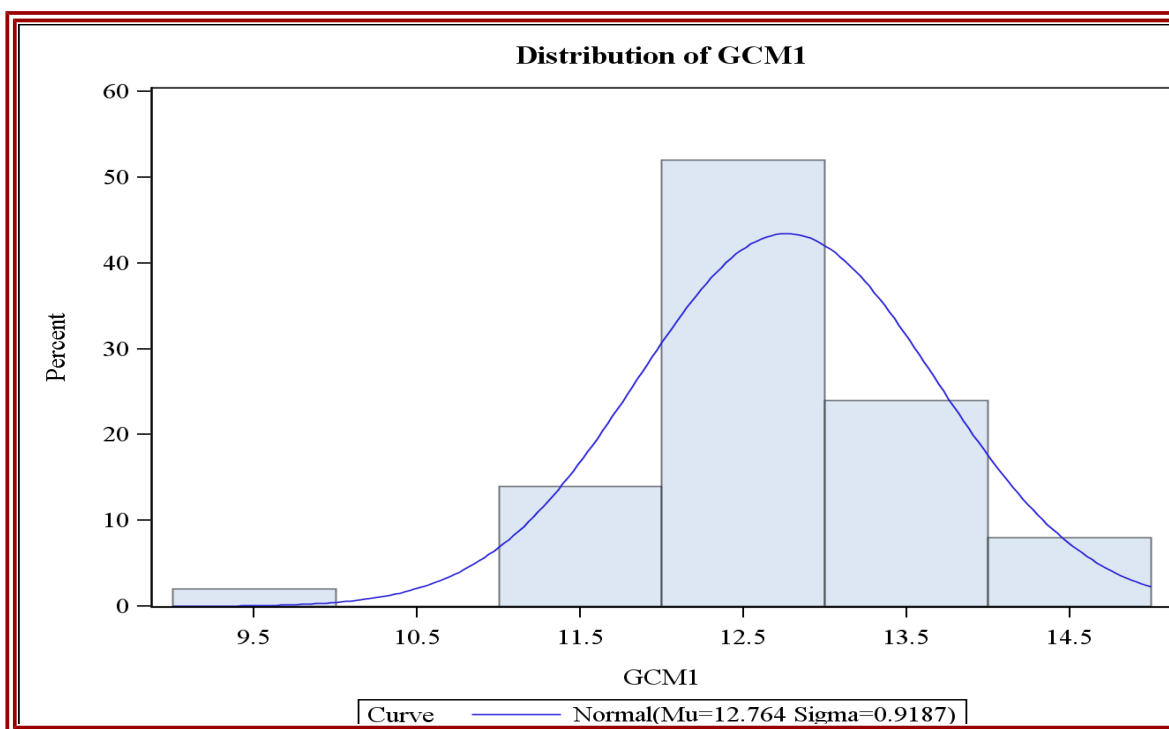
The volumetric method without correction factor gave lower values of TS as is also evident from significant statistical difference. While using M₁ and M₂ formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as in consonance with gravimetric method.

The values of two sample t-test for TS content in raw milk samples of cows from Dairy Plant D has been presented in Table 4.4.2.2. No significant difference was found between gravimetric and volumetric mean by M₁ and M₂ formulae. Thus, it could be inferred that the TS by gravimetric method and volumetric method were almost same for cows milk from Dairy Plant D.

Table 4.4.2.3 Frequency distribution of total solids of cows milk from Dairy Plant D by M₁ formula

Results and Discussion

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	9.00-9.50	1	2.00	1	2.00
2	9.50-10.00	0	0.00	1	2.00
3	10.00-10.50	0	0.00	1	2.00
4	10.50-11.00	0	0.00	1	2.00
5	11.00-11.50	2	4.00	3	6.00
6	11.50-12.00	5	10.00	8	16.00
7	12.00-12.50	10	20.00	18	36.00
8	12.50-13.00	16	32.00	34	68.00
9	13.00-13.50	8	16.00	42	84.00
10	13.50-14.00	4	8.00	46	92.00
11	14.00-14.50	2	4.00	48	96.00
12	14.50-15.00	2	4.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		12.7641	
Std Dev		Sigma		0.918687	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.13585461	Pr > D	0.021



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Fig. 4.4.2.1 The grouped frequency distribution curve of total solids of cows milk from Dairy Plant D by M_1 formula

Table 4.4.2.4 Frequency distribution of total solids of cow milk from Dairy Plant D by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	9.00-9.50	1	2.00	1	2.00
2	9.50-10.00	0	0.00	1	2.00
3	10.00-10.50	0	0.00	1	2.00
4	10.50-11.00	0	0.00	1	2.00
5	11.00-11.50	2	4.00	3	6.00
6	11.50-12.00	6	12.00	9	18.00
7	12.00-12.50	9	18.00	18	36.00
8	12.50-13.00	16	32.00	34	68.00
9	13.00-13.50	8	16.00	42	84.00
10	13.50-14.00	4	8.00	46	92.00
11	14.00-14.50	2	4.00	48	96.00
12	14.50-15.00	2	4.00	50	100.00

Parameters for Normal Distribution		
Parameter	Symbol	Estimate
Mean	Mu	12.7641
Std Dev	Sigma	0.934326

Goodness-of-Fit Tests for Normal Distribution				
Test	Statistic		p Value	
Kolmogorov-Smirnov	D	0.14119000	Pr > D	0.014

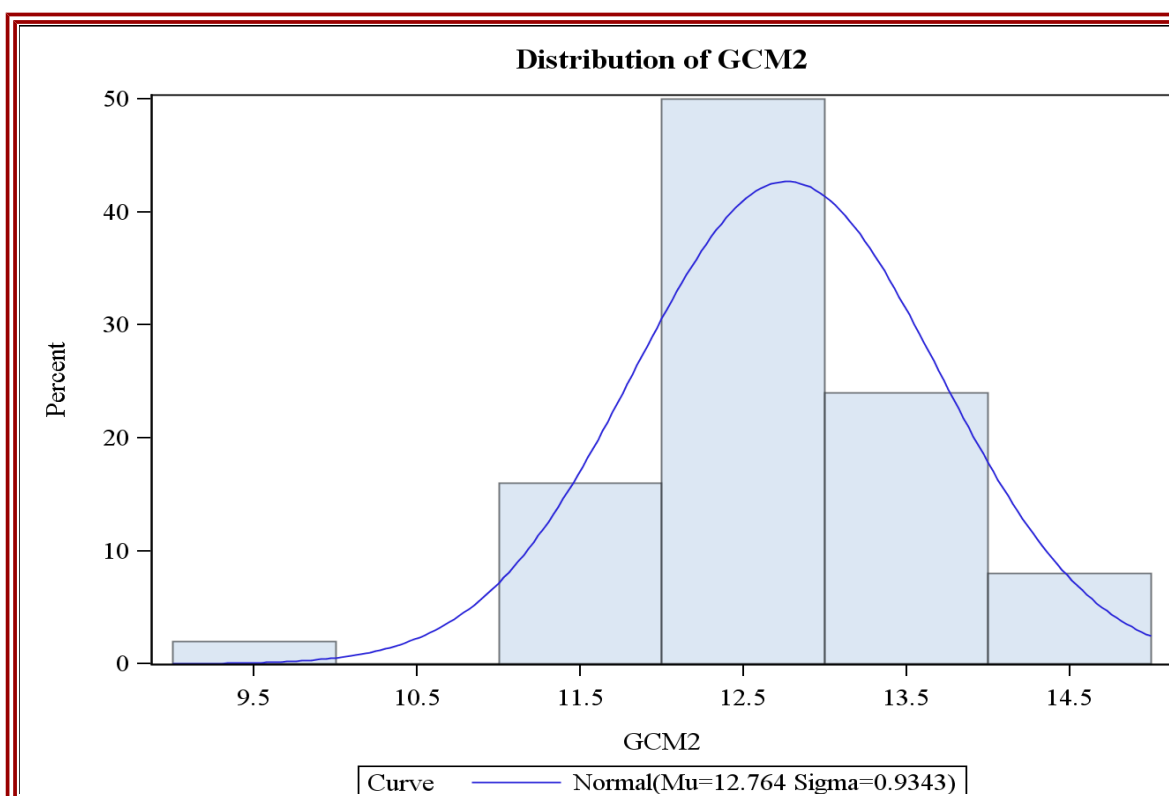


Fig. 4.4.2.2 The grouped frequency distribution curve of total solids of cows milk from Dairy Plant D by M₂ Formula

The frequency distribution calculated for total solids of cows milk by M₁ and M₂ formulae is presented in Table 4.4.2.3 and 4.4.2.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution as is evident from graphical presentation in Figure 4.4.2.1 and 4.4.2.2, respectively. All the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of cows milk collected from Dairy Plant D, two probable equations have been derived statistically and are given below.

$$TS = \frac{CLR}{4} + 1.22 F + 1.24$$

$$TS = \frac{CLR}{4} + 1.25 F + 1.11$$

4.4.3 Mixed milk

The average values for TS by gravimetric method, milk fat by Gerber method, LR at 29 C and total solids by lactometer method for raw mixed milk from Dairy Plant D are given in Table 4.4.3.1.

Table 4.4.3.1 Milk fat, TS (gravimetric) and TS (lactometer) for mixed milk from Dairy Plant D

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
	I	II	Average			
1	13.50	13.40	13.45	25.00	5.10	12.37

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2	13.02	13.04	13.03	25.00	4.70	11.89
3	15.11	15.10	15.11	25.50	6.20	13.82
4	13.91	13.90	13.91	25.00	5.30	12.61
5	12.95	12.90	12.93	24.00	4.70	11.64
6	13.29	13.28	13.29	22.00	5.40	11.98
7	13.41	13.43	13.42	22.50	5.40	12.11
8	13.36	13.36	13.36	21.00	5.50	11.85
9	13.27	13.28	13.28	21.50	5.30	11.74
10	15.47	15.40	15.44	23.00	6.60	13.67
11	14.39	14.45	14.42	23.00	5.70	12.59
12	13.98	14.02	14.00	23.00	5.50	12.35
13	13.83	13.92	13.88	22.00	5.60	12.22
14	14.00	14.05	14.03	23.00	5.50	12.35
15	13.78	13.85	13.82	24.00	5.10	12.12
16	14.34	14.31	14.33	24.50	5.70	12.97
17	13.92	13.99	13.96	24.50	5.30	12.49
18	14.19	14.17	14.18	25.00	5.50	12.85
19	14.42	14.48	14.45	24.00	5.80	12.96
20	16.74	16.78	16.76	25.00	7.30	15.01
21	15.64	15.69	15.67	23.50	6.80	14.04
22	17.68	17.65	17.67	26.00	7.80	15.86
23	16.94	16.90	16.92	26.00	7.30	15.26
24	15.40	15.35	15.38	24.50	6.60	14.05
25	15.60	15.55	15.58	25.00	6.60	14.17
26	15.62	15.68	15.65	25.00	6.60	14.17
27	14.40	14.45	14.43	24.00	5.90	13.08
28	14.61	14.68	14.65	24.00	6.10	13.32
29	15.08	15.12	15.10	25.00	6.20	13.69
30	15.89	15.95	15.92	23.50	6.80	14.04
31	14.48	14.55	14.52	24.00	5.80	12.96
32	14.48	14.58	14.53	24.00	5.80	12.96
33	14.47	14.56	14.52	24.00	5.80	12.96
34	14.34	14.39	14.37	24.00	5.70	12.84
35	14.46	14.49	14.48	23.50	6.00	13.08
36	13.40	13.40	13.40	22.50	5.20	11.87
37	15.08	14.96	15.02	26.00	5.80	13.46
38	16.04	16.11	16.08	25.50	6.70	14.42
39	14.43	14.36	14.40	25.50	4.90	12.26
40	14.61	14.68	14.65	24.00	6.10	13.32
41	15.08	15.12	15.10	25.00	6.20	13.69
42	15.47	15.40	15.44	23.00	6.60	13.67
43	14.39	14.45	14.42	23.00	5.70	12.59
44	14.00	14.05	14.03	23.00	5.50	12.35
45	14.65	14.68	14.67	24.00	6.10	13.32
46	15.10	15.13	15.12	25.00	6.20	13.69
47	14.48	14.58	14.53	24.00	5.80	12.96
48	14.45	14.51	14.48	24.00	5.80	12.96
49	14.38	14.42	14.40	24.00	5.70	12.84

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50	16.96	16.95	16.96	26.00	7.30	15.26
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The minimum, maximum and average values for TS content in mixed milk by gravimetric and lactometric method without correction factor and by using correction factor (M_1 and M_2 formulae) have been presented in Table 4.4.3.2.

