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Effect of Casein/Fat Ratio on Milk Fat Recovery in Cheddar Cheese

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EFFECT OF CASEIN/FAT RATIO ON MILK FAT
RECOVERY IN CHEDDAR CHEESE

by

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Recovery in Cheddar Cheese

by

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Cheddar cheese was made by the traditional 4.5-h method from three experimental lots of milk, each standardized to casein/fat ratios of approximately 0.64, 0.67 and 0.70. The effect of casein/fat ratio on milk fat recovery was determined. The effects of milk composition on curd firmness at cutting, cheese composition and resulting yield of cheese were evaluated. Correlations between milk constituents and various cheese components were obtained. Milk fat recovery was unaffected by casein/fat ratios within the limits of 0.64 and 0.71. Average milk fat recovery was 91.58 ± 1.73%. Cheese yield was a function of milk protein, milk fat and cheese moisture; and a modified Van Slyke equation predicted cheese yield better than the original equation within the limits of casein/fat ratio studied. Strong negative correlations were observed between casein/fat ratio and cheese fat and cheese fat in the dry matter whereas positive correlations were observed between casein/fat ratio and cheese protein. At constant protein levels curd firmness increased directly with the amount of fat in cheese milk.

(65 pages)

INTRODUCTION

The value of milk to a cheese plant is determined by the efficiency of recovery of milk constituents in cheese making. Knowledge of milk constituent recovery is important in determining milk quality, cheese yield and price of cheese milk. Intense competition among cheese manufacturing companies has necessitated the need to know both theoretical yields and actual yields in order to satisfactorily evaluate plant performance.

A number of formulas have been suggested for estimating cheese yield (4,13,30,61). However, they differ in assumptions made regarding losses of fat and casein in whey and final moisture content of cheese. The Van Slyke formula (61,62) is most commonly used in the U.S. to predict cheese yields. Variations in milk composition has led to questions about the accuracy of the formula, as used in different parts of the country.

U.S. standards for Cheddar cheese require at least 50% fat in the dry matter (FDM) and not more than 39% moisture. There is no legal limit to the maximum percent FDM that cheese can have. However, there is a practical limit above which the moisture content must be reduced and other cheese properties changed. Casein to fat (C/F) ratio in cheese milk controls the FDM in cheese which in turn affects quality and yield of cheese (11,33,37).

Good cheese can be made from high fat milks but the concentration of casein must be increased to balance the amount of fat present. Hillers, et al. (20) reported an economic advantage in using milk high in protein for cheese making. They also reported that the value of additional fat in milk used to manufacture hard cheese is greater than its value in butter.

The Van Slyke formula (61) assumes that under ideal conditions 93% of the fat in cheese milk will be recovered in the cheese. However, it has been suggested that the percentage of fat recovered might decrease as the casein/fat ratio decreases below .7 (5,25,26). The profitability of increasing the fat content of cheese makes it important to know how fat recovery is affected by casein/fat ratios at different casein levels in milk.

The objectives of this study were to investigate the effect of casein/fat ratios between .64 and .70 on fat recovery in Cheddar cheese, and show whether the Van Slyke formula for predicting cheese yields will hold within these casein/fat ratios. Effects of milk composition on curd firmness at cutting, cheese composition and yield were also determined.

REVIEW OF LITERATURE

Origin of Cheddar Cheese

Cheddar cheese (otherwise known as American Cheddar cheese) is made by the "Cheddar" process from heated and pressed curd obtained by action of rennet or similar milk clotting enzyme on whole milk. In the U.S., it contains not more than 39% moisture and not less than 50% fat in the dry matter (FDM).

Cheddar cheese originated in Great Britain, along the base of Mendip Hills, from Axbridge to Shepton Mallet (13). It was introduced into the U.S. during the 19th century when the first commercial cheese plant was built in Rome, New York in 1851. Since then there has been a vast amount of research carried out to improve its methods of manufacture, yield and quality.

U.S. Cheese Production and Consumption

Cheese production and consumption in the U.S. has increased over the past few decades. In 1964, 13% of U.S. total milk supply was used by cheese manufacturers and in 1983, 30% was used (57). Cheddar cheese represents over 43% of total cheese produced in the U.S. (Table 1). In 1982, Cheddar cheese production increased by 9% to 2.12 billion pounds (960 thousand metric tons) while other American cheese varieties declined 11%. Figures for 1983 also show a 9% increase to 2.35 billion pounds (1.07 million metric tons). These figures indicate the ever growing output of Cheddar cheese and hence, its importance in the dairy industry.

Between 1965 and 1983, per capita consumption of cheese rose from 9.6 lb to 20.6 lb while per capita consumption of other dairy products continue to decline (Table 2). These figures show the increasing awareness of the value of cheese as food.

Table 1. Total and Cheddar cheese production, United States, 1979-1983 (56,57,58,59).

Year	Production (1000 lb) Total	Cheddar	Cheddar as % of total
1979	3717241	1597326	43.0
1980	3983129	1749560	44.0
1981	4277561	1933126	45.2
1982	4539822	2116078	46.6
1983	4818449	2351398	48.8

Table 2. Dairy Products: Per capita civilian consumption, United States, 1965, 1975-1983 (56,57,58,59).

Year	Per capita consumption (lb)		
	Butter	Cheese	Condensed & Evaporated Milk
1965	6.4	9.6	10.6
1975	4.7	14.4	5.2
1976	4.3	15.6	4.9
1977	4.3	16.1	4.3
1978	4.4	16.9	4.1
1979	4.5	17.2	4.1
1980	4.5	17.6	3.8
1981	4.3	18.4	4.1
1982	4.5	20.0	4.0
1983	n/a	20.6	n/a

n/a = not available

The Scientific Basis of Cheese Making

During the conversion of milk into cheese curd, there is a separation of milk constituents into two groups: (1) those that are retained in the curd and (2) those that are lost in whey.

The division of milk constituents in 100 kg of milk during Cheddar cheese manufacture is shown in Table 3.

Table 3. Cheddar cheese manufacture. Division of milk constituents (61,62).

Constituent	Milk	Cheese	Whey
	--------	kg	--------
Water	87.0	3.90	83.10
Lactose	5.1	0.70	4.30
Fat	4.0	3.70	0.30
Casein	2.5	2.40	0.10
Whey protein	0.7	0.05	0.65
Salts	0.7	0.35	0.35
Total	100.0	10.60	89.40

Cheese curd retains a large portion of the fat and casein from the original milk. Conversely, whey expelled from curd contains mostly lactose and those proteins and minerals which are soluble at the pH of cheese making.

Casein is the predominant protein in milk which makes possible the manufacture of cheese. It exists as a suspension of spheres (micelles) and aggregates to form a network which entraps fat globules. It also functions to retain desired amounts of whey in curd while permitting superfluous whey to escape from the curd mass. In addition, casein gives to finished cheese, firmness and solidity of body under a wide range of temperatures. Its conversion into soluble nutritive compounds during curing adds greatly to the value of cheese as a superior food (61,62).

Milk fat plays a passive rather than an active role in cheese making since the details of cheese manufacture aim at retaining as much milk fat as possible in cheese and losing the smallest possible amount in whey. Milk fat plays a role in increasing yield, enhancing flavor, providing quality and giving the characteristic mellowness to the body of cheese (61,62).

The presence of water in cheese influences cheese body. Water imparts to cheese smoothness and a certain degree of mellowness. It also furnishes suitable conditions for changing insoluble cheese proteins to soluble forms. Water activity is also important in controlling the action of microorganisms during curing (61,62).

Lactose acts as a substrate for starter cultures to produce lactic acid. The development of acid is important in regulating the manufacturing process and resulting pH of the final cheese. Lactic acid does not remain in milk as free or uncombined acid, but as fast as it is formed, it reacts with some of the milk salts and proteins which serve as buffer constituents (61,62).

Factors Affecting Cheese Yield

Factors that affect cheese yielding capacity of milk can be grouped into:

(1) Chemical composition of milk

(2) Losses of milk constituents in whey

(3) Cheese moisture

(4) Milk handling and treatment

(5) Cheese manufacturing procedures

Chemical Composition of Milk

The relation of chemical composition of milk to yield of cheese is a subject of highest practical interest and importance to cheese makers.

A number of factors are known to affect milk composition. These include:

Seasonal effects

Feeding

Age of cow

Breed of cow

Stage of lactation

Disease

Seasonal effects

Seasonal effects on variation in milk composition have been extensively investigated (13,35,52). In a study of seasonal variations in fat, protein and cheese yield in Canada, Irvine (22) reported a minimum concentration of milk fat in August and a maximum in October. He observed that protein variation paralleled that of fat except for an unexpected increase in June.

He also reported a variation in cheese yields with seasonal deviations in milk fat and protein. This relationship he claimed, was not consistent at certain times of the year. Similar results were reported by Steinsholt and Ystgaard (53). There are fluctuations in casein due to season (22,53). Szijarto, et al. (54) observed an increase in milk casein during May, June and July, and a decrease in August, September and October. Though the effect of month of the year may depend on geographical location, milk produced in Spring and Summer are lower in fat content than that produced in Autumn and Winter.

In general, there is a decrease in cheese yielding capacity of milk between March and August (21,51,53). Low yields during this period are due to lower content fat and solids-not-fat (SNF) in milk. Conversely, increased yields are observed between October and January.

Feeding

When cows are fed rations with 25% less than normal energy requirements, there is a decrease in SNF content of milk, mostly due to decreased protein (29). Rook et al. (47) observed a rise in SNF of milk by 0.3 to 0.4% when cows were transferred from winter feeding to spring grazing. The increase in SNF content with grazing was essentially due to increased protein. Much of this change was due to casein. The rise in SNF content of milk with spring grazing resulted from the high nutritional value of spring grass compared to winter feed.

Prolonged feeding of cows without green fodder of any kind may lead to milk which clots poorly with rennet, hence grass hay, dried grass and silage are of special significance to the cheese milk farmer (13). Schingoethe, et al. (52) found that feeding cows on whey prevented the large decrease in milk fat which occurs due to feeding high-grain rations (ground shell corn and soy bean meal with 1% urea and 5% molasses). They claimed the minerals in the whey are the main components responsible for preventing the decrease in milk fat.

Age of Cow

The age of cows affects milk composition (23,54). There is a decline in percent SNF with age of cow or advancing lactation which is almost twice the magnitude of decline in percentage fat (63,64). These authors also reported a decrease in SNF from 0.45 to 0.21% during the first seven years of lactation.

Johnson (24) also reported a decline in percent fat and percent SNF with age of cow. He indicated that lactose was most affected of the SNF constituents. Turner (55) also observed a decrease in average fat content of milk with age of cow.

Breed of Cow

Variations in milk composition from different breeds of cows are shown in Table 4. These variations indicate that the breed of cow is the biggest factor influencing milk composition in any country (9).

Jersey cows produce milk of high fat content while Milking Shorthorn and Holsteins produce low fat milk (Table 4). Cerbulis and Farrell (9) reported that cheese yields depend directly on the amount of casein in milk. They therefore suggested that since casein is the principal protein component of milk, milk from Jersey cows would be best suited for manufacturing of cheese while milk from Milking Shorthorn will be least suited.

Table 4. Fat, protein, casein and lactose in milk from different breeds of cows (9).

Breed	Fat	Protein	Casein	Lactose
Holstein	3.73	3.22	2.53	4.93
Jersey	5.42	4.22	3.39	4.99
Guernsey	4.76	3.70	2.88	4.66
Ayrshire	4.12	3.47	2.73	4.67
Brown Swiss	4.28	4.05	3.14	5.15
Milking shorthorn	3.58	3.42	2.56	4.80

Source: Cerbulis and Farrell (9).

Legates (29) also reported that breed of cows affect milk composition and that fat content is mostly affected. He indicated that most of the variation in SNF occurs in protein.

Chapman (10) and Davis (13) believe that quite apart from the fat and SNF values, there are some finer points about milk from various breeds and their suitability for cheese making. They claim that milk from Ayrshire cows is most suitable for cheese making due to its small even-sized fat globules.

Stage of Lactation

The first secretion of milk after calving is called colostrum. Colostrum is not legal milk and therefore cannot be used for cheese making.

Percent fat and protein in milk decrease up to the second month of lactation. However, they rise at slightly different rates as lactation progresses and increase most rapidly at the end of lactation (24). Fat content decreases as milk yield increases; most of the decrease takes place up to the 75th day of lactation. This is followed by a slow rise which increases markedly after the 195th day of lactation (63). Protein and casein content decrease to a minimum near the 45th day of lactation and then increase to a maximum on the 285th day (63).

Highest levels of protein and fat are found in second and third lactation milk. After the third lactation, protein levels decline while fat levels stay relatively constant (24).

Late lactation milk biochemically resembles subclinical mastitic milk. It is slightly alkaline, high in albumin and chloride but low in calcium, casein and lactose. These changes start about eight months after calving and vary with degree of lateness of lactation (13).

Disease

All changes brought about in milk by mastitis are undesirable to the cheese plant. The adverse effects of mastitis are due almost entirely to changes in chemical composition of milk.

Waite et al (63) reported a decrease in lactose and SNF by 0.38% and 0.25% respectively as total leucocyte count increased to 500,000 cells per ml. They also reported a negative correlation between casein and cell count. Somatic cells, at levels ranging from 50,000 to 200,000 cells/ml, are normal constituents of raw milk supply (49). Ali, et al. (1) reported that during Cheddar cheese manufacture, increased somatic cell count from 45,000 to 2,000,000 cells/ml resulted in increased renent coagulation time and higher fat losses in whey. As somatic cell count increases, total protein increases, however, casein decreases. The increase in protein is due to leakage of serum albumin and immunoglobins from damaged tissue cells into milk (65). More recent reports by Barbano (6) indicate that milk with high somatic cell count (667,000 cells/ml) resulted in proteolytic damage to milk casein and caused casein losses in the whey. He also reported a decrease in cheese yield of 0.27 lb/cwt when Cheddar cheese was made from milk with somatic cell count of 529,000 cells/ml as compared to cheeses made from milk with cell count of 667,000 cells/ml.

Rhodes (45) attributed losses in cheese yield from mastitic milk to its low casein content and alkaline pH. He reported losses of 0.31 kg of cheese per 100 kg milk when the leucocyte count was above 640,000 cells per ml.

Losses of Milk Constituents in Whey

During cheese making, some milk constituents are unavoidably lost in the whey. Although whey is almost always utilized in a variety of ways, its value is much less than that of cheese. Hence, good cheese making involves retention of as much fat and casein as possible in the curd.

Casein Losses

These occur mostly as casein "fines" when whey is drawn from the curd. It occurs as a result of partial proteolysis of milk by milk clotting enzymes (62) or cutting curd roughly and stirring when removing whey from curd (35). According to Davis (13), the question of casein losses is complicated by the fact that more than one protein is present in milk and that the casein value depends on the analytical methods employed. Van Slyke (60) reported casein losses varying from 0.4 to 0.16 kg per 100 kg of whey. Olson (35) reported average losses of casein resulting from partial proteolysis by milk-clotting enzymes is equivalent to about 4% of the total casein. Prolonged storage of milk may cause casein losses due to activities of psychotrophic bacteria and milk proteases while heat precipitation can facilitate incorporation of whey proteins in cheese curd (35). Lelievre (30) has reported casein retention of 0.97 ± 0.01 during Cheddar cheese manufacture.

Fat Losses

Davis (13) attributed fat losses to methods of cheese making. He claimed that milk fat influences absolute fat losses and that high milk fat levels lead to smaller proportional fat losses in whey. Chapman (11) refuted this idea and reported fat losses as being independent of milk fat content. She attributed fat losses to poor agitation, weak rennet gels, salting curds at temperatures above 32°C (90°F), rough handling of curd, pressing warm curds and rapid application of pressure to the curd.