4.4.3.2 Total solids of mixed milk obtained by gravimetric and volumetric method by different formulae of Dairy plant D

	Total Solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M_1	M_2	M_1	M_2
		$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+1.41}{4}$	$\frac{CLR+1.25F+1.23}{4}$
Minimum	12.92	11.73	11.87	13.14	13.10
Maximum	17.66	16.01	16.25	17.42	17.47
Average	14.68	13.27	13.45	14.68	14.68
t-test					
t value	-	6.93	5.99	1.70×10^{-14}	4.30×10^{-14}
Result	-	S	S	NS	NS

In gravimetric method the minimum, maximum and average values of total solids were 12.92, 17.66 and 14.68, respectively.

By using volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids were 11.73, 16.01 and 13.27, respectively while using M_2 formula, these values were 11.87, 16.25 and 13.45, respectively. While addition of 1.41 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.14, 17.42 and 14.68, respectively and addition of 1.23 correction factor in M_2 formula these values were 13.10, 17.47 and 14.68, respectively.

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It indicated that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as comparable to gravimetric method.

The values of two sample t-test for TS content in mixed milk from Dairy Plant D as presented in Table 4.4.3.2 showed no significant difference between gravimetric and volumetric mean by M_1 and M_2 formulae. Thus, it could be said that the TS contents by gravimetric and volumetric method were almost same for mixed milk from Dairy Plant D.

Table 4.4.3.3 Frequency distribution of total solids of mixed milk from Dairy Plant D by M_1 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.00-13.50	6	12.00	6	12.00
2	13.50-14.00	9	18.00	15	30.00
3	14.00-14.50	13	26.00	28	56.00
4	14.50-15.00	6	12.00	34	68.00
5	15.00-15.50	6	12.00	40	80.00
6	15.50-16.00	6	12.00	46	92.00
7	16.00-16.50	0	0.00	46	92.00
8	16.50-17.00	3	6.00	49	98.00
9	17.00-17.50	1	2.00	50	100.00

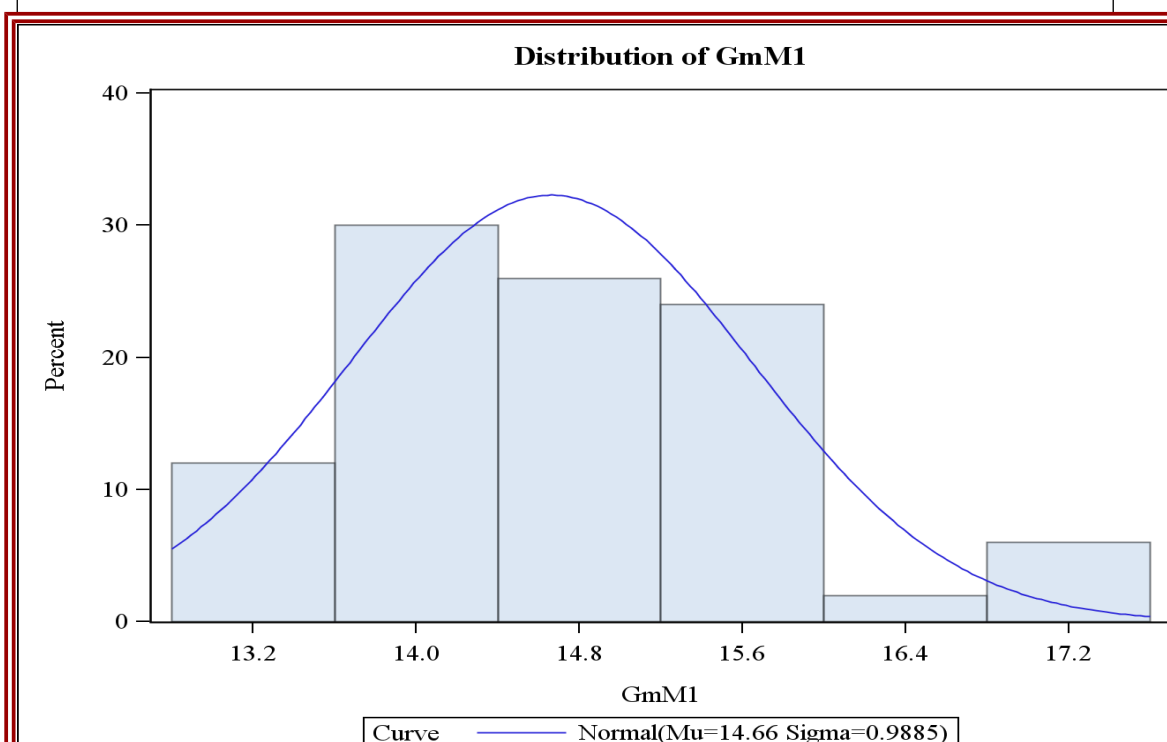


Fig - 4.4.3.1 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant D by M_1 formula

Table 4.4.3.4 Frequency distribution of total solids of mixed milk from Dairy Plant D by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	13.00-13.50	6	12.00	6	12.00
2	13.50-14.00	9	18.00	15	30.00
3	14.00-14.50	13	26.00	28	56.00
4	14.50-15.00	6	12.00	34	68.00
5	15.00-15.50	6	12.00	40	80.00
6	15.50-16.00	6	12.00	46	92.00
7	16.00-16.50	0	0.00	46	92.00
8	16.50-17.00	3	6.00	49	98.00

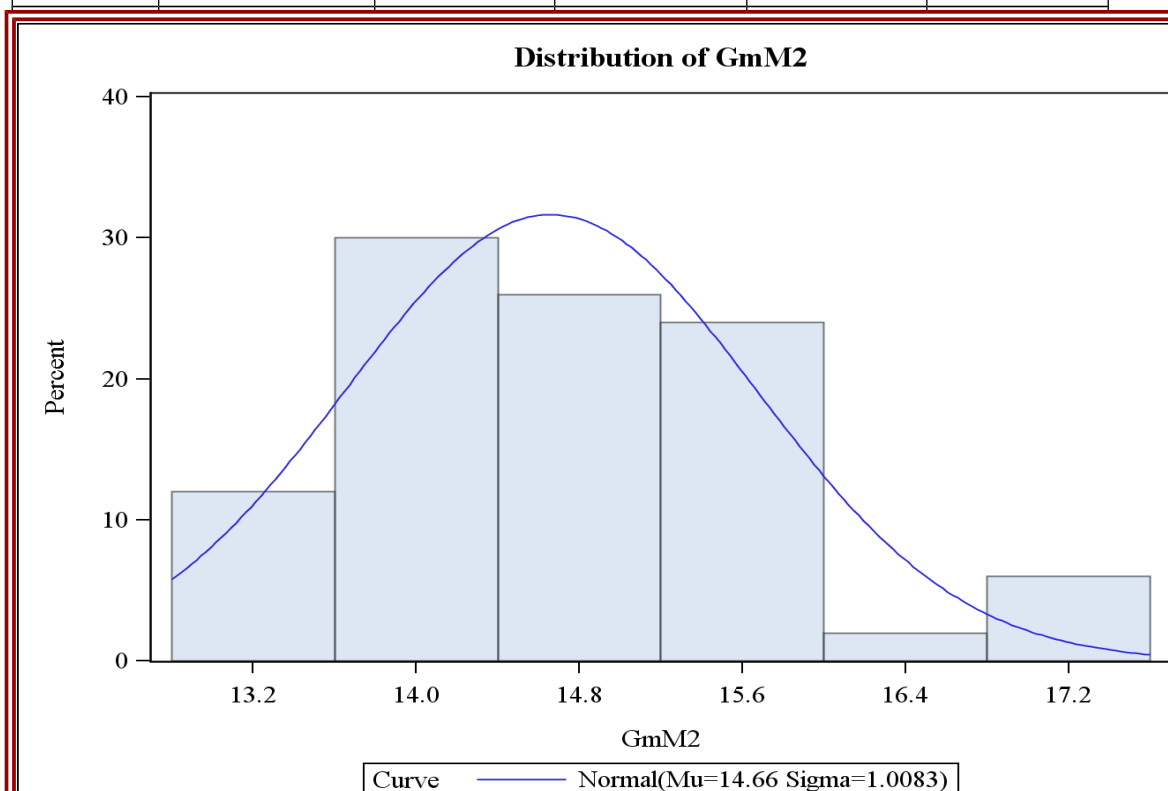


Fig. 4.4.3.2 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant D by M₂ formula

The frequency distribution as worked out for total solids of mixed milk by M₁ and M₂ formulae is presented in Table 4.4.3.3 and 4.4.3.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The same is also depicted graphically in Figure 4.4.3.1 and 4.4.3.2, respectively. All the data for TS contents of mixed milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant B, two probable equations are derived statistically given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 1.41$$

$$TS = \frac{CLR}{4} + 1.25 F + 1.23$$

4.5 Dairy plant E

Total of 150 samples each of cows, buffaloes and mixed milk were analyzed for milk fat, total solids (gravimetric) and TS/SNF (lactometer) methods.

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4.5.1 Buffaloes Milk

The results for milk fat, TS (gravimetric) and TS (lactometer), for buffaloes milk of Dairy Plant E are given in Table 4.5.1.1.

Table 4.5.1.1 Milk fat, TS (gravimetric) and TS (lactometer) for buffaloes milk from Dairy Plant E

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent					
	I	II	Average	LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
1	17.86	17.47	17.67	25.00	8.50	16.45
2	17.47	17.52	17.50	25.00	8.40	16.33
3	17.13	16.72	16.93	26.50	7.90	16.11
4	16.71	17.51	17.11	25.00	7.80	15.61
5	17.62	17.84	17.73	26.00	8.60	16.82
6	16.34	16.19	16.27	24.00	7.80	15.36
7	17.12	16.86	16.99	27.00	7.40	15.63
8	15.52	15.30	15.41	26.00	6.60	14.42
9	15.15	14.79	14.97	27.00	6.50	14.55
10	18.44	18.55	18.50	25.00	9.30	17.41
11	17.06	17.15	17.11	24.50	8.00	15.73
12	16.85	16.45	16.65	23.50	8.50	16.08
13	17.91	17.91	17.91	27.00	8.80	17.31
14	15.91	15.84	15.88	24.00	7.80	15.36
15	16.96	16.99	16.98	27.00	7.80	16.11
16	17.58	17.70	17.64	28.00	8.10	16.72
17	17.67	17.75	17.71	27.00	8.60	17.07
18	16.51	16.45	16.48	28.00	7.20	15.64
19	18.44	18.55	18.50	28.00	8.80	17.56
20	17.27	17.22	17.25	27.00	8.00	16.35
21	17.24	17.18	17.21	25.00	8.30	16.21
22	16.98	17.07	17.03	28.00	7.80	16.36
23	17.31	17.36	17.34	27.00	7.70	15.99
24	16.87	16.91	16.89	28.00	7.80	16.36
25	18.13	18.01	18.07	29.00	7.80	16.61
26	17.45	17.35	17.40	25.00	8.80	16.81
27	15.60	15.67	15.64	27.00	7.00	15.15
28	16.35	16.43	16.39	26.00	7.60	15.62
29	15.83	15.77	15.80	25.00	7.50	15.25
30	14.75	14.74	14.75	25.00	6.60	14.17
31	16.42	16.58	16.50	26.00	8.00	16.10
32	18.32	18.28	18.30	28.00	8.70	17.44

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33	16.18	15.47	15.83	26.00	7.30	15.26
34	18.00	18.18	18.09	30.00	8.20	17.34
35	17.65	17.80	17.73	28.00	8.10	16.72
36	18.04	18.29	18.17	27.00	8.70	17.19
37	16.34	16.40	16.37	26.00	7.50	15.50
38	17.55	17.76	17.66	28.00	8.10	16.72
39	17.18	17.14	17.16	30.00	7.30	16.26
40	16.26	16.27	16.27	26.00	7.40	15.38
41	17.58	17.72	17.65	28.00	8.30	16.96
42	16.01	16.03	16.02	26.00	7.30	15.26
43	16.93	17.00	16.97	28.00	7.60	16.12
44	16.54	16.57	16.56	29.00	7.30	16.01
45	16.24	16.23	16.24	27.00	7.40	15.63
46	18.06	18.09	18.08	30.00	8.20	17.34
47	17.19	17.16	17.18	30.00	7.60	16.62
48	17.10	17.23	17.17	30.00	7.60	16.62
49	17.56	17.26	17.41	29.00	8.00	16.85
50	17.09	17.23	17.16	28.00	7.60	16.12

The minimum, maximum and average values for TS content in buffaloes milk by gravimetric and lactometric method without correction factor and by using M₁ and M₂ equation have been presented in Table 4.5.1.2.