Van Slyke and Price (61) reported average fat losses to be about 7% however, manufacture of Cheddar cheese by modern techniques results in losses of about 10% of original milk fat (35). Olson (35) believes that fat losses can occur at any stage during cheese manufacturing, for instance, pumping milk with inadequately sized pumps or improper separation of cream cause disruption of fat globules. He also believes that indiscriminate splashing of milk in cheese vats also results in disruption of fat globules, hence greater fat losses.

Cheese Moisture

Retention of moisture in cheese curd depends on conditions of manufacture such as fineness or coarseness of cutting rennet gels, cooking temperature and rate of temperature change, rate of acid development and amount of salt used (11). In addition, Van Slyke and Price (61) observed that small sized cheese blocks and faster rate of turning during cheddaring lead to removal of extra moisture from curd.

In their study involving methods of moisture expulsion in relation to fat losses in Cheddar cheese, Feagan et al. (18) reported that where cheese making requires additional removal of moisture, the following practices result in minimum fat losses:

(a) Using 1/4 inch knives to cut curd.

(b) Cooking curd in whey at 103°F (39°C).

(c) Increasing salting rate up to 3.75% of expected yield.

By Federal standards, Cheddar cheese should not contain more than 39% moisture. Hence, the amount of moisture retained in curd significantly affects cheese yields. It is therefore appropriate that any comparison of yields be based on cheeses containing a uniform moisture content if the results are to have any relation to milk constituents.

Milk Handling and Treatment

Inaccurate determination of milk weight and volume losses during handling reduce both theoretical and actual yield of cheese in a plant. Gross mishandling to cause churning of fat with subsequent losses of fat into whey lowers yields. Losses of casein occur if microbial action causes its degradation and destroys its ability to clot. Hence, long periods of storage (3-7 days) at temperatures of up to 5-10°C (41-50°F) results in growth of psychrotrophic bacteria, which cause losses of protein (presumably casein) into whey (35).

To the cheese maker pasteurization of milk is to destroy undesirable micro-organisms, to give a more uniform product of higher quality and to increase yield. Excessively high temperatures and long pasteurization time impairs flavor and body quality of the resulting cheese. Drastic heat treatment leads to poor renneting, weak and soft curd and inferior cheese texture (13).

There is an increase of 3.33% in yield of cheese made from pasteurized Buffalo milk as compared to that made from raw Buffalo milk (15). This increase is attributed to the production of a soft curd which is capable of holding more moisture than curd made from unheated milk.

Casein to Fat Ratio

The cheese yielding capacity of milk varies with the fat and casein content. Variations of fat and casein content of milk and factors affecting them have already been stated.

As a rule, when milk fat increases, milk casein also increases and cheese yield increases in proportion. However, milk fat increases more rapidly than casein (61,62). In bulk milk there is a relationship between fat and casein, but when fat increases faster than casein the balance between them is expressed as a decrease in casein/fat ratio. Imbalance between fat and casein in cheese milk leads to problems associated with quality, yield and economics of cheese production. Joost, et al. (27) have reported a correlation between milk composition and yield of Cheddar cheese.

Casein/fat ratio affects cheese yields, quality and body. Hence, precise control of this characteristic is achieved by standardizing milk to a desired casein to fat ratio (11,32,37). Standardization is achieved by removing from whole milk, a known portion of fat, or by adding to it, a known portion of skim milk or skim milk powder or cream. Methods of standardization based on simple analytical procedures have been described by a number of researchers (21,38,39) and various formulas and tables have been published.

Price and Germain (40) reported that adjusting high fat milk to a casein/fat ratio of 0.7 leads to decreased cheese yield, increased cheese moisture, decreased cheese fat and overall decrease in cheese quality.

An increase of 0.02 to 0.03 in casein/fat ratio causes a decrease of 1% in cheese FDM (36) and an increase of 1% in milk fat results in a decrease of 1.82 to 1.92% in cheese moisture (36) unless cheese making procedures are changed.

Optimum casein/fat ratios of 0.68 to 0.72 have been suggested for Cheddar cheese manufacture (11). For compliance with the minimum standards of 48% FDM in Britain, Chapman (11) suggested standardization of milk to fat/SNF ratio of 0.33-0.35. She also reported that milk with fat/SNF ratio of 0.46-0.48 could be the highest for economic production because within these ratios, she obtained 56-57% FDM in cheese.

Although McDowall (33) has reported variations in FDM values at different casein/fat ratios, Phelan (37) believes that casein/fat ratio is meaningless for FDM control unless it is taken in conjunction with the average fat recovery figures for each plant. Within casein/fat ratios of 0.71-0.80, Phelan (37) reported average monthly fat recovery of 87.9-90.2% in Irish factories. His data did not show a correlation between casein/fat ratio and fat recovery within the range of casein/fat ratio studied.

Lelievre (30) has shown that in commercial cheese making factories, relationships exist between the casein/fat ratio in milk, manufacturing conditions and the FDM, moisture in non-fat substance (MNFS), fat and moisture percentages in cheese. He reported that if manufacturing conditions are suitably modified to compensate for variations in the casein/fat ratio in milk, then the MNFS can be kept constant. When MNFS is fixed, mathematical consideration dictate that as casein/fat ratio increases, FDM decreases, fat percent in the cheese decrease and moisture percentage increases. He also reported that with fixed manufacturing conditions, a decrease in casein/fat ratio causes an increase in FDM and MNFS while an increase in casein/fat ratio causes a decrease in FDM and in the MNFS levels. In a mass balance study of Cheddar cheese making, Lelievri, et al. (31) reported an average fat retention of .91 ± 0.01% and casein retention of .97 ± 0.01%. A critical examination of their data showed that the cheeses were made from milk with casein/fat ratio varying from 0.55 to 0.63, indicating that fat recovery was not affected by casein/fat ratios within those limits.

Estimating Cheese Yield

As the cost of raw materials has escalated, cheese makers have increasingly turned their attention towards the efficiency of cheese making. A number of formulas have been suggested for estimating cheese yield. However, they differ in assumptions regarding losses of fat and casein in whey and final moisture content of cheese.

Typical formulas which have been used in different parts of the world are:

1) Yield = 2.7 x fat (62)

The factor 2.7 is based on amount of cheese made per pound of milk fat. This formula works best when casein/fat ratio equals 0.665, and cheese contains 37% moisture. When casein/fat ratios are higher or lower than 0.665 the use of this formula makes yield predictions inaccurate.

2) Yield = 1.1 fat + 5.9 (62)

Multiplying milk fat by 1.1 is based on the assumption that a pound of milk fat in butter readily holds 0.18 pounds water. Since some fat is lost during cheese manufacture, a value of 1.1 instead of 1.18 is assumed. Hence, in case of excessive fat losses, multiplying milk fat by 1.1 makes estimated yields too high.

The estimate of 5.9 pounds as a measure of cheese making value of casein in skim milk is based on skim milk of average composition. Therefore the factor is too high for milk low in casein, and too low for milk high in casein. However, the method is fairly good for milk containing 3.50 to 3.75% milk fat.

3) Yield = 1.1 fat + 2.5 casein (62)

This formula is based on the assumption that casein is capable of holding mechanically, one-tenth of its own weight of water. Multiplying milk casein by 2.5 resulted from a study which showed that one pound of casein holds enough water to increase its weight to 2.25 pounds. The difference of 0.25 is due to amount of ash in cheese.

Variation in fat losses makes this formula inaccurate. Secondly, when cheese milk contains high casein/fat ratios, cheese moisture is greater in yield calculated by this method.

4) Yield = (SNF/3 + 0.91 fat) x 1.58 (62)

This formula assumes 91% fat recovery. In using the factor of 1.58, cheese solids are calculated to an equivalent amount of cheese containing 37% moisture. The method involves determination of specific gravity of milk. Variations in SNF in different milks results in irregularities in the use of this formula. The method produces least satisfactory results at levels of milk fat between 3.50 and 3.75.

5) Yield = 2.3 fat + 1.4 (62)

This method is satisfactory for milk containing 3 to 3.50% fat and cheese containing 37% moisture. However, in case of milk containing 3.50 to 3.75% milk fat, yield predictions with this formular are unsatisfactory.

6) Shelton (1937); Shelton and Meany (1938) (13)

Yield = (F - 4F/100) + (C - 4C/100 + 22C/100) x 2.26

This formula assumes 4% fat losses in whey, 4% casein losses and that non-casein solids-not-fat retained in cheese is equivalent to 22% of the casein. It also assumes that cheese moisture is equivalent to 126% of solids-not-fat retained in cheese.

7) Bergman and Joost (1953) (13)

Yield = 0.91 F + 0.77 P + 0.48 + W(0.77P + 0.48)/100 - W

where F = % milk fat

P = % milk protein

W = % cheese moisture

8) Schulz and Kay (1957) (13)

$$\text{Yield} = \text{net fat} + (0.75 + 0.825W_{ff})P$$

where net fat = % milk fat - % whey fat

W_{ff} = moisture content of the fat free cheese

P = % protein in milk, assuming that 75% of this goes into the casein

Equations 7 and 8 seem to be very complex and thus restricted in practical value.

9) Yield = 1.32 (fat% + casein %) + 1.58 (4)

This equation assumes a standard moisture of 35%. Banks et al. (4) believe that the equation is applicable to seasonal and standardized cheese milk. They also claim that the only significant drawback is that the equation requires the estimation of the casein content of milk. For this reason, the equation was modified to

Yield = 1.32 (% fat + 1) + % crude protein

10) $$\text{Weight of cheese} = \frac{[F \times FR + C \times CR]\ 1.08 \text{ to } 1.10}{100 - W} \quad (37)$$

where C = % casein in milk

CR = casein recovery

F = % fat in milk

FR = fat recovery

W = % moisture in cheese

11) $$\text{Weight of cheese} = \frac{W\ (F \times R_f + aC \times Rc + b)}{100 - M} \quad (31)$$

where a and b are constants

C = % casein in milk

Rc = casein recovery

F = % fat in milk

Rf = fat recovery

W = weight of milk

M = moisture content of cheese

All of the above formulas have been used to predict the yield of Cheddar and other cheese varieties. However, the Van Slyke formula (61) is the most accurate of all the formulas and has therefore received the best acceptance. The Van Slyke formula predicts cheese yield as

12) $\text{Yield} = [(0.93F + C - 0.1) \times 1.09]/(1 - W)$

where F = % fat in milk

C = % casein in milk

W = kilogram of moisture per kilogram of cheese

This formula assumes 93% fat recovery and that 0.10 kg casein per 100 kg milk is lost during Cheddar cheese manufacture. It also assumes that other constituents of cheese solids, consisting mostly of salts, form about 9% of cheese fat and cheese casein. Therefore, multiplying amount of cheese fat and casein by 1.09 gives total cheese solids.

There are variations in milk composition across the U.S. As a result of these variations, the relationship between fat and casein content of cheese milk can be upset, causing the predicted theoretical yield to vary from actual yields obtained in a cheese plant (5). Suggestions have been made for component pricing of cheese milk based on fat, protein and solids-not-fat (28).

Due to cumbersome and time consuming casein determinations, as well as higher fat recoveries assumed by the Van Slyke formula, a modification of Van Slyke's formula has been suggested (8,16). A modified Van Slyke formula which is used in current cheese yield (16). Predictions in some plants as a basis of milk pricing is:

$$\text{Yield} = [(.9F + 0.78\,P - 0.10) \times 1.09]/(1 - W) \qquad (8,16)$$

where F = % fat in milk

P = % protein in milk

W = kilogram of moisture per kilogram of cheese

The modified formula suggests that casein forms 78% of total protein in milk. This suggestion is based on studies by Cerbulis and Farrell (9) which show that casein forms about 78% of total protein in milk, and work by Blake et al. (7) which show that casein as a percentage of total protein, varies from cow to cow but variations in mixed herd milk is not large. It also suggests that fat recovery for each cheese plant be used instead of the ideal fat recovery of 93% assumed by the original formula. However, since cheese manufacture by modern techniques result in about 10% fat losses (35), an arbitrary value of 90% fat recovery is used in the modified yield equation.

Relation of Curd Tension to Cheese Yield

Forming and cutting rennet coagulum is one of the most important stages in cheese making. Mechanization of cheese making procedures has led to interest in measuring curd firmness. Determination of curd firmness at time of cutting has only recently been mechanized and several devices are being used in different cheese plants (35).

Composition and properties of milk affect milk clotting and curd firmness. Variations in curd firmness at cutting may result in greater losses of milk components and reduced cheese yield (34). Fisk (19) observed extreme differences in curd strength at cutting and reported that cutting soft curd resulted in greater losses of fat in whey, reduced yield of cheese per unit of milk, and decreased moisture content in the finished cheese as compared to cutting curd that was hard. Olson (34) also reported that variations in curd firmness at cutting may result in greater losses of milk components and reduced cheese yield. He, however, does not support a correlation between curd firmness at cutting and moisture in Cheddar cheese.

Refrigerated storage significantly affects curd forming properties of milk (12,43). Breed of cow (34), method of standardization (10), acidity (42), and heat treatment (14) have been reported to influence curd firmness. Seasonal variations in milk constituents such as calcium and casein (66), inorganic salts (23) have an effect on milk coagula.

Chapman and Burnett (12) reported that milk gel rigidity at cutting, firmness of Cheddar cheese and percent moisture in nonfat portion of cheese are related.

Chapman (10) reported that rennet gels of acceptable firmness at cutting were made when fat to SNF ratios were varied between 0.35 and 0.48. She observed that milks with ratios below 0.35 and above 0.48 formed weak gels and generally made poorer curds and poorer quality cheese. A critical look at Chapman's data (10) showed an increase in curd firmness when percent SNF was held constant at 8.6% and fat content in milk was increased from 2.5 to 3.5% after which there was a sharp decrease in firmness, then a sudden rise till concentration of milk fat was 4.0%.