Table 4.5.1.2. Total solids of buffaloes milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant E

	Total Solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
	$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.67}{4}$	$\frac{CLR+1.25F+0.44}{4}$	
Minimum	14.75	14.30	14.50	14.97	14.93
Maximum	18.50	17.75	18.00	18.40	18.43
Average	17.00	16.32	16.56	17.00	17.00
t-test					
t value	-	3.96	2.54	2.09X10 ⁻¹⁴	4.14X10 ⁻¹⁴
Result	-	S	S	NS	NS

S= Significant NA= Non significant

In volumetric method using M₁ equation without correction factor, the minimum, maximum and average values of total solids were 14.30, 17.75 and 16.32 respectively, while using M₂ equation, these values were 14.50, 18.00 and 16.56,

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respectively. On addition of 0.67 correction factor in M_1 equation, the minimum, maximum and average values of total solids were 14.97, 18.40 and 17.00 respectively, and on addition of 0.44 correction factor in M_2 equation, these values were 14.93, 18.43 and 17.00, respectively. The gravimetric method resulted 14.75, 18.50 and 17.00 per cent as minimum, maximum and average values of total solids respectively.

It indicated that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 equations with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values quite comparable with gravimetric method.

The values of two sample t-test for TS content of raw milk samples from Dairy Plant E is presented in Table 4.5.1.2. It showed no significant difference between gravimetric and volumetric mean by M_1 and M_2 equations. Thus, it was inferred that the TS by gravimetric method and volumetric method were almost similar for buffaloes milk from Dairy Plant E.

Table 4.5.1.3 Frequency distribution of total solids of buffaloes milk from Dairy Plant E by M_1 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	14.50-15.00	1	2.00	1	2.00
2	15.00-15.50	2	4.00	3	6.00
3	15.50-16.00	1	2.00	4	8.00
4	16.00-16.50	12	24.00	16	32.00
5	16.50-17.00	9	18.00	25	50.00
6	17.00-17.50	10	20.00	35	70.00
7	17.50-18.00	8	16.00	43	86.00
8	18.00-18.50	7	14.00	50	100.00

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Parameters for Normal Distribution				
Parameter	Symbol		Estimate	
Mean	Mu		17.0021	
Std Dev	Sigma		0.818311	
Goodness-of-Fit Tests for Normal Distribution				
Test	Statistic		p Value	
Kolmogorov-Smirnov	D	0.07916872	Pr > D	>0.150

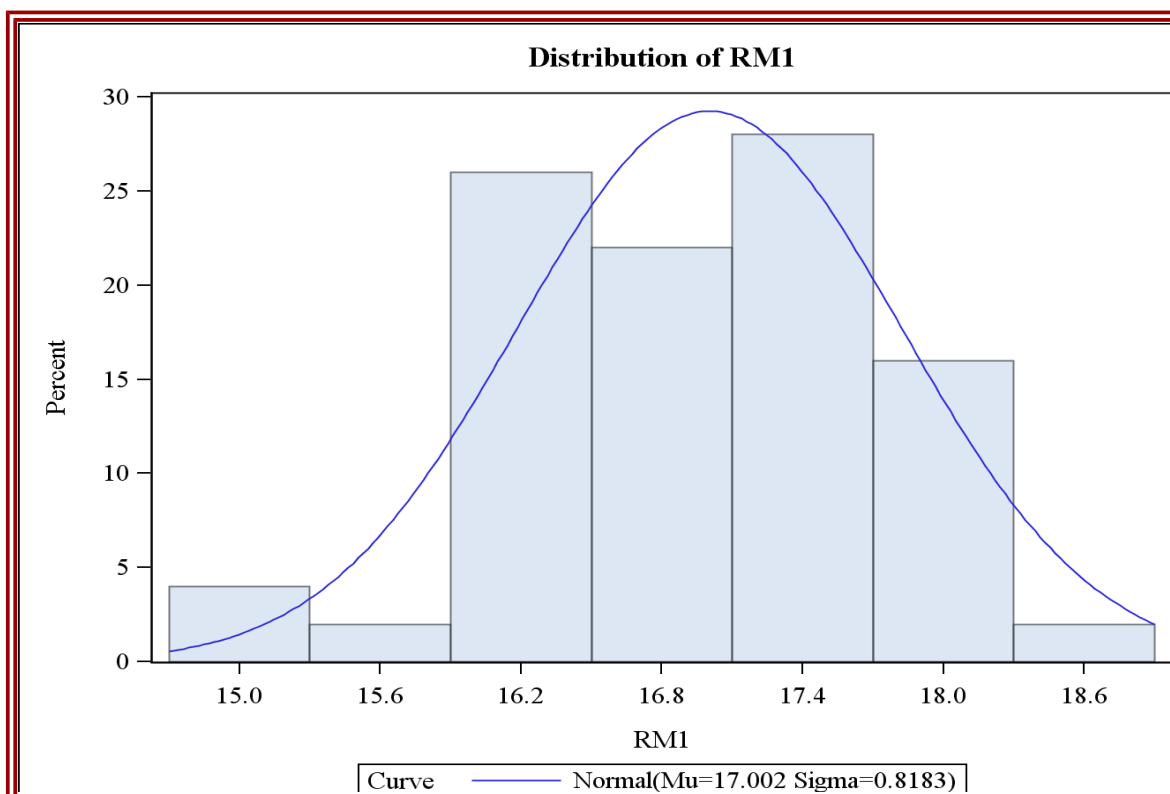


Fig. 4.5.1.1 The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant E by M_1 formula

Table 4.5.1.4 Frequency distribution of total solids of buffaloes milk from Dairy Plant E by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	14.50-15.00	1	2.00	1	2.00
2	15.00-15.50	2	4.00	3	6.00
3	15.50-16.00	1	2.00	4	8.00
4	16.00-16.50	12	24.00	16	32.00
5	16.50-17.00	9	18.00	25	50.00
6	17.00-17.50	10	20.00	35	70.00

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7	17.50-18.00	8	16.00	43	86.00
8	18.00-18.50	7	14.00	50	100.00
Parameters for Normal Distribution					
Parameter	Symbol		Estimate		
Mean	Mu		17.0021		
Std Dev	Sigma		0.83385		
Goodness-of-Fit Tests for Normal Distribution					
Test	Statistic		p Value		
Kolmogorov-Smirnov	D	0.08893326	Pr > D	>0.150	

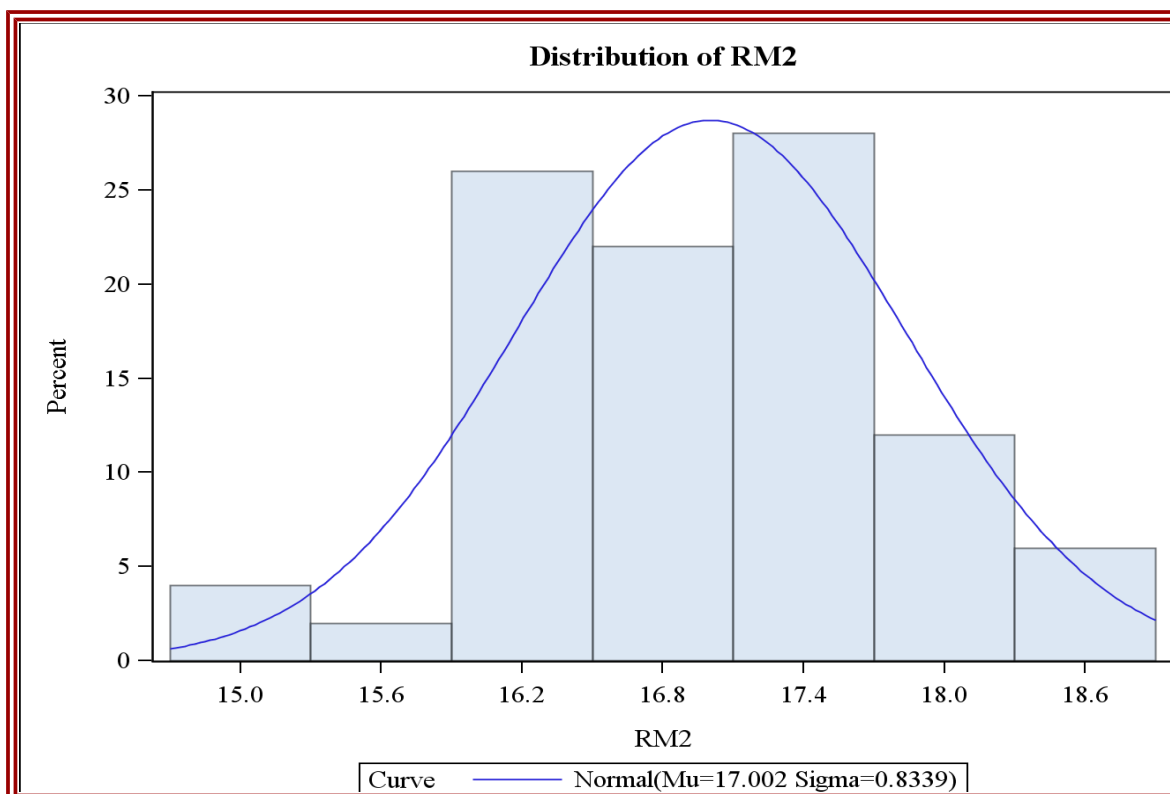


Fig. 4.5.1.2 The grouped frequency distribution curve of total solids of buffaloes milk from Dairy Plant E by M₂ formula

The frequency distribution was calculated for total solids of buffaloes milk by M₁ and M₂ formulae and is presented in Table 4.5.1.3 and 4.5.1.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The results for TS contents when plotted followed the normal distribution as is evident in Figure 4.5.1.1 and 4.5.1.2, respectively. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

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Based on analysis of 50 samples of buffalo milk collected from Dairy Plant E, two probable equations are worked out statistically given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 0.67$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.44$$

4.5.2 Cows Milk

The results for milk fat, TS (gravimetric) and TS (lactometer), for cow milk from Dairy Plant E are given in Table 4.5.2.1.