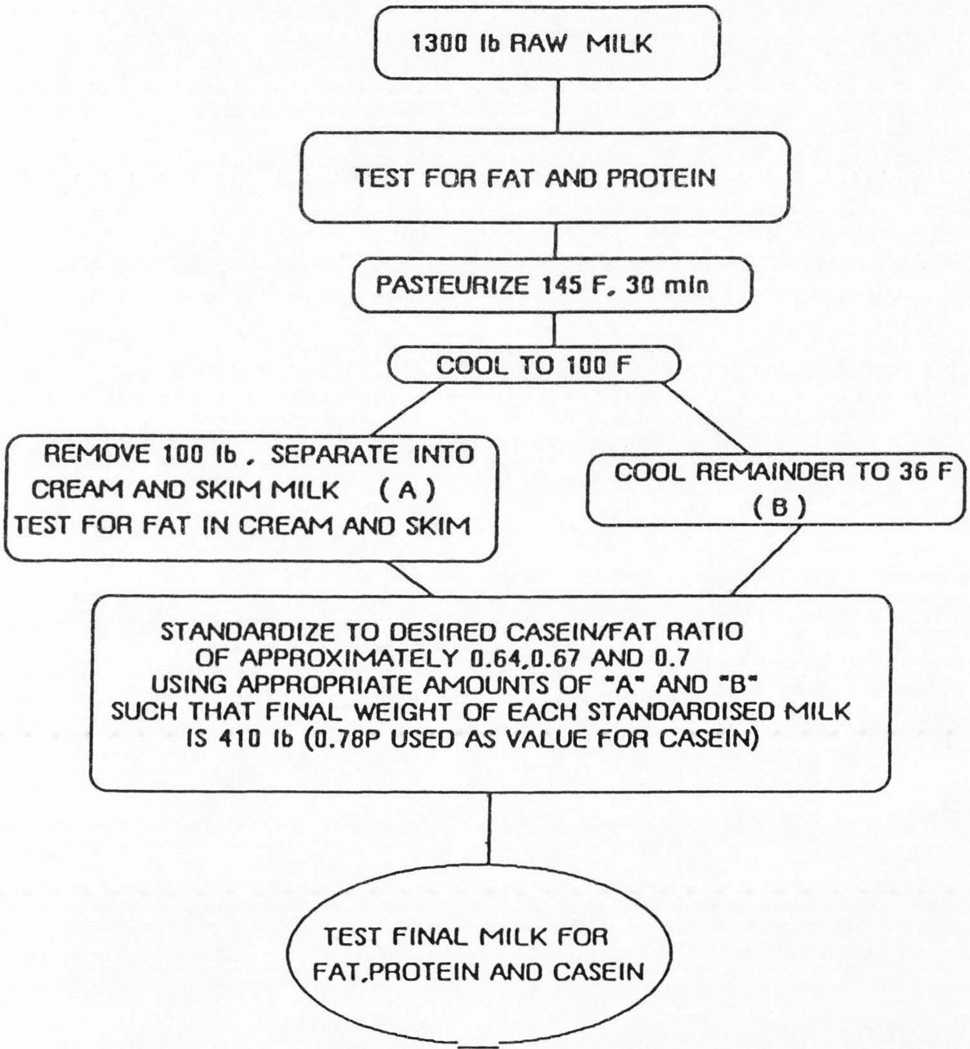
MATERIALS AND METHODS

Cheese Making

Traditional Cheddar cheese was made from three experimental lots (A, B, and C) of milk at Utah State University (U.S.U.) Dairy Products Laboratory between January and April, 1984. Lot A was Holstein milk, lot C was Jersey milk and lot B was a 50:50 blend of A and C. Each lot was pasteurized (145°F, 30 min), cooled, and part of it separated with a 514 Delaval Separator. Separation was at 100°F to avoid churning of the fat. The pasteurized milk was divided into three batches and standardized to the desired casein/fat ratio by addition of separated cream or skim milk (39) then stored at 36°F till used the following day (Figure 1).

One hundred and eighty-eight kilograms (410 pounds) of each standardized milk was accurately weighed into 650 lb. cheese vats and cheese was made by the normal 4.5 h method (Appendix I) using 0.7 - 0.8% freshly prepared whey-based, pH control lactic starter culture containing a mixture of two strains (UC310 and UC77) of *Streptococcus cremoris* (Appendix II). Cultures were obtained from the Department of Nutrition and Food Sciences culture bank. Acid development was monitored in all lots to ensure a uniform pH of 5.4 at milling. Milled curds were hooped into 20 lb cheese hoops and pressed in a horizontal hydraulic press overnight at 50 psig (344.7 kPa).

Figure 1. Flow chart for standardization of cheese milk.


1300 lb RAW MILK
TEST FOR FAT AND PROTEIN
PASTEURIZE 145 F, 30 min
COOL TO 100 F
REMOVE 100 lb, SEPARATE INTO CREAM AND SKIM MILK (A) TEST FOR FAT IN CREAM AND SKIM
COOL REMAINDER TO 36 F (B)
STANDARDIZE TO DESIRED CASEIN/FAT RATIO OF APPROXIMATELY 0.64,0.67 AND 0.7 USING APPROPRIATE AMOUNTS OF "A" AND "B" SUCH THAT FINAL WEIGHT OF EACH STANDARDISED MILK IS 410 lb (0.78P USED AS VALUE FOR CASEIN)
TEST FINAL MILK FOR FAT,PROTEIN AND CASEIN

Curd Firmness

Curd firmness at cutting was measured with a Vat Timer (46). This device consists of a horizontal circular plate attached to a vertical rod. The plate was immersed in milk and oscillated vertically during milk clotting. The force required to move the plate was recorded as a direct measure of curd firmness. The instrument was removed just before the curd was cut.

Sampling

Milk samples were taken from the cheese vat just before starter culture was added. All the whey collected at dipping was weighed, mixed thoroughly and sampled. Whey drippings during pressing of the curd were collected, weighed and sampled. Cheese samples were taken from corners and centers of cheese blocks immediately after removal from the press. Whey and milk samples were frozen and cheese samples were stored at 36°F till analyzed.

Compositional Analysis

Raw milk from each lot was tested for fat and protein with a Multispec IR Analyzer (Multispec Ltd., England). Results of this analysis were used in standardizing the milk using a value of 0.78 x protein for casein (9). Milk samples from the cheese vat also were analyzed by IR. However, actual compositional analysis was by the Babcock procedure (2) for milk fat and cheese fat was by a modification of the Babcock procedure where 10 ml boiling water was used instead of 9 ml of hot water. Whey fat was determined by the Mojonnier modification of the Roese-Gottlieb method (17). Milk protein was determined by analyzing milk samples for total nitrogen by the Kjeldahl procedure (3). Non casein nitrogen determinations were by procedures of Rowland (48) and Cerbulis and Farrell (9) with some modification. Filtration was done with Watman 42 filter paper followed by Gelman 0.45 millipore filter paper to ensure that filtrate was totally devoid of casein. Casein nitrogen was calculated as the difference between total nitrogen and non casein nitrogen. Cheese samples were analyzed for total protein by the AOAC method (16.200) (3) except that sample size was reduced to 0.5g, 2g Na_2SO_4 was used during digestion with 2 ml of 10% $HgSO_4$ as catalyst. The titrating acid was 0.0554 N HCl. A nitrogen conversion factor of 6.38 was used in converting nitrogen to protein and its fractions. All nitrogen fractions were measured on the Kjeltec Auto System Analyzer.

Cheese moisture was determined by the method of Price et al. (41) with slight modification in which 50 ml beakers were used instead of moisture dishes to prevent splashing of cheese solids during drying. Moisture was taken as weight loss after drying 2-3g of cheese in a forced air oven at 110C for 16h.

Total solids in milk was determined by drying 2-3g of milk in a forced air oven at 105C for 3h after pre-drying samples on a steam bath to dryness (61). Care was taken to prevent case hardening and splashing of samples during pre-drying.

Statistical Analysis

Correlations between milk constituents and various cheese constituents were determined. A linear regression model to predict cheese yield using the following variables (milk casein, milk fat and cheese moisture) was developed. A regression analysis of variance to show the effects of casein, fat and moisture on cheese yield were also done. All statistical analysis were done using Statistical Analysis System (SAS) programs (50).

RESULTS AND DISCUSSION

Composition of Cheese Milk

Protein, casein and fat levels of cheese milk are shown in Table 5. The choice of milk from two breeds of cows and the blend of their milks to form a third experimental lot ensured significant variations in protein levels. For each lot, protein and casein were almost constant while fat levels varied. Three protein levels were used, and casein/fat ratios were between 0.64 and 0.71. Concentration of milk casein formed 77.70 ± 0.44% of milk protein. This falls within the range of 71.4 to 87.1% reported by Cerbulis and Farrell (9) for casein fractions in milk.

Table 5. Average protein, casein and fat concentrations in cheese milk.

Lot	Protein	Casein	Fat			C/F Ratios		
			1	2	3	1	2	3
	(%)	(%)	(%)	(%)	(%)			
A	3.33	2.56	3.62	3.85	4.00	0.702	0.668	0.640
B	3.48	2.71	3.89	4.02	4.20	0.699	0.669	0.645
C	3.87	3.02	4.22	4.48	4.68	0.711	0.679	0.647

Composition of Cheese

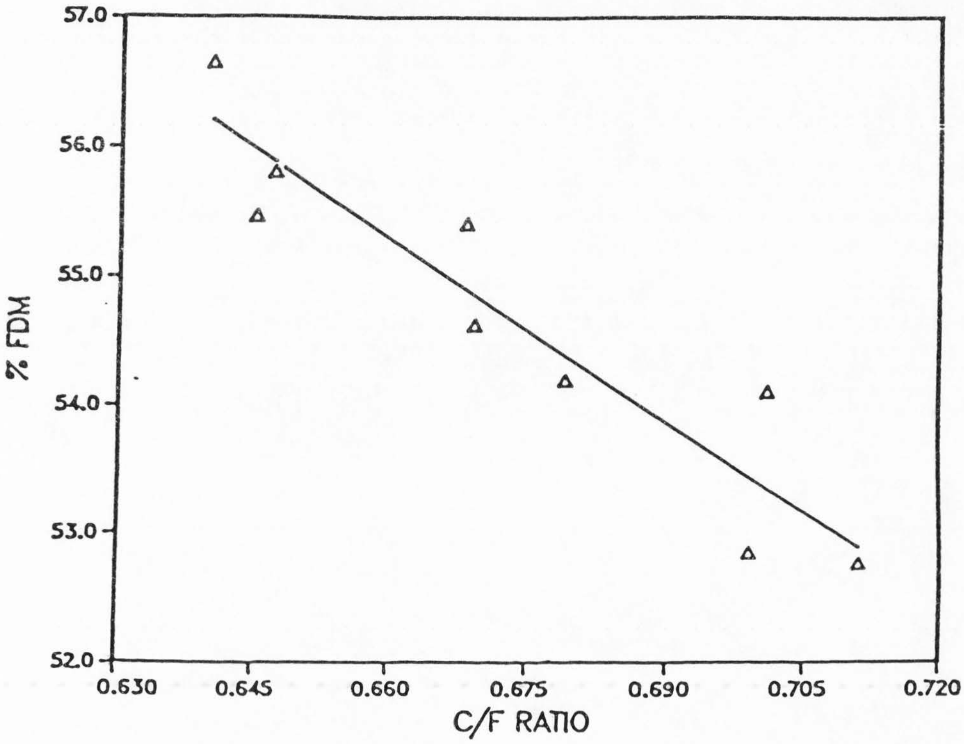
Compositions of Cheddar cheeses immediately after pressing are compared in Table 6.

Table 6: Concentration of constituents in Cheddar cheese immediately after pressing

C/F Ratio	Cheese Constituent				
	Fat (%)	Protein (%)	Moisture (%)	FDM (%)	MNFS (%)
	35.8	23.50	36.8	56.65	57.32
0.644±0.003	36.0	23.73	35.5	55.81	55.47
	34.5	23.70	37.8	55.47	57.71
	34.3	23.30	38.1	55.41	57.99
0.671±0.006	34.8	25.04	35.8	54.21	54.91
	33.5	24.07	38.7	54.65	58.20
	33.5	24.32	38.1	54.12	57.29
0.704±0.006	33.5	24.96	36.5	52.76	54.89
	32.5	24.91	38.5	52.85	57.04

An increase in casein/fat ratio resulted in a decrease in cheese fat ($r = -0.8$, $p < .02$), and a decrease in cheese FDM. The relationship between FDM and casein/fat ratio is shown in Figure 2. The increase in FDM at low casein/fat ratios is due to a higher percentage of fat associated with cheese made from milk with lower casein/fat ratio. Results in Table 6 agree with previous reports (32)

Figure 2. Relationship between casein/fat ratio and cheese FDM.


57.0
56.0
55.0
54.0
53.0
52.0
% FDM
0.630
0.645
0.660
0.675
0.690
0.705
0.720
C/F RATIO

which indicate that any change in fat content of cheese is accompanied by a change in the moisture content that is inversely proportional to the FDM unless compensated for by changes in cheese making. For Cheddar cheese, typical FDM values are 52-55% and an increase of 1% in cheese fat can result in a decrease of 1.82 - 1.92% in cheese moisture (36). An increase in casein/fat ratio resulted in an increase in cheese protein which was due to a higher relative concentration of casein as compared to fat at high casein/fat ratios.

No significant differences were observed in cheese MNFS at the three casein/fat ratios. Typical MNFS values of 52-55% for Cheddar cheese were reported by Pearce (36). MNFS values obtained in this study were higher than those reported by Pearce (36) but were close to the value of 56% reported by Olson (34). A strong correlation between moisture and MNFS has been reported (36). Results from this study also show a positive correlation between MNFS and cheese moisture ($r = 0.85$ $p < .005$). Variations in MNFS may be related to casein/fat ratios because of variations in cheese moisture since moisture levels were not controlled in the experiment. However, a strong correlation was observed between milk protein and MNFS ($r = -0.9$, $p < 0.001$). Lelievre (30) has reported that if manufacturing conditions are suitably modified to compensate for variations in casein/fat ratio in milk, then MNFS can be kept constant. He also reported that if manufacturing conditions are not altered when casein/fat ratio of a given milk is changed, then MNFS will not remain constant. Data from this study show that at a given protein level, changing the casein/fat ratio in milk resulted in a change in MNFS. This change is difficult to explain.

Whey Composition

Cheese whey collected at dipping was 88.26 ± 0.81% of milk weight whereas whey drippings from the press formed about 1% of milk weight. Table 7 shows fat balance data during cheese making. Fat concentration in whey collected at dipping averaged 0.32 ± 0.06%. There were large variations in the fat content of whey drippings collected during pressing. Average concentration of fat in these drippings was 7.50 ± 3.70%. It was observed at each protein level, that increasing casein/fat ratio resulted in a lower fat content of whey at the point of dipping. However, when fat content of whey drippings from the press were taken into consideration no significant relation between fat loss and casein/fat ratio was observed.

Recovery of Milk Fat and Yield of Cheddar Cheese

Milk fat recovery is of major importance in determining cheese yields. Comparison of milk fat recoveries at different casein/fat ratios are shown in Table 8.

Average fat recovery was 91.58%. At dipping, recovery of milk fat was about 94.04%. Additional fat losses which occurred during pressing accounted for the lower fat recoveries than assumed by the original Van Slyke equation. Milk fat recovery fell within ranges of 86.49 to 94.32% reported by Van Slyke and Price (61), but were higher than the range of 83.3 to 87.2% found by Barbano and Sherbon (5). No

Table 7. Mass balance data for fat during Cheddar cheese manufacture.

Milk			Whey				Cheese		Fat balance
			Dipping		Pressing				
Weight (lb)	Casein (%)	Fat (%)	Weight (lb)	Fat (%)	Weight (lb)	Fat (%)	Weight (lb)	Fat (%)	
410	2.54	3.62	366.45	0.26	3.90	2.50	41.15	33.5	99.9
410	2.51	3.85	364.10	0.27	4.55	3.42	42.80	34.3	100.2
410	2.56	4.00	363.95	0.34	4.05	3.58	42.20	35.8	100.5
410	2.72	3.89	363.60	0.36	3.40	6.36	43.35	32.5	97.9
410	2.69	4.02	362.30	0.39	3.50	14.56	44.10	33.5	101.3
410	2.71	4.20	360.20	0.41	4.95	10.46	44.70	34.5	101.1
410	3.00	4.22	358.05	0.24	3.85	8.20	48.00	33.5	99.7
410	3.04	4.48	357.70	0.29	3.80	9.25	48.80	34.8	100.0
410	3.03	4.68	356.50	0.35	4.00	9.16	49.60	36.0	101.5

Table 8. Fat recovery in Cheddar cheese at various casein/fat ratios.