Table 4.5.2.1 Milk fat, TS (gravimetric) and TS (lactometer) for cows milk from Dairy Plant E

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent (CLR+1.2F) 4
	I	II	Average			
1	12.75	12.75	12.75	26.00	4.90	12.38
2	12.81	12.88	12.85	24.00	5.40	12.48
3	11.33	11.25	11.29	25.00	4.00	11.05
4	11.27	11.18	11.23	25.00	3.40	10.33
5	12.64	12.61	12.63	26.00	4.40	11.78
6	11.02	11.17	11.10	24.00	3.90	10.68
7	11.71	11.85	11.78	25.00	4.40	11.53
8	12.09	12.00	12.05	26.00	4.40	11.78
9	10.54	10.38	10.46	24.00	3.40	10.08
10	12.50	12.24	12.37	24.00	4.90	11.88
11	12.68	12.57	12.63	25.00	4.40	11.53
12	13.00	12.97	12.99	26.00	4.50	11.90
13	12.62	12.70	12.66	25.00	4.30	11.41
14	12.82	12.90	12.86	24.00	4.80	11.76
15	12.86	12.69	12.78	26.00	4.50	11.90
16	13.27	13.37	13.32	26.00	4.70	12.14
17	13.11	13.18	13.15	25.00	4.70	11.89
18	11.50	11.06	11.28	24.00	4.00	10.80
19	11.30	11.41	11.36	23.00	3.80	10.31
20	12.94	13.00	12.97	27.00	4.50	12.15
21	11.79	11.40	11.60	24.00	4.30	11.16

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22	12.17	11.58	11.88	24.00	3.90	10.68
23	12.48	12.53	12.51	26.00	4.50	11.90
24	12.91	12.78	12.85	26.00	4.90	12.38
25	12.77	12.42	12.60	25.00	4.90	12.13
26	12.60	12.78	12.69	26.00	5.00	12.50
27	11.49	11.51	11.50	23.00	4.30	10.91
28	13.06	12.64	12.85	28.00	4.50	12.40
29	12.25	12.19	12.22	24.00	4.70	11.64
30	12.79	13.28	13.04	27.00	4.40	12.03
31	13.54	13.30	13.42	26.00	5.20	12.74
32	10.98	11.04	11.01	24.00	3.07	9.68
33	12.85	13.04	12.95	25.00	4.80	12.01
34	13.95	13.77	13.86	27.00	4.90	12.63
35	13.21	13.51	13.36	28.00	4.70	12.64
36	12.79	12.77	12.78	30.00	3.70	11.94
37	13.38	13.64	13.51	29.00	4.40	12.53
38	12.85	12.70	12.78	24.00	5.20	12.24
39	13.21	13.51	13.36	28.00	4.70	12.64
40	12.33	12.55	12.44	27.00	4.30	11.91
41	14.20	14.17	14.19	28.00	4.50	12.40
42	12.48	12.42	12.45	26.00	4.60	12.02
43	15.00	14.88	14.94	26.00	6.50	14.30
44	13.66	13.61	13.64	27.00	5.00	12.75
45	12.70	12.67	12.69	25.00	4.70	11.89
46	13.03	13.70	13.37	27.00	4.50	12.15
47	13.50	13.70	13.60	28.00	4.40	12.28
48	13.03	13.11	13.07	27.00	4.90	12.63
49	13.19	13.19	13.19	29.00	4.40	12.53
50	13.27	14.23	13.75	27.00	5.00	12.75

The minimum, maximum and average TS content in cows milk by gravimetric and lactometric method without correction factor and using M₁ and M₂ equation have been presented in Table 4.5.2.2.

Table 4.5.2.2 Total solids of cows milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant E

	Total Solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
		$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.68}{4}$	$\frac{CLR+1.25F+0.54}{4}$
Minimum	10.46	9.74	9.83	10.42	10.37
Maximum	14.94	14.43	14.62	15.10	15.16
Average	12.65	11.97	12.10	12.65	12.65

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t-test					
t value	-	3.92	3.11	2.09X10 ⁻¹⁴	1.022X10 ⁻¹⁴
Result	-	S	S	NS	NS

S= Significance NS= Non significance

In volumetric method using M₁ equation without correction factor, the minimum, maximum and average values of total solids were 9.74, 14.43 and 11.97 respectively, while using M₂ equation, these values were 9.83, 14.62 and 12.10, respectively. Addition of 0.68 and 0.54 correction factor yielded 10.42, 15.10 and 12.65 and 10.37, 15.16 and 12.65 as the minimum, maximum and average values of total solids in M₁ and M₂ equation respectively. By using gravimetric method the respective minimum, maximum and average values of total solids were 10.46, 14.94 and 12.65.

Above results indicated that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M₁ and M₂ equation with correction factor, the values for TS using correction factor showed a non significant difference showing almost similar values for TS as compared to gravimetric method.

The values of two sample t-test for TS content in raw milk samples of cows supplies from Dairy Plant E as shown in Table 4.5.2.2 revealed no significant difference between gravimetric and volumetric mean by M₁ and M₂ equation. Thus, it could be said that the TS by gravimetric method and volumetric method were almost same for cows milk from Dairy Plant E.

Table 4.5.2.3 Frequency distribution of total solids of cows milk from Dairy Plant E by M₁ formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	10.00-10.50	1	2.00	1	2.00
2	10.50-11.00	1	2.00	2	4.00

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3	11.00-11.50	4	8.00	6	12.00
4	11.50-12.00	4	8.00	10	20.00
5	12.00-12.50	4	8.00	14	28.00
6	12.50-13.00	18	36.00	32	64.00
7	13.00-13.50	14	28.00	46	92.00
8	13.50-14.00	3	6.00	49	98.00
9	14.00-14.50	0	0.00	49	98.00
10	14.50-15.00	0	0.00	49	98.00
11	15.00-15.50	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		12.65	
Std Dev		Sigma		0.834414	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
Kolmogorov-Smirnov		D	0.16398438	Pr > D	<0.010

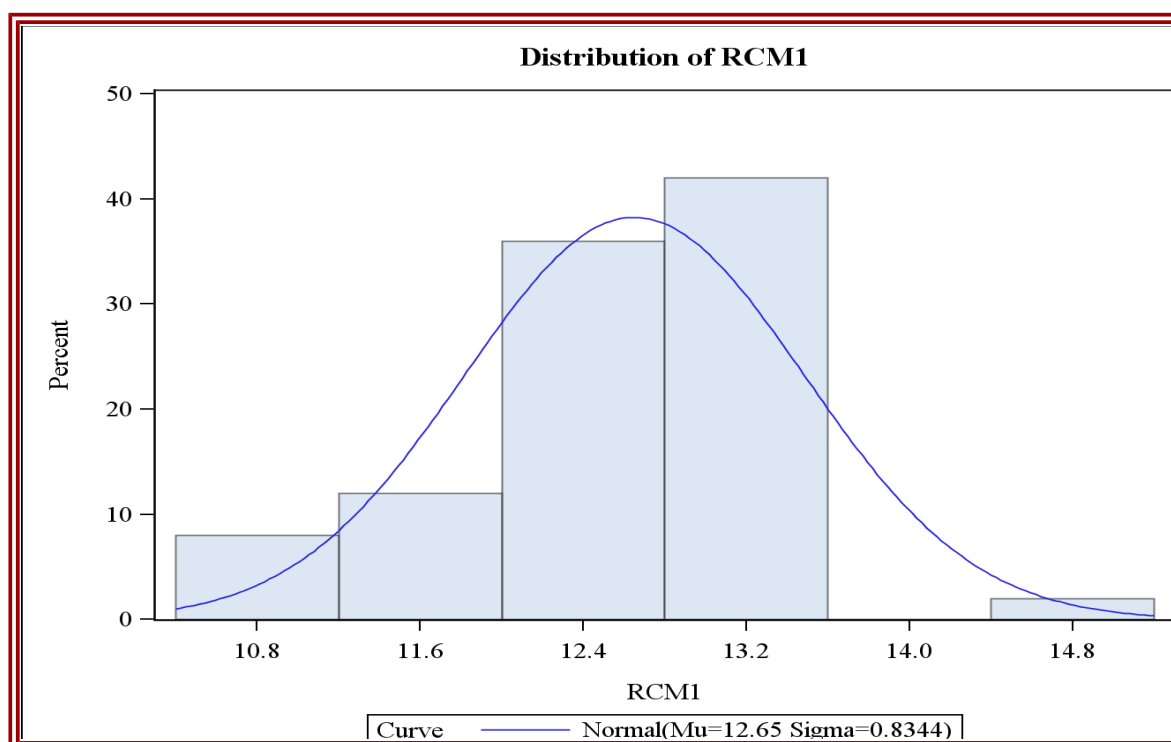


Fig. 4.5.2.1 The grouped frequency distribution curve of total solids of cows milk from Dairy Plant E by M_1 formula

Table 4.5.2.4 Frequency distribution of total solids of cows milk from Dairy Plant E by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative
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Results and Discussion

				Frequency	Per cent
1	10.00-10.50	1	2.00	1	2.00
2	10.50-11.00	1	2.00	2	4.00
3	11.00-11.50	4	8.00	6	12.00
4	11.50-12.00	4	8.00	10	20.00
5	12.00-12.50	4	8.00	14	28.00
6	12.50-13.00	18	36.00	32	64.00
7	13.00-13.50	14	28.00	46	92.00
8	13.50-14.00	3	6.00	49	98.00
9	14.00-14.50	0	0.00	49	98.00
10	14.50-15.00	0	0.00	49	98.00
11	15.00-15.50	1	2.00	50	100.00

Parameters for Normal Distribution		
Parameter	Symbol	Estimate
Mean	Mu	12.65
Std Dev	Sigma	0.848937

Goodness-of-Fit Tests for Normal Distribution			
Test	Statistic		p Value
Kolmogorov-Smirnov	D	0.16880133	Pr > D < 0.010

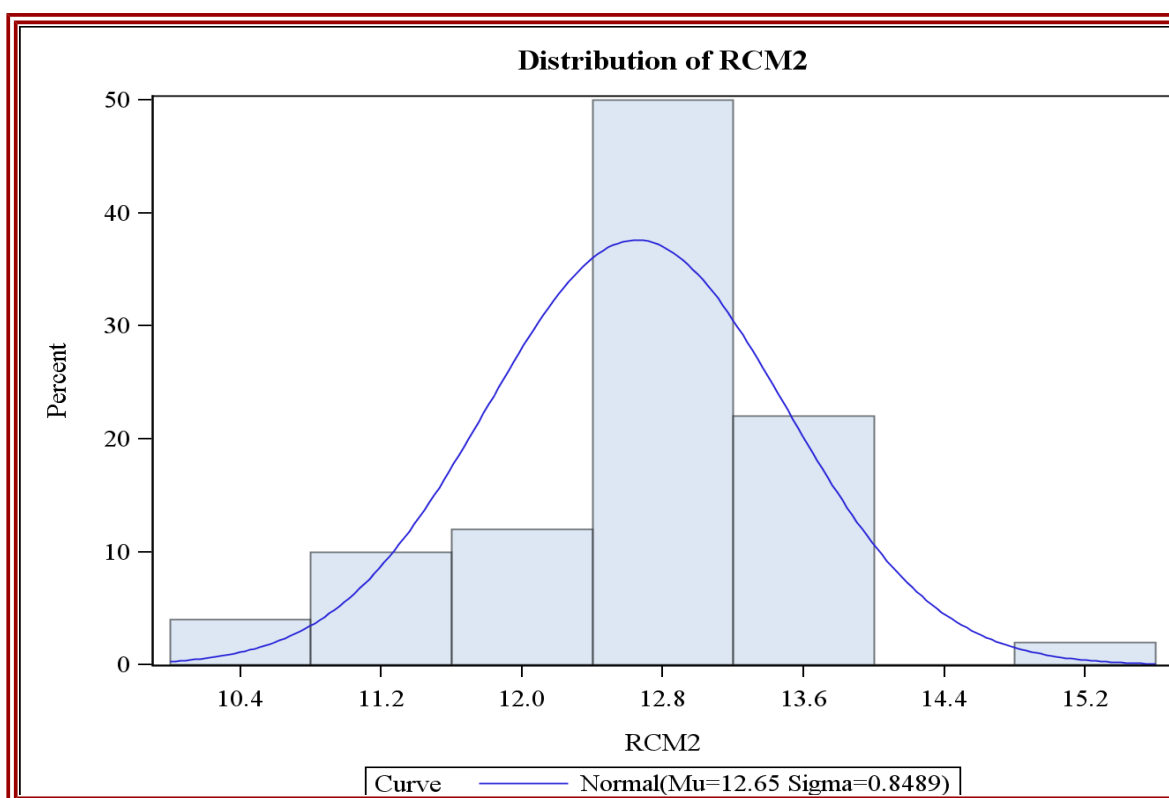


Fig. 4.5.2.2 The grouped frequency distribution curve of total solids of cows milk from Dairy Plant E by M₂ formula

Results and Discussion

The frequency distribution patterns for total solids of cows milk by M₁ and M₂ formulae are presented in Table 4.5.2.3 and 4.5.2.4, respectively. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The same is also indicated graphically in Figure 4.5.2.1 and 4.5.2.2, respectively. All the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of cows milk collected from Dairy Plant E, two probable equations derived statistically are given as under.

$$TS = \frac{CLR}{4} + 1.22 F + 0.68$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.54$$

4.5.3 Mixed Milk

The results for average values for TS (gravimetric), LR at 29 C, milk fat and corresponding TS by putting LR in basic equation for mixed milk from Dairy Plant E have been presented in Table 4.5.3.1.