C/F ratio	0.640	0.645	0.647	0.668	0.669	0.679	0.699	0.702	0.711
Milk Fat (%)	4.00	4.20	4.68	3.85	4.02	4.48	3.89	3.62	4.22
Fat recovery (%)	92.12	89.56	93.06	93.00	89.63	92.46	88.44	92.99	92.94
Mean ± S.D.		91.58±1.81			91.69±1.81			91.46±2.61	

significant effect of casein/fat ratio on milk fat recovery was observed within the range of casein/fat of 0.64 to 0.71 at three different casein levels. Fat losses in whey were therefore independent of the casein/fat ratio within the limits studied. Lelievre et al. (31) reported average fat retention of 0.91 ± 0.01% within casein/fat ratio of 0.55 to 0.63 and Phelan (37) reported average yearly fat recoveries between 85.8 ± 0.85 and 90.0 ± 0.58% within casein/fat ratios of 0.71 to 0.78. Data from this study in conjunction with previous reports by Lelievre et al (30) and Phelan (37) show clearly that fat recovery is independent of the amount of fat present (within limits of casein/fat ratio of 0.64 to 0.71) in cheese milk.

Observed differences in average moisture content of cheeses demonstrated that mathematical adjustment of actual yield to an equal moisture of 37% was necessary for varied yield comparisons. At each protein level, increased amount of milk fat resulted in increased cheese yield at adjusted moisture levels (Table 9).

Table 9. Cheese yield adjusted to equal moisture of 37%

Milk Protein (%)	Casein/fat Ratio	Cheese Moisture (%)	Cheese Yield Actual (%)	Cheese Yield Adjusted (%)
	0.640	36.8	10.29	10.35
3.33	0.668	38.1	10.44	10.14
	0.702	38.1	10.05	9.76
	0.645	37.8	10.90	10.67
3.48	0.669	38.7	10.76	10.29
	0.699	38.5	10.59	10.18
	0.647	35.5	12.10	12.61
3.87	0.679	35.8	11.90	12.30
	0.711	36.5	11.71	11.87

A comparison of actual yield with predicted cheese yield using the original Van Slyke equation showed that the actual yields were within 95.4 to 99.2% of the predicted yield (Table 10). However, when the original equation was modified and cheese yields were predicted by the equation

$$\text{Yield} = [(.9F + .78P - 0.1) \times 1.09]/(1 - W)$$

where F = % fat in milk

P = % protein in milk

W = kg moisture/kg cheese,

actual yields were better predicted than yield predictions with the original equation. These predictions were between 96.9 and 101.5%.

The variations observed in actual yield calculated as a percentage of predicted yield could be due to variations in milk fat recovery. Though the accuracy of yield prediction varied between the experimental lots, there were no significant differences within each lot. The higher percent predictions observed for cheeses made from Jersey milk could be due to a generally higher casein content in Jersey milk (9).

At a 95% confidence level, no significant differences were observed between actual yields and predicted yields using a modification of the Van Slyke equation at all protein levels within the limits of casein/fat ratio of 0.64 and 0.71. A correlation of 0.98 was obtained between actual yield and predicted yield using the modified Van Slyke equation. Therefore using a modification of the Van Slyke equation in the end product pricing of cheese milk is laudable.

Table 10. Cheese yield comparison. Predicted yield using original Van Slyke equation and actual yield.

Milk Protein (%)	Casein/fat ratio	Cheese Yield Actual (%)	Cheese Yield Predicted[a] (%)	Actual/Predicted[a] X 100
	0.640	10.29	10.66	96.5
3.33	0.668	10.44	10.65	98.0
	0.702	10.05	10.24	98.1
	0.645	10.90	11.42	95.4
3.48	0.669	10.76	11.25	95.6
	0.699	10.59	11.06	95.7
	0.647	12.10	12.60	96.0
3.87	0.679	11.90	12.30	96.7
	0.711	11.71	11.81	99.2

[a]Yield = $[(.93F + C - 0.1) \times 1.09]/(1 - W)$

Table 11. Cheese yield comparison. Predicted yield using the modified Van Slyke equation and actual yield.

Milk Protein (%)	Casein/fat ratio	Cheese Yield Actual (%)	Cheese Yield Predicted[a] (%)	Actual/Predicted[a] X 100
	0.640	10.29	10.52	97.8
3.33	0.668	10.44	10.50	99.4
	0.702	10.05	10.12	99.3
	0.645	10.90	11.19	97.4
3.48	0.669	10.76	11.10	96.9
	0.699	10.59	10.84	97.7
	0.647	12.10	12.06	100.3
3.87	0.679	11.90	11.80	100.8
	0.711	11.71	11.54	101.5

[a]Yield predicted by equation $[(0.9F + 0.78P - 0.1) \times 1.09]/(1 - W)$

When adjusted yield was gauged by amount of cheese produced per unit milk fat, results indicated that at constant casein levels, amount of cheese produced per unit milk fat increased with increasing casein/fat ratio. Conversely, the amount of cheese produced per unit casein decreased as casein/fat ratio was increased (Table 12).

Table 12. Ratio of adjusted cheese yield to fat and casein.

% casein in milk	C/F Ratio	kg cheese/kg fat	kg cheese/kg casein
	0.640	2.59	4.04
2.56 ± 0.01	0.668	2.63	3.96
	0.702	2.70	3.80
	0.645	2.54	3.94
2.71 ± 0.02	0.669	2.56	3.79
	0.699	2.61	3.75
	0.647	2.69	4.18
3.02 ± 0.02	0.679	2.75	4.07
	0.711	2.81	3.93

Chapman (11) also observed a decrease in ratio of cheese yield to fat as percent fat in milk increased. She however attributed this to less fat losses from high-fat milk. Her results should be interpreted with caution since results from the present study revealed that within casein/fat ratios of 0.64 to 0.71, fat losses were independent of amount of fat in milk. It is also difficult to relate the decrease in ratio of cheese yield to fat at varying fat levels of cheese milk to variations in moisture since moisture levels were not controlled during cheese making. Fat and casein in the cheese milk were correlated (Table 17), hence the observed decrease in ratio of yield to fat and increase in ratio of yield to casein as fat levels increase could be due a possible interaction between fat and casein during cheese manufacture.

Coagula Firmness

Mechanization of cheese making procedures has led to interests in measuring curd firmness. Olson (34) has suggested that monitoring curd firmness offers a potential for reducing losses of cheese yield. It should be mentioned here that no standard device for measuring curd firmness is available. Literature on firmness have been related to how firmness was measured and with what instrument. Olson (34) reported an increase in the rate of firming and firmness at cutting with an increase in casein levels in milk, addition of calcium and a lower milk pH. He believes that fat levels within a reasonable range, had no effect. Results of this study are contrary to his observations. Variations in curd firmness at cutting were observed as fat levels in cheese milk varied. At constant protein levels, increased milkfat (low casein/fat ratio), resulted in a more rigid curd (Table 13).

Table 13. Coagula firmness of cheese milk

% Protein	Casein/Fat Ratio	Curd Firmness
	0.640	1.895
3.33	0.668	1.225
	0.702	0.730
	0.645	1.024
3.48	0.669	1.006
	0.699	0.840
	0.647	1.772
3.87	0.679	1.412
	0.711	1.378

It is difficult to relate curd firmness at cutting to cheese yield because coagula were not cut at the same firmness but 30 min after renneting. Curd firmness at cutting correlated with cheese fat ($r = 0.8$ $p < .01$) and a negative correlation ($r = 0.76$, $P < 0.05$) was observed between coagula firmness and cheese moisture.

Regression Analysis

There was a high correlation of cheese yield with milk casein ($r = 0.98$, $P <= 0.0001$) and milk fat ($r = 0.93$, $P <= 0.0002$). Table 14 is a regression analysis summary showing the effect of milk casein, milk fat and cheese moisture on cheese yield.

Table 14. Regression Analysis Summary for cheese yield study.

Source	SS	df	MS	F	Significant alpha-level
milk casein	4.3136	1	4.3136	442.93	0.0001
milk fat	0.1094	1	0.1094	11.23	0.0203
cheese moisture	0.0004	1	0.0004	0.04	0.8540
Error	0.0500	5	0.0097		
Total	4.4734	8			

R^2 = .9891   C.V. = 0.8996   MSE = 0.987

F-values obtained show that at alpha-level of 0.01, there is a significant different between the individual effects of milk casein and milk fat on cheese yield. There was no significant difference between moisture levels and their effect on the yield of cheese. Table 15 is a mixed effect regression analysis to show differences in the effect of milk casein and milk fat on yield. Results indicated that milk casein and milk fat are independent variables which affect cheese yield however variations in milk casein affect cheese yield to a greater extent than variations in milk fat.

Table 15. Regression analysis table for cheese yield study. (Effect of milk casein and milk fat)

Source	SS	df	MS	F	Significant alpha-level
milk casein	0.5101	1	0.5101	52.38	0.0008
milk fat	0.0881	1	0.0881	9.04	0.0299
cheese moisture	0.0004	1	0.0004	0.04	0.8540
Error	0.0500	5	0.0097		
Adj. Total	0.6486	8			

A General Linear model to estimate cheese yield within confidence intervals of concentration milk casein and milk fat is in the form

$$Y = 0.45 + 2.54C + 0.76F + 0.01W$$

where Y = cheese yield

C = % milk casein

F = % milk fat

W = % cheese moisture

This equation, when adjusted for equal moisture of 37%, reduces to $Y = 2.54C + 0.76F + 0.82$. It must be mentioned that the equations above fit data presented in this study and does not represent equations to predict general cheese yields.

CONCLUSIONS

1. Efficiency of recovery of milk fat and casein, as well as concentration of fat and casein in cheese milk and final moisture content of cheese largely determine cheese yield.

2. Within the limits of casein/fat ratio of 0.64 to 0.71, observed milk fat recoveries were between 88.44 and 93.06%. Milk fat recovery was unaffected by casein/fat ratio within these limits. The variations observed in milk fat recovery could be attributed to the manufacturing process.

3. The original Van Slyke equation (61) does a good job in estimating the magnitude and direction of change in cheese yield with variations in casein/fat ratio. Within the limits of casein/fat ratio of 0.64 to 0.71, the modified Van Slyke equation predicted cheese yield quite accurately and was better than the original equation.

4. Variations in concentration of milk protein and casein had a greater influence on cheese yield as compared to variations in milk fat at constant protein levels. Hence, economics of standardization may be marginal but it is a useful aid in achieving cheese of good quality.

5. As casein/fat ratio increased in cheese milk, total nitrogen concentration in cheese increased while percent fat in the dry matter (FDM) in cheese decreased.

6. At constant protein levels, curd firmness increased directly with the amount of fat present in cheese milk.

RECOMMENDATIONS FOR FURTHER STUDY

1. A direct method for obtaining casein in cheese milk is recommended in order to predict cheese yield more accurately.
2. A study to evaluate the relationship between milk fat and curd firmness is also recommended.

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Table 16. Milk composition, cheese composition and fat recovery for all experimental lots

Milk Constituent				Cheese Constituent						Fat Recovery (%)
Protein (%)	Casein (%)	Fat (%)	Total Solids (%)	Yield (%)	Moisture (%)	Fat (%)	Protein (%)	FDM (%)	MNFS (%)	
3.33	2.56	4.00	11.15	10.29	36.8	35.8	23.50	56.65	57.32	92.12
3.47	2.71	4.20	10.30	10.90	37.8	34.5	23.70	55.47	57.71	89.56
3.88	3.03	4.68	11.29	12.10	35.5	36.0	23.73	55.81	55.47	93.06
3.33	2.57	3.85	10.89	10.44	38.1	34.3	23.30	55.41	57.99	93.00
3.49	2.69	4.02	10.26	10.76	38.7	33.5	24.07	54.65	58.20	89.63
3.87	3.04	4.48	10.60	11.90	35.8	34.8	25.04	54.21	54.91	92.46
3.32	2.54	3.62	9.89	10.05	38.1	33.5	24.32	54.12	57.29	92.99
3.48	2.72	3.89	10.04	10.59	38.5	32.5	24.91	52.85	57.04	88.44
3.87	3.00	4.22	9.90	11.71	36.5	33.5	24.96	52.76	54.89	92.94

Table 17. Correlation coefficients; milk components, cheese components, fat recovery, curd firmness, yield

	MPr	MFt	MCs	CMo	CFt	CPr	FDM	MNFS	C/F ratio	FR	CdFm	Actual Yield	Adj. Yield
MPr	1.000												
MFt	0.859[b]	1.000											
MCs	0.996	0.874[b]	1.000										
CMo	-0.780[c]	-0.821[c]	-0.761[c]	1.000									
CFt	0.214	0.590	0.211	-0.707[c]	1.000								
CPr	0.522	0.108	0.525	-0.137	-0.555	1.000							
FDM	-0.306	0.175	-0.303	-0.198	0.833[d]	-0.878[b]	1.000						
MNFS	-0.904[b]	-0.691[c]	-0.893[b]	0.846[b]	-0.221	-0.609[e]	0.355	1.000					
C/F ratio	0.154	-0.366	0.131	0.218	-0.798[c]	0.782[c]	-0.935[a]	-0.300	1.000				
FR	0.264	0.183	0.213	-0.606[e]	0.495	-0.141	0.217	-0.461	-0.038	1.000			
CdFm	0.396	0.614[e]	0.388	-0.763[c]	0.798[d]	-0.247	0.507	-0.448	-0.526	0.406	1.000		
Act. Yield	0.978[a]	0.934[a]	0.982[a]	-0.793	0.344	-0.361	-0.143	-0.837	-0.026	0.258	0.457	1.000	
Adj. Yield	0.946[a]	0.942[a]	0.956[a]	-0.899	0.480	0.304	-0.037	-0.880	-0.089	0.388	0.578	0.980[a]	1.000
Pred. Yield	0.934[a]	0.958[a]	0.948[a]	-0.712	0.343	0.306	-0.082	-0.727	-0.142	0.075	0.439	0.976[a]	0.935[a]

[a]=probability of greater r < .0005
[b]=probability of greater r < .005
[c]=probability of greater r < .05
[d]=probability of greater r < .01
[e]=probability of greater r < 0.1

MPr = milk protein
MFt = milk fat
MCs = milk casein
CMo = cheese moisture
CFt = cheese fat
Cpr = cheese protein

CdFm = curd firmness
FR = fat recovery
Adj. Yield = Adjusted Yield

APPENDIXES

Appendix 1

Cheddar Cheese Making Record

Steps in Making	Time of Step (h:min)	Temp (°F)	Acid (%)	Comments
Add starter	0:00	88°	0.16	0.7-0.8%
Add color	0:00	88°	0.16	65 ml/1000 lb milk
Add rennet	0:00	88°		90 ml/1000 lb milk
Stir	0:00-0:05	88°		
Insert Vat timer	0:05	88°		
Remove Vat timer	0:30	88°		
Cut	0:30	88°	0.10	
Steam on	0:45	88°	0.10	
Steam off	1:15	102°	0.11	
Start dipping	2:15	102°	0.12	
End dipping	2:30	102°	0.14	
Pack	2:45	101°	0.18	
Pile two high	3:30	96°	0.28	
Pile three high	4:00	93°	0.35	
Mill	4:30	90°	0.40-0.45	
1st salt application	4:40	88°		2.75 lb/1000 lb milk
2nd salt application	4:50			
3rd salt application	5:00			
Hoop	5:10			
Press	5:30			50 psig

Appendix II

Recipe and Method for Preparing pH Control Media

Recipe:

6143 ml deionized water

325 g whey powder

26 g AYE yeast extract

6.5 g NZ Amine Type E casein hydrolysate

Mix ingredients above in clean stainless steel bucket.

Autoclave at 100°C, 19 min.

Slow exhaust and cool.

Standardize pH control meter to pH 7.0.

*Innoculate with 10 ml each of *Streptococcus cremoris* UC 310 and UC 77, propagated in sterile 10% NDM.

Set pH control with NH_4OH to automatic shut off at pH 6.2.

Allow about 14 hr to reach desired pH, cells would have multipled and reached appropriate cell mass.

*Refrigerated cultures were incubated for 24h at 22°C before inoculations were made.