Table 4.5.3.1 Milk fat, TS (gravimetric) and TS (lactometer) for mixed milk from Dairy Plant E

Sr. No.	Methods					
	Gravimetric method			Volumetric method		
	TS per cent			LR at 29 C	Fat per cent (Gerber)	TS per cent $\left(\frac{CLR+1.2F}{4}\right)$
	I	II	Average			
1	15.76	15.12	15.44	25.00	6.10	13.57
2	14.63	14.53	14.58	25.00	5.90	13.33
3	16.50	16.57	16.54	24.00	7.50	15.00
4	14.91	15.87	15.39	26.00	6.10	13.82
5	14.81	14.94	14.88	26.00	6.00	13.70
6	16.50	16.50	16.50	26.00	7.50	15.50
7	15.01	15.15	15.08	26.00	6.20	13.94

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8	15.85	16.76	16.31	24.00	7.00	14.40
9	16.32	16.47	16.40	26.00	7.10	15.02
10	17.19	17.10	17.15	28.00	7.40	15.88
11	16.73	16.90	16.82	27.00	7.70	15.99
12	16.75	16.63	16.69	27.00	7.20	15.39
13	15.60	14.88	15.24	27.00	6.50	14.55
14	15.77	15.74	15.76	26.00	6.90	14.78
15	16.23	16.30	16.27	25.00	7.10	14.77
16	15.13	15.22	15.18	27.00	6.30	14.31
17	15.10	15.87	15.49	26.00	7.00	14.90
18	15.04	15.43	15.24	27.00	6.30	14.31
19	16.33	16.63	16.48	27.00	7.40	15.63
20	14.81	15.33	15.07	28.00	6.10	14.32
21	14.80	14.86	14.83	28.00	5.80	13.96
22	14.62	14.58	14.60	26.00	5.90	13.58
23	13.35	13.41	13.38	27.00	4.60	12.27
24	12.80	12.88	12.84	27.00	4.20	11.79
25	15.92	15.79	15.86	27.50	6.20	14.32
26	15.96	15.98	15.97	28.00	6.50	14.80
27	15.76	15.72	15.74	27.50	6.70	14.92
28	15.57	15.49	15.53	27.50	6.30	14.44
29	14.14	14.17	14.16	26.50	5.50	13.23
30	14.88	14.80	14.84	27.50	5.50	13.48
31	14.64	14.59	14.62	28.00	5.60	13.72
32	14.33	14.48	14.41	26.00	5.70	13.34
33	16.31	16.15	16.23	28.00	6.50	14.80
34	15.12	15.12	15.12	28.50	6.00	14.33
35	15.96	15.93	15.95	28.50	6.60	15.05
36	15.69	16.23	15.96	28.00	6.70	15.04
37	15.59	15.62	15.61	28.00	6.20	14.44
38	14.62	14.64	14.63	26.00	6.00	13.70
39	15.92	15.94	15.93	29.50	6.30	14.94
40	15.76	15.70	15.73	27.50	6.70	14.92
41	15.74	15.69	15.72	27.50	6.70	14.92
42	14.14	14.17	14.16	26.50	5.60	13.35
43	14.32	14.42	14.37	26.50	5.70	13.47
44	14.87	14.82	14.85	27.50	5.90	13.96
45	15.92	15.96	15.94	28.00	6.70	15.04
46	16.31	16.42	16.37	29.00	6.80	15.41
47	15.14	15.16	15.15	28.50	5.90	14.21
48	15.87	15.89	15.88	28.50	6.50	14.93
49	14.65	14.62	14.64	28.00	5.60	13.72
50	15.38	15.40	15.39	27.50	6.30	14.44

The minimum, maximum and average TS content in mixed raw milk by gravimetric method, by lactometric method without correction factor and by using M₁ and M₂ equation have been presented in Table 4.5.3.2.

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Table 4.5.3.2 Total solids of mixed milk obtained by gravimetric and volumetric method by different formulae for Dairy Plant E

	Total Solid, per cent				
	Gravimetric Method	Volumetric Method			
		Without correction factor		With correction factor	
		M ₁	M ₂	M ₁	M ₂
	$\frac{CLR+1.22F}{4}$	$\frac{CLR+1.25F}{4}$	$\frac{CLR+1.22F+0.94}{4}$	$\frac{CLR+1.25F+0.75}{4}$	
Minimum	12.84	11.87	12.00	12.81	12.74
Maximum	17.14	16.14	16.37	17.08	17.05
Average	15.41	14.45	14.64	15.40	15.40
t-test					
t value	-	5.38	4.25	0.00	1.29X10 ⁻¹³
Result	-	S	S	NS	NS

S = Significant NS= Non Significant

In volumetric method using M₁ equation without correction factor, the minimum, maximum and average values of total solids were 11.87, 16.14 and 14.45 respectively, while using M₂ equation, these values were 12.00, 16.37 and 14.64, respectively. While on addition of 0.94 correction factor in M₁ equation, the minimum, maximum and average values of total solids were 12.81, 17.08 and 15.40 respectively, and on addition of 0.75 correction factor in M₂ equation these values were 12.74, 17.05 and 15.40, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 12.84, 17.14 and 15.41, respectively.

It showed that the volumetric method without correction factor gave lower values of TS and also statistically significant difference between the estimated values for TS by gravimetric and volumetric method. While using M₁ and M₂ equations with correction factor, the values for TS using correction factor showed a non significant difference revealing almost similar values for TS by both the methods.

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The values of two sample t-test for TS content of raw mixed milk supplies from Dairy Plant E as presented in Table 4.5.3.2. There was no significant difference between gravimetric and volumetric mean for TS by M_1 and M_2 equation. Thus, it was inferred that the TS by gravimetric method and volumetric method were almost same for mixed milk from Dairy Plant E.

Table 4.5.3.3 Frequency distribution of total solids of mixed milk from Dairy Plant E by M_1 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	12.50-13.00	1	2.00	1	2.00
2	13.00-13.50	1	2.00	2	4.00
3	13.50-14.00	0	0.00	2	4.00
4	14.00-14.50	4	8.00	6	12.00
5	14.50-15.00	9	18.00	15	30.00
6	15.00-15.50	12	24.00	27	54.00
7	15.50-16.00	12	24.00	39	78.00
8	16.00-16.50	7	14.00	46	92.00
9	16.50-17.00	3	6.00	49	98.00
10	17.00-17.50	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		15.4162	
Std Dev		Sigma		0.86617	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	
K-S		0.11100670		0.117	

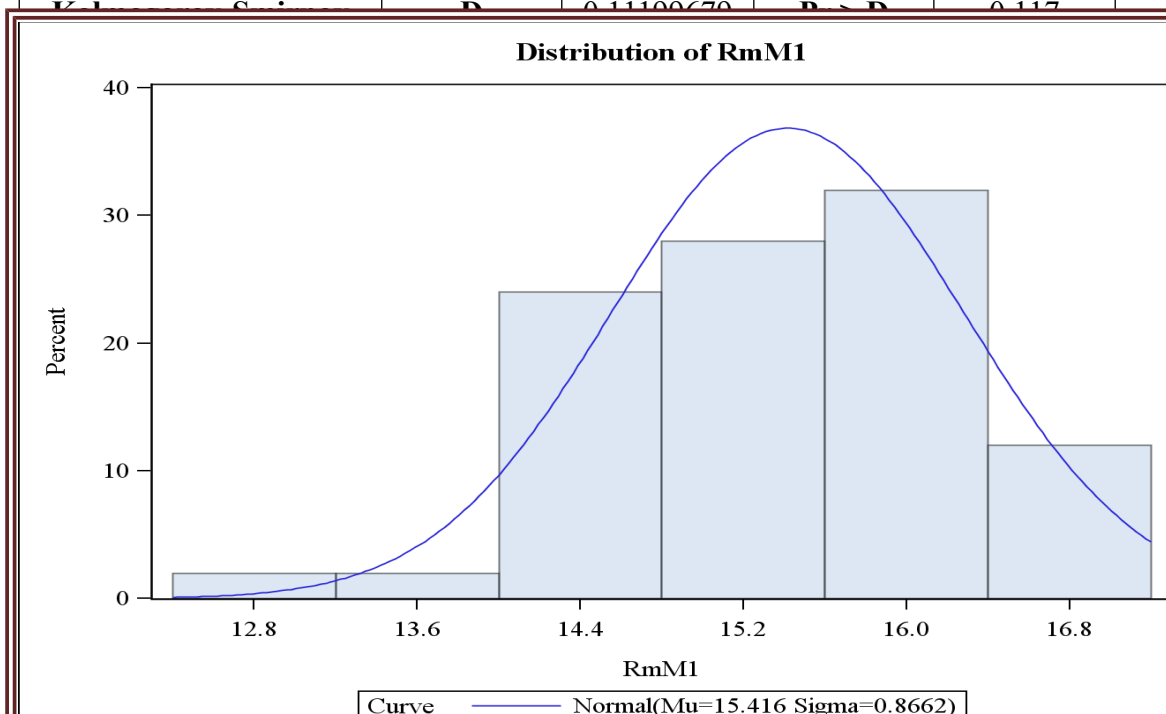


Fig. 4.5.3.1 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant E by M_1 formula

Table 4.5.3.4 Frequency distribution of total solids of mixed milk from Dairy Plant E by M_2 formula

Sr. No.	Class limit	Frequency	Per cent	Cumulative	
				Frequency	Per cent
1	12.50-13.00	1	2.00	1	2.00
2	13.00-13.50	1	2.00	2	4.00
3	13.50-14.00	0	0.00	2	4.00
4	14.00-14.50	6	12.00	8	16.00
5	14.50-15.00	10	20.00	18	36.00
6	15.00-15.50	10	20.00	28	56.00
7	15.50-16.00	11	22.0	39	78.00
8	16.00-16.50	7	14.00	46	92.00
9	16.50-17.00	3	6.00	49	98.00
10	17.00-17.50	1	2.00	50	100.00
Parameters for Normal Distribution					
Parameter		Symbol		Estimate	
Mean		Mu		15.4162	
Std Dev		Sigma		0.885905	
Goodness-of-Fit Tests for Normal Distribution					
Test		Statistic		p Value	

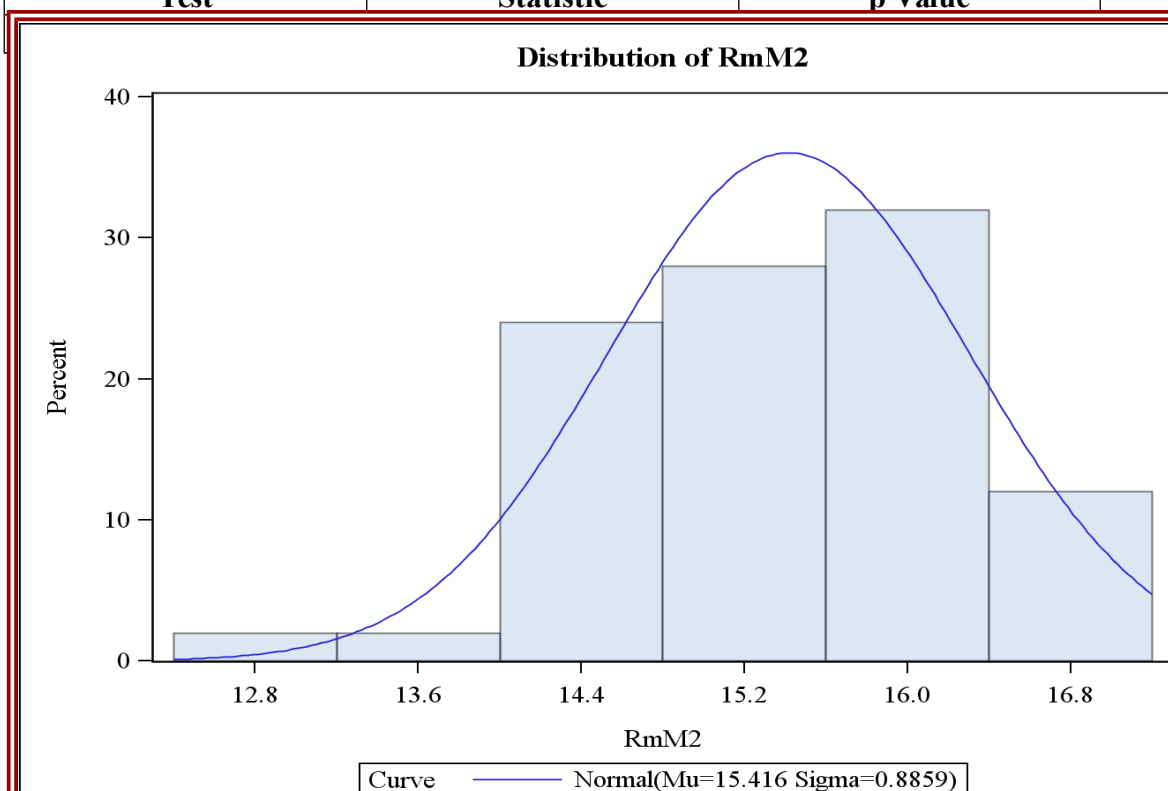


Fig. 4.5.3.2 The grouped frequency distribution curve of total solids of mixed milk from Dairy Plant E by M₂ formula

The frequency distribution patterns was worked out for total solids of mixed milk by M₁ and M₂ formulae are presented in Table 4.5.3.3 and 4.5.3.4, respectively. The test for normality was also carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The same is also depicted graphically in Figure 4.5.3.1 and 4.5.3.2, respectively. All the data for TS contents of mixed milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant E, two probable equations derived statistically have been given below.

$$TS = \frac{CLR}{4} + 1.22 F + 0.94$$

$$TS = \frac{CLR}{4} + 1.25 F + 0.75$$

4.6 Overall Dairy Plants

4.6.1 Buffaloes milk

The proposed equations for computing TS/SNF for buffaloes milk from different Dairy Plants are narrated given in Table 4.6.1. The results revealed that maintaining all the aspects almost same, the correction factor varied from 0.44 to 1.45 for various dairy plants. It could be seen that a correction to be applied in M₁ equation

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ranged from 0.67 to 1.66, while it varied from 0.44 to 1.45 in M₂ equation. The variations in correction factor in present study were within the limits reported by earlier workers.

The overall equations derived for computing TS values by volumetric method for buffaloes are,

$$1. \text{ TS} = \frac{\text{CLR}}{4} + 1.22 \text{ F} + 1.09$$

$$2. \text{ TS} = \frac{\text{CLR}}{4} + 1.25 \text{ F} + 0.86$$

Table 4.6.1 Probable TS formulas for buffalo milk for different Dairy Plants of Gujarat state

Sr. No.	Type of milk	No. of samples	Name of the Dairy Plant	Probable TS formula by taking a factor of 1.22F	Probable TS formula by taking a factor of 1.25F
1	Buffaloes milk	50	Dairy Plant A	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 1.30}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 1.05}{4}$
2		50	Dairy Plant B	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.86}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.61}{4}$
3		50	Dairy Plant C	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.97}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.75}{4}$
4		50	Dairy Plant D	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 1.66}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 1.45}{4}$
5		50	Dairy Plant E	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.67}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.44}{4}$
Overall		250		$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 1.09}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.86}{4}$

4.6.2 Cows milk

The individual equations for TS in cow milk from various Dairy Plants have been presented in Table 4.6.2. The correction factor varied from 0.57 to 1.24 in M₁ equation while it ranged between 0.42 and 1.11 in M₂ equation.

The overall proposed equations for calculating TS in cows milk are given below.

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$$1. \text{ TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.86}{4}$$

$$2. \text{ TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.88}{4}$$

Table 4.6.2 Probable TS formula of cows milk for different Dairy Plants of Gujarat state

Sr. No.	Type of milk	No. of samples	Name of the Dairy Plant	Probable TS formula by taking a factor of 1.22F	Probable TS formula by taking a factor of 1.25F
1	Cows milk	50	Dairy Plant A	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.86}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.73}{4}$
2		50	Dairy Plant B	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.57}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.42}{4}$
3		50	Dairy Plant C	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.66}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.52}{4}$
4		50	Dairy Plant D	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 1.24}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 1.11}{4}$
5		50	Dairy Plant E	$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.68}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.54}{4}$
Overall		250		$\text{TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.86}{4}$	$\text{TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.88}{4}$

4.6 Mixed milk

The probable formulas TS in mixed milk from various Dairy Plants are shown in Table 4.6.3. Here the correction factor to be applied for calculation of TS ranged from 0.70 to 1.41 for M₁ equation while it varied from 0.51 to 1.23 for M₂ equation. The overall equations proposed for the calculation of TS in mixed milk are as under,

$$1. \text{ TS} = \frac{\text{CLR} + 1.22 \text{ F} + 0.97}{4}$$

$$2. \text{ TS} = \frac{\text{CLR} + 1.25 \text{ F} + 0.79}{4}$$

Table 4.6.3 Probable TS formula of mixed milk for different Dairy Plants of Gujarat state

Sr. No.	Type of milk	No. of samples	Name of the Dairy Plant	Probable TS formula by taking a factor of 1.22F	Probable TS formula by taking a factor of 1.25F
1	Mixed milk	50	Dairy Plant A	$TS = \frac{CLR}{4} + 1.22 F + 1.04$	$TS = \frac{CLR}{4} + 1.25F + 0.86$
2		50	Dairy Plant B	$TS = \frac{CLR}{4} + 1.22 F + 0.75$	$TS = \frac{CLR}{4} + 1.25F + 0.58$
3		50	Dairy Plant C	$TS = \frac{CLR}{4} + 1.22 F + 0.75$	$TS = \frac{CLR}{4} + 1.25F + 0.58$
4		50	Dairy Plant D	$TS = \frac{CLR}{4} + 1.22 F + 1.41$	$TS = \frac{CLR}{4} + 1.25F + 1.23$
5		50	Dairy Plant E	$TS = \frac{CLR}{4} + 1.22 F + 0.94$	$TS = \frac{CLR}{4} + 1.25F + 0.75$
Overall		250		$TS = \frac{CLR}{4} + 1.22 F + 0.97$	$TS = \frac{CLR}{4} + 1.25F + 0.79$

From the above findings the following points have emerged out:

The modified Richmond formulas for calculating TS/SNF in different milks have been proposed for individual specific Dairy Plant. The specific equation derived for each individual Dairy Plant reflects the region specific chemical composition of milk, array of factors affecting milk composition, numbers of samples taken for working out formulae and other unforeseen observations, which could be seen from correction factor ranging from 0.40 to 1.45 in M₁ and 0.57 to 1.66 in M₂ equation respectively to match with total solids measurement by official method for different milks.

These Dairy Plants can adopt the overall equations specified for each type of milk, if they enter into any agreement for the purchase and sale of milk among Dairy Plants.

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It showed that the equation $TS = CLR/4 + 1.25 F + \text{correction factor}$ was more convenient, and provided the TS/SNF values very close proximity to the results for TS obtained by gravimetric method.

It reflected that these variations in equations proposed for each Dairy Plant might be from non assignable causes and therefore, each Dairy Plant has to evolve its own equation for faster measurement of TS/SNF by lactometer method.

SUMMARY AND CONCLUSION

Milk has long been recognised as the most complete single food available in nature for the maintenance of health and promotion of growth of the mammal. Milk is a fluid secreted by the female of all mammalian species for the primary function of meeting the complete nutritional requirements of the neonate of the species. In addition, milk serves several physiological functions for the neonate (Singh *et al.*, 1997). Milk is a very variable biological fluid. Milk differs widely in composition; the greatest differences are among milks of different species of mammals. The variations in milks within a species depend on so many factors that it is difficult to determine accurately the relationship between a specific factor and composition. Differences in the composition of milks may be compared in two ways: by comparing the percentages of individual components as they occur in whole milk, or by comparing the percentages of individual components as they occur in the total solids of milk (Webb and Johnson, 1974). As per PFA (2009) milk, according to the PFA rules, is the normal mammary secretion derived from the complete milking of healthy milch animal without either addition thereto or extraction there from. It shall be free from colostrum. Milk is a heterogeneous product in which fat, protein, sugar, vitamins and mineral salts are held in emulsion, colloidal suspension or solution in the major constituent, water.

Milk is in a qualitative sense, fairly constant in composition and properties; there is a considerable quantitative variation. Chemical composition, size and stability of structural elements, and physical properties may all differ among lots of milk. In recent years, the solids-not- fat content of milk has also been regarded as of equal or

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of greater importance, than the fat percentage. Milk is valued commercially for its two important parameters: (I) milk fat (II) solids- not- Fat (SNF). The SNF largely consists of proteins, lactose and minerals. These solids are also referred to as ‘serum solids’. These two parameters are usually forming the basis of payment to milk producers in India. The term Total Solids’ (TS) refers to the quantity of SNF plus fat present in milk (Aneja and Mathur, 2002). In the dairy industry, SNF of milk plays an important role. SNF is the second important component of milk, after fat. It is extensively used while receiving, dispatching and in- process standardization of milk etc. Farmers should get due price for their milk as they are paid correctly on fat and SNF basis (Sandhu, 2003). Judicious payment of milk to producers requires quick methods for estimation of both fat and SNF in milk. Fat can be easily determined by the Gerber and Babcock methods fairly accurately (Pruthi and Dutt, 1977). Different dairies using different methods of SNF determination, when they get into contract of purchase and sale of milk in large quantities, it is quite likely that shortages in SNF contents will create big disputes. The close relationship existing between specific gravity, fat and total solids of milk has successfully been exploited for the estimation of SNF content in milk (Pruthi and Dutt, 1977). In India there are 20 varieties of Richmond formula for SNF estimation by volumetric method (Ganguly and Kuchroo, 1980). When different dairies get into contract for purchase and sale of milk in large quantities, it is quite likely that shortages in SNF contents will create big disputes (Patel and Gandhi, 1979). It is necessary to modify the above price formula in such a way that the legitimate interests of milk producers, contractors, dairy plants and consumers are safeguarded. Therefore there is an urgent need for using a uniform Richmond formula for all dairies or otherwise use constant in basic Richmond

equation to have computed value for large number of samples agreeable to gravimetric method.

Under study, 5 well-known dairy plants of big capacity of Gujarat state were selected. Fifty samples of each in raw form from cows, buffaloes and mixed milk supplies were collected. In all 150 samples were taken for a period of study from each dairy plant.

Dairy Plant A

Buffaloes Milk

From Dairy Plant A, total of 50 samples of buffaloes milk were analyzed for milk fat, total solids by gravimetric and lactometer (volumetric) methods. In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids were 15.54, 18.09 and 16.72 respectively, while using M_2 formula, these values were 15.75, 18.37 and 16.96, respectively. While addition of 1.30 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 16.83, 19.38 and 18.02 respectively, and addition of 1.05 correction factor in M_2 formula, these values were 16.80, 19.42 and 18.02, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 16.55, 19.46 and 18.02, respectively.

It indicated that volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS showed a non significant difference indicating almost similar values for TS as comparable to the values obtained by gravimetric method.

Based on values of two sample t-test for TS contents in buffaloes milk from Dairy Plant A, no significant difference was found between gravimetric and

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volumetric mean for TS in milk by M_1 and M_2 formulae with correction factor. Thus, it could be said that the TS finding by gravimetric and volumetric method were almost same for buffaloes milk from Dairy Plant A.

The frequency distribution was worked out for total solids of buffaloes milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant A, two probable equations are derived statistically which are as under

$$TS = CLR/4 + 1.22 F + 1.3, \text{ and}$$

$$TS = CLR/4 + 1.2F + 1.05$$

It is inferred that the values for TS content in buffaloes milk obtained either by M_1 and M_2 formulae without correction factor were very low indicating requirement of correction factors for both the equations is required.

Cows Milk

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids were 10.96, 13.70 and 12.13 respectively, while using M_2 formula, these values were 11.06, 13.87 and 12.26, respectively. Addition of 0.86 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 11.82, 14.56 and 12.99 respectively, while addition of 0.73 correction factor in M_2 formula these values were 11.79, 14.60 and 12.99, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 11.83, 14.55 and 12.99, respectively.

It indicated that volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS

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showed statistically a non significant difference indicating almost similar values for TS as comparable to gravimetric method.

Based on values of two sample t-test for TS for raw cows milk from Dairy Plant A, no significant difference was seen between TS obtained by gravimetric and volumetric mean either by M_1 and M_2 formulae. Thus, it could be said that the TS by gravimetric and volumetric method were almost same for cows milk from Dairy Plant A.

The frequency distribution was worked out for total solids of cows milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. All the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of cows milk collected from Dairy Plant A, two probable equations are derived statistically which are mentioned here under

$$TS = CLR/4 + 1.22F + 0.86, \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.73$$

Mixed Milk

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids in mixed milk were 12.30, 15.22 and 13.88 respectively, while using M_2 formula, these values were 12.43, 15.43 and 14.06, respectively. Addition of 1.04 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.34, 16.26 and 14.92 respectively, while addition of 0.86 correction factor in M_2 formula, these values were 13.29, 16.29 and 14.92, respectively. The minimum, maximum and average values of total solids by using gravimetric method were 13.28, 16.45 and 14.92, respectively.

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It indicated that the volumetric method without correction factor gave lower values of TS, whose differences were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS showed a non significant difference indicating almost similar values for TS as comparable with gravimetric method.

There was no statistical significant difference between gravimetric and volumetric mean for TS in mixed milk by M_1 and M_2 formulae based on the sample t-test. Thus, it could be inferred that the values of TS obtained by gravimetric and volumetric method were almost same for mixed milk from Dairy Plant A.

The test for normality was carried out by using Kolmogorov-Smirnov test and plotting frequency distribution. The statistical analysis indicated that the data followed the normal distribution. All the data for TS contents of mixed milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant A, two probable equations are derived statistically which are given as under

$$TS = CLR/4 + 1.22 F + 1.04, \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.86$$

Dairy Plant B

Buffaloes Milk

Form Dairy Plant B, total of 50 samples of buffaloes milk were analyzed for milk fat, total solids by gravimetric and lactometer (volumetric) methods. In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids were 14.22, 21.26 and 17.20 respectively, while using M_2 formula, these values were 14.37, 21.62 and 17.45, respectively. While addition of 0.86 correction factor in M_1 formula, the minimum, maximum and

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average values of total solids were 15.09, 22.12 and 18.07 respectively, and addition of 0.61 correction factor in M₂ formula, these values were 14.99, 22.24 and 18.07, respectively. The minimum, maximum and average values of total solids by using gravimetric method were 15.14, 22.22 and 18.07, respectively.

This revealed that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the results of gravimetric method. While using M₁ and M₂ formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS quite comparable with the results of gravimetric method.

Based on values of two sample t-test for TS contents in buffaloes milk from Dairy Plant B, no significant difference was found between gravimetric and volumetric mean for TS in milk by M₁ and M₂ formulae with correction factor. Thus, it could be said that the TS by gravimetric and volumetric method were almost same for buffaloes milk from Dairy Plant B.

The frequency distribution was worked out for total solids of buffaloes milk by M₁ and M₂ formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant B, two probable equations are derived statistically are given below

$$TS = CLR/4 + 1.22 F + 0.86 \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.61$$

It is inferred that the values for TS content in buffaloes milk determined by either of M₁ and M₂ formulae without correction factor were very low to the values of

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gravimetric method. This indicated requirements of correction factors for both the equations so as to get non significant.

Cows Milk

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids from cows milk were 10.27, 16.20 and 12.78 respectively, while using M_2 formula, these values were 10.37, 16.43 and 12.92, respectively. While addition of 0.57 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 10.83, 16.77 and 13.35 respectively, and addition of 0.42 correction factor in M_2 formula, these values were 10.80, 16.86 and 13.35, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 10.69, 17.01 and 13.35, respectively.

It indicated that the volumetric method without correction factor gave lower values of TS, which were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS almost in consonance with gravimetric method.

Based on values of two sample t-test for TS for raw cow milk from Dairy Plant B, no significant difference was seen between TS obtained by gravimetric and volumetric mean either by M_1 and M_2 formulae. Thus, it could be said that the TS by gravimetric and volumetric method were almost same for cows milk from Dairy Plant B.

The frequency distribution was worked out for total solids of cows milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-

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Smirnov test. The statistical analysis showed that the data followed the normal distributio. All the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of cows milk collected from Dairy Plant B, two probable equations are derived statistically given as under

$$TS = CLR/4 + 1.22 F + 0.57 \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.42$$

Mixed Milk

In volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids of mixed milk were 13.22, 17.36 and 14.82 respectively, while using M_2 formula, these values were 13.37, 17.62 and 15.01, respectively. While addition of 0.75 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.94, 18.08 and 15.53 respectively, and addition of 0.58 correction factor in M_2 formula, these values were 13.90, 18.15 and 15.54, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 14.04, 18.20 and 15.54, respectively.

It indicated that the volumetric method without correction factor gave lower values of TS. This was also evidenced by statistical significant difference. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as compared to gravimetric method.

There was no statistical significant difference between gravimetric and volumetric mean for TS in mixed milk by M_1 and M_2 formulae based on the sample t-test. Thus, it could be inferred that the TS by gravimetric and volumetric method were almost same for mixed milk from Dairy Plant B.

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The test for normality was carried out by using Kolmogorov-Smirnov test and plotting frequency distribution. The statistical analysis indicated that the data followed the normal distribution. All the data for TS contents of mixed milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant B, two probable equations are derived statistically given as under

$$TS = CLR/4 + 1.22 F + 0.75 \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.58$$

Dairy Plant C

Buffaloes Milk

Form Dairy Plant C, total of 50 samples of buffaloes milk were analyzed for milk fat, total solids by gravimetric and lactometer (volumetric) methods. The minimum, maximum and average values of total solids were 14.67, 17.06 and 15.81, respectively in volumetric method using M_1 formula without correction factor, while these values were 14.87, 17.31 and 16.03, respectively using M_2 formula. By addition of 0.97 correction factor in M_1 formula, the minimum, maximum and average values of total solids in buffaloes milk were 15.64, 18.02 and 16.78, respectively and addition of 0.75 correction factor in M_2 formula, these values were 15.62, 18.05 and 16.78, respectively. The minimum, maximum and average values of total solids were 15.38, 18.13 and 16.78, respectively by using gravimetric method.

It indicated that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as compared to gravimetric method.

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Based on values of two sample t-test for TS contents in buffaloes milk from Dairy Plant, no significant difference was found between gravimetric and volumetric mean for TS in milk by M₁ and M₂ formulae. Thus, it could be said that the TS by gravimetric and volumetric method were almost same for buffaloes milk from Dairy Plant C.

The frequency distribution was worked out for total solids of buffaloes milk by M₁ and M₂ formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant C, two probable equations are derived statistically given as under

$$TS = CLR/4 + 1.22 F + 0.97 \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.75$$

Cows Milk

Based on the analysis for milk fat, TS (gravimetric) and TS (lactometer) of cows milk from Dairy Plant C, the minimum, maximum and average values of total solids were 11.81, 13.46 and 12.50 respectively, while using M₂ formula, these values for TS were 11.93, 13.62 and 12.64, respectively in volumetric method using M₁ formula without correction factor. Addition of 0.66 correction factor in M₁ formula gave minimum, maximum and average values of 12.46, 14.11 and 13.16 per cent total solids respectively and addition of 0.52 correction factor in M₂ formula these values were 12.45, 14.14 and 13.16, respectively in the same method using M₁ formula without correction factor. By using gravimetric method the minimum, maximum and average values of total solids were 12.39, 14.20 and 13.16, respectively.

The results indicated that volumetric method using basic Richmond formula without correction factor gave lower values of TS in cows milk and the difference

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between the TS by both the methods was statistically significant. While using M_1 and M_2 formulae with correction factor, the values for TS were quite comparable with gravimetric method and these values showed a non significant difference.

The values of two sample t-test of TS of milk collected from Dairy Plant C revealed no significant difference between gravimetric and volumetric mean by M_1 and M_2 formulae. Thus, it could be inferred that the TS by both the methods were almost alike for cows milk from Dairy Plant C.

The frequency distribution was derived for total solids of cows milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The graphical distribution of all the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of cows milk collected from Dairy Plant C, two probable equations are derived statistically given as under

$$TS = CLR/4 + 1.22 F + 0.66, \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.52$$

Mixed Milk

In mixed milk from Dairy Plant C, the minimum, maximum and average values for TS content were 12.70, 14.96 and 13.74 and 12.85, 15.16 and 13.91 using M_1 and M_2 formula without correction factor in lactometer method respectively. While addition of 0.75 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.45, 15.72 and 14.49 respectively, and addition of 0.58 correction factor in M_2 formula, these values were 13.43, 15.74 and 14.49, respectively. The minimum, maximum and average values of total solids were 13.41, 15.59 and 14.49, respectively by using gravimetric method.

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It showed that the volumetric method without correction factor gave lower values of TS with statistically significant difference. While using M_1 and M_2 formulae with correction factor, the values for TS showed a non significant difference indicating almost similar values for TS as comparable with gravimetric method.

The values of two sample t-test of TS content in mixed milk from Dairy Plant C indicated no significant difference between gravimetric mean and volumetric mean by M_1 and M_2 formulae. Thus, it could be said that the TS by gravimetric method and volumetric method were almost same for mixed milk from Dairy Plant C.

The frequency distribution was worked out for total solids of mixed milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. All the data for TS contents of mix milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant C, two probable equations are derived statistically given as under

$$TS = CLR/4 + 1.22 F + 0.75, \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.58$$

Dairy Plant D

Buffaloes Milk

In Dairy Plant D, total of 50 samples buffaloes milk were analyzed for milk fat, total solids (gravimetric) and TS/SNF (lactometer) methods. The minimum, maximum and average TS content in buffaloes milk by gravimetric and lactometric method without correction factor and by using correction factor (M_1 and M_2 formulae) were 13.52, 18.98 and 16.47; 12.08, 17.24 and 14.81 and 12.25, 17.50 and 15.02, respectively. On addition of 1.66 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.74, 18.90 and 16.47 respectively,

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and on addition of 1.45 correction factor in M_2 formula, these values were 13.70, 18.95 and 16.47, respectively.

It revealed that the volumetric method without correction factor gave lower values of TS, whose difference was statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as compared to gravimetric method.

For values of two sample t-test of TS in raw buffaloes milk samples from Dairy Plant D, no significant difference was seen between gravimetric and volumetric mean by M_1 and M_2 formulae. Thus, it was concluded that the TS by gravimetric method and volumetric method were almost same for buffaloes milk from Dairy Plant D.

The frequency distribution was calculated for total solids of buffaloes milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution as is also evident from graphical presentation. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant D, two probable equations derived statistically are as under

$$TS = CLR/4 + 1.22 F + 1.66, \text{ and}$$

$$TS = CLR/4 + 1.25F + 1.45$$

Cows Milk

The minimum, maximum and average values of total solids in cows milk from Dairy Plant D were 7.91, 13.33 and 11.49 respectively for M_1 formula while these values were 8.00, 13.50 and 11.62, respectively for M_2 formula without correction

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factor in volumetric method. On addition of 1.24 correction factor in M₁ formula, the minimum, maximum and average values of total solids were 9.15, 14.57 and 12.72, respectively and on addition of 1.11 correction factor in M₂ formula, these values were 9.10, 14.60 and 12.72, respectively. The minimum, maximum and average values of total solids were 13.52, 18.98 and 16.47, respectively in gravimetric method.

The volumetric method without correction factor gave lower values of TS as is also evident from significant statistical difference. While using M₁ and M₂ formulae with correction factor, the values for TS showed a non significant difference indicating almost similar values for TS as in consonance with gravimetric method.

The values of two sample t-test for TS content in raw milk samples of cow from Dairy Plant D have been computed. No significant difference was found between gravimetric and volumetric mean by M₁ and M₂ formulae. Thus, it could be inferred that the TS by gravimetric and volumetric method were almost same for cows milk from Dairy Plant D.

The frequency distribution patterns was calculated for total solids of cows milk by M₁ and M₂ formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution as was also evident from graphical presentation. All the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of cows milk collected from Dairy Plant D, two probable equations are derived statistically as given below

$$TS = CLR/4 + 1.22 F + 1.24, \text{ and}$$

$$TS = CLR/4 + 1.25F + 1.11$$

Mixed Milk

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For mixed milk from Dairy Plant D, the minimum, maximum and average values for TS content by gravimetric method were 12.92, 17.66 and 14.68, respectively. For volumetric method using M_1 formula without correction factor, the minimum, maximum and average values of total solids were 11.73, 16.01 and 13.27 respectively, while using M_2 formula, these values were 11.87, 16.25 and 13.45, respectively. On addition of 1.41 correction factor in M_1 formula, the minimum, maximum and average values of total solids were 13.14, 17.42 and 14.68 respectively, and on addition of 1.23 correction factor in M_2 formula these values were 13.10, 17.47 and 14.68, respectively.

It indicated that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 formulae with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values for TS as comparable to gravimetric method.

The values of two sample t-test for TS content in mixed milk from Dairy Plant D showed no significant difference between gravimetric and volumetric mean by M_1 and M_2 formulae. Thus, it could be said that the TS contents by gravimetric and volumetric method were almost similar for mixed milk from Dairy Plant D.

The frequency distribution as well as the test for normality was carried out by using Kolmogorov-Smirnov test was carried out for total solids of mixed milk by M_1 and M_2 formulae. The statistical analysis showed that the data followed the normal distribution as also shown graphically. All the data for TS contents of mixed milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant D, two probable equations derived statistically are given as under

TS = CLR/ 4 + 1.22 F + 1.41, and

TS = CLR/4 + 1.25F + 1.23

Dairy Plant E

Buffaloes Milk

For Dairy Plant E, total of 50 samples buffaloes milk were analyzed for milk fat, total solids (gravimetric) and TS/SNF (lactometer) methods. In volumetric method using M_1 equation without correction factor, the minimum, maximum and average values of total solids were 14.30, 17.75 and 16.32 respectively, while using M_2 equation, these values were 14.50, 18.00 and 16.56, respectively. On addition of 0.67 correction factor in M_1 equation, the minimum, maximum and average values of total solids were 14.97, 18.40 and 17.00 respectively, and on addition of 0.44 correction factor in M_2 equation, these values were 14.93, 18.43 and 17.00, respectively. The gravimetric method resulted 14.75, 18.50 and 17.00 per cent as minimum, maximum and average values of total solids respectively.

It indicated that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 equations with correction factor, the values for TS using correction factor showed a non significant difference indicating almost similar values quite comparable with gravimetric method.

The values of two sample t-test for TS content of raw milk samples from Dairy Plant E were carried out. It showed no significant difference between gravimetric and volumetric mean by M_1 and M_2 equations. Thus, it was inferred that

the TS by gravimetric method and volumetric method were almost similar for buffaloes milk from Dairy Plant E.

The frequency distribution was calculated for total solids of buffaloes milk by M_1 and M_2 formulae. The test for normality was carried out by using Kolmogorov-Smirnov test. The results for TS contents when plotted followed the normal distribution as is evident graphically also. All the data for TS contents of buffaloes milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of buffaloes milk collected from Dairy Plant E, two probable equations were derived statistically given as under

$$TS = CLR/4 + 1.22 F + 0.67, \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.44$$

Cows Milk

Cow milk was analyzed for TS by gravimetric method, milk fat by Gerber method, LR at 29 C and TS by lactometric method. In volumetric method using M_1 equation without correction factor, the minimum, maximum and average values of total solids were 9.74, 14.43 and 11.97 respectively, while using M_2 equation, these values were 9.83, 14.62 and 12.10 respectively. Addition of 0.68 and 0.54 correction factor yielded 10.42, 15.10 and 12.65 and 10.37, 15.16 and 12.65 as the minimum, maximum and average values of total solids in M_1 and M_2 equation respectively. By using gravimetric method the respective minimum, maximum and average values of total solids were 10.46, 14.94 and 12.65.

Above results indicated that the volumetric method without correction factor gave lower values of TS, whose difference were statistically significant than the gravimetric method. While using M_1 and M_2 equation with correction factor, the values for TS showed a non significant difference revealing almost similar values for TS as compared to gravimetric method.

The values of two sample t-test for TS content in raw milk samples of cows supplies from Dairy Plant E revealed no significant difference between gravimetric and volumetric mean by M_1 and M_2 equation. Thus, it could be said that the TS by gravimetric method and volumetric method were almost same for cows milk from Dairy Plant E.

The frequency distribution patterns for total solids of cows milk by M_1 and M_2 formulae and the test for normality was carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. The graphic presentation of all the data for TS contents of cows milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of cows milk collected from Dairy Plant E, two probable equations were derived statistically given as under

$$TS = CLR/4 + 1.22 F + 0.68, \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.54$$

Mixed Milk

For mixed milk, in volumetric method using M_1 equation without correction factor, the minimum, maximum and average values of total solids were 11.87, 16.14 and 14.45 respectively, while using M_2 equation, these values were 12.00, 16.37 and 14.64 respectively. While on addition of 0.94 correction factor in M_1 equation, the minimum, maximum and average values of total solids were 12.81, 17.08 and 15.40 respectively, and on addition of 0.75 correction factor in M_2 equation these values were 12.74, 17.05 and 15.40, respectively. By using gravimetric method the minimum, maximum and average values of total solids were 12.84, 17.14 and 15.41, respectively.

It showed that the volumetric method without correction factor gave lower values of TS and also statistically significant difference between the estimated values

for TS by gravimetric and volumetric method. While using M_1 and M_2 equations with correction factor, the values for TS using correction factor showed a non significant difference revealing almost similar values for TS by both the methods.

The values of two sample t-test for TS content of raw mixed milk supplies from Dairy Plant E was done. There was no significant difference between gravimetric and volumetric mean for TS by M_1 and M_2 equation. Thus, it was inferred that the TS by gravimetric method and volumetric method were almost same for mixed milk from Dairy Plant E.

The frequency distribution patterns was worked out for total solids of mixed milk by M_1 and M_2 formulae as well as the test for normality was also carried out by using Kolmogorov-Smirnov test. The statistical analysis showed that the data followed the normal distribution. Graphical presentation of all the data for TS contents of mixed milk followed the $\mu \pm 3\sigma$ range.

Based on analysis of 50 samples of mixed milk collected from Dairy Plant E, two probable equations are derived statistically given as under

$$TS = CLR/4 + 1.22 F + 0.94, \text{ and}$$

$$TS = CLR/4 + 1.25F + 0.75$$

Overall Dairy Plants

Buffaloes Milk

The results revealed that maintaining all the aspects almost same, the correction factor varied from 0.44 to 1.45 for various Dairy Plants. It could be seen that a correction to be applied in M_1 equation ranged from 0.67 to 1.66, while it varied from 0.44 to 1.45 in M_2 equation. The variations in correction factor in present study were within the limits as reported by earlier workers.

.....Summary and Conclusion

It showed that the equation $TS = \frac{CLR}{4} + 1.25 F + \text{correction factor}$ was more convenient as compared to $TS = \frac{CLR}{4} + 1.22 F + \text{correction factor}$, and provided the TS/SNF in very close proximity to the results for TS obtained by gravimetric method. It reflected that variations are non assignable causes and therefore, every Dairy Plant has to evolve its own equation for TS/SNF by lactometer method.

The overall equations for buffaloes milk derived were,

1. $TS = \frac{CLR}{4} + 1.22 F + 1.09$

2. $TS = \frac{CLR}{4} + 1.25F + 0.86$

Cows Milk

In cases of cows milk of all Dairy Plants, the correction factor varied from 0.57 to 1.24 in M₁ equation while it ranged between 0.42 and 1.11 in M₂ equation.

The overall proposed equations for calculating TS in cows milk are given below

1. $TS = \frac{CLR}{4} + 1.22 F + 0.86$

2. $TS = \frac{CLR}{4} + 1.25 F + 0.88$

Mixed Milk

The correction factor to be applied ranged from 0.75 to 1.41 for M1 equation while it varied from 0.58 to 1.23 for M2 equation with overall equations proposed as under,

1. $TS = \frac{CLR}{4} + 1.22 F + 0.97$

2. $TS = \frac{CLR}{4} + 1.25F + 0.79$

.....Summary and Conclusion

From this study, the modified Richmond formulas for calculating TS/SNF in different milks have been proposed for a specific Dairy Plant. The Dairy Plant specific equation worked out reflects the region specific chemical composition of milk, array of factors affecting milk composition, numbers of samples taken for working out formulae and other unforeseen observations, which could be seen from correction factor ranging from 0.40 to 1.45 in M₁ and 0.57 to 1.66 in M₂ equation respectively to match with total solids by official method for different milks.

These Dairy Plants can adopt the overall equations specified for each type of milk, if they enter into business for purchase and sale of milk among Dairy Plants.

It is concluded that the equation $TS = CLR/4 + 1.25 F + \text{correction factor}$ was more convenient, and provided the TS/SNF values very close to the results of TS obtained by gravimetric method.

It is inferred that these variations in equations proposed for each Dairy Plant might be from non assignable causes and therefore, every Dairy Plant has to evolve its own equation for measurement of TS/SNF by lactometer method.

In nut shell it is concluded that the suitably modified Richmond formulas evolved for the volumetric measurement of TS/SNF in individual type of milk collected by individual Dairy plant gives a reliable results in agreement to the similar findings of gravimetric measurement.

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