5-1984

The Relationship Between Milk Composition and Swiss Cheese Yields

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THE RELATIONSHIP BETWEEN MILK COMPOSITION AND SWISS CHEESE YIELD

by

Adnan Ba-Jaber

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Nutrition and Food Science

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1984

ACKNOWLEDGMENTS

I would like to give special thanks to my major adviser, Dr. C. A. Ernstrom for his guidance throughout my masters program, and this study. I have appreciated his suggestions, encouragement, and support.

Dr. R. J. Brown has given me much assistance which I appreciate very much.

I also wish to thank Dr. D. V. Sisson and Dr. D. T. Bartholomew for their help.

I would like to thank Stephen L. Larsen from Cache Valley Dairy Association for his cooperation and Dr. Aly Gamay and Gheyath Majeed for their help.

I acknowledge the financial support given by The University of Suad in Riyadh, Saudi Arabia which made my studies possible.

Adnan Ba-Jaber

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ABSTRACT

The Relationship Between Milk Composition

and Swiss Cheese Yields

by

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Utah State University, 1984

Major Professor: Dr. C. Anthon Ernstrom
Department: Nutrition and Food Science

From Cache Valley Dairy Association in Smithfield, Utah, milk from two to three cheese vats plus the corresponding Swiss cheese trimmings, salted cheese, and whey were sampled each week from October 1981 to October 1982. The weights of the Swiss Cheese were recorded. Milk samples were analyzed for fat and protein; cheese samples were analyzed for fat, protein, and moisture; whey samples were analyzed for fat.

By using Gauss-Newton nonlinear Least Squares method of iteration, the data was analyzed. Two formulas for predicting Swiss cheese yield were derived. A good relationship was found to exist between Swiss cheese yield and fat and protein.

In this study it was found that the season affected the percentage of fat and protein in the milk and thereby the cheese yield.

The highest cheese yields corresponded with the months with highest protein and fat percentage in the milk.

(70 pages)

INTRODUCTION

Many researchers have developed equations for estimating Cheddar cheese yield. Such equations are used (a) to establish cheese making values for milks of different compositions, (b) to determine the costs of making the cheese, and (c) to check on losses during cheese making (33).

The equation proposed by Van Sylke and Price (59) is now used by many cheese factories as a basis for milk payment to farmers (20). Plants manufacturing other varieties of cheese are in need of similar equations to help establish milk values.

Majeed (33) proposed a cheese yield equation for Swiss cheese, but there is little else in the literature to establish a relationship between milk composition and Swiss cheese yield. Swiss cheese is nearly always made from milk standardized by removing cream. Thus yield values must be based on the composition of the standardized rather than the original milk.

In Majeed's study (33), equations were derived to predict Swiss cheese yield, but he assumed that the fat which was not accounted for in the cheese was lost in the whey. He did not verify this assumption by analyzing the whey.

The purpose of this study was to repeat the work of Majeed (33), but to attempt to account for fat losses in the whey. A cheese yield equation for Swiss cheese will be derived from data collected at a large factory. The equation will then be compared with the one reported by Majeed (33). Information concerning variations in milk composition at the plant will also be reported.

REVIEW OF LITERATURE

Swiss Cheese

The U.S. counterpart of Swiss Emmentaler is made from cooled and pressed curd formed by rennet action on partially skimmed or whole milk (8). The characteristic "eyes" or holes are caused by special gas-producing bacteria. This milk is usually standardized to a definite ratio of fat and casein.

Increased milk production during past years in the United States has resulted in increased cheese production, including increased Swiss cheese production (51). The total pounds of cheese produced in the United States in 1956 (50) was 1,386,650,000 including 991,193,000 pounds of American cheese and 123,151,000 pounds of Swiss cheese. In 1960 (51), cheese production increased to 1,477,920,000 pounds of cheese, including 996,147,000 pounds of American cheese, but Swiss cheese decreased to 121,081,000 pounds. Cheese production increased dramatically from 1960 to 1981 when 4,277,561,000 pounds of cheese (excluding cottage cheese) were produced (52) including 2,642,263,000 American cheese and 214,410,000 pounds of Swiss. In 1982 (52) the total amount of cheese produced was 4,541,669,000 pounds of cheese, including 2,752,298,000 pounds of American and 221,085,000 pounds of Swiss.

Figure 1 shows the amount of whole milk used in manufactured dairy products in the United States from 1970 to 1982 (52).

Figure 1. Milk used in manufacturing dairy products in the United States of America from 1970 to 1982 (52).

WHOLE MILK USED IN MANUFACTURED

DAIRY PRODUCTS

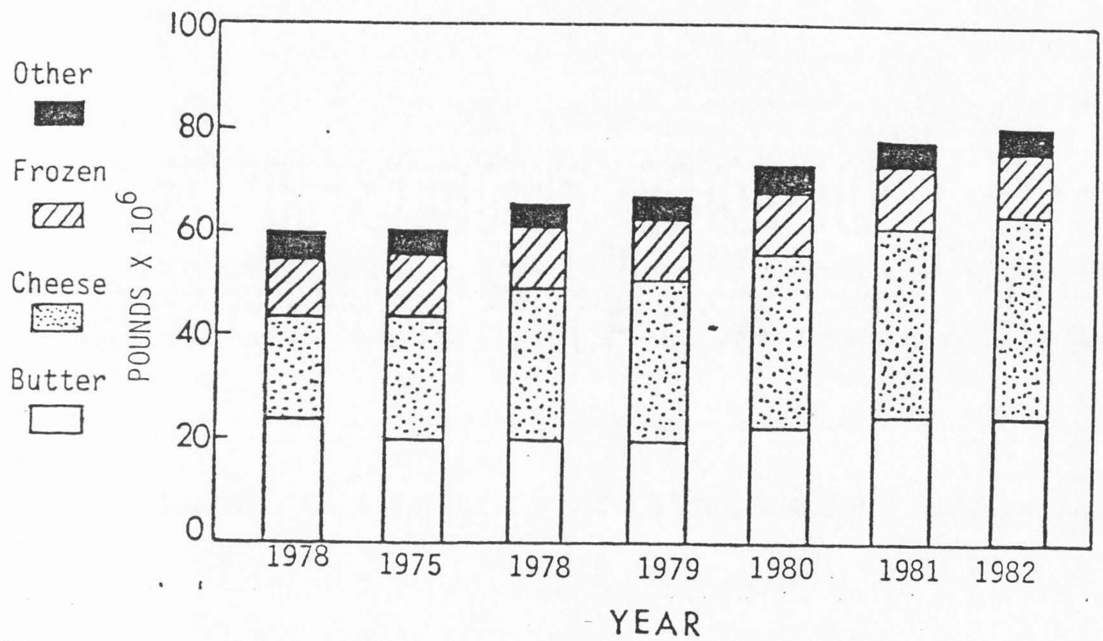


Figure 2 shows that in 1982 the Swiss cheese production represented about 4.9% of the total cheese production in the United States.

Gross Composition of Milk and Cheese Composition

Milk is the liquid food secreted by the mammary gland for the nourishment of the newly born (13). It contains protein, lactose, fat, water, and minerals. An average gross composition of cows milk would be: water, 87%; fat, 3.9%; lactose, 4.9%; protein, 3.5%; and minerals, 0.7% (60).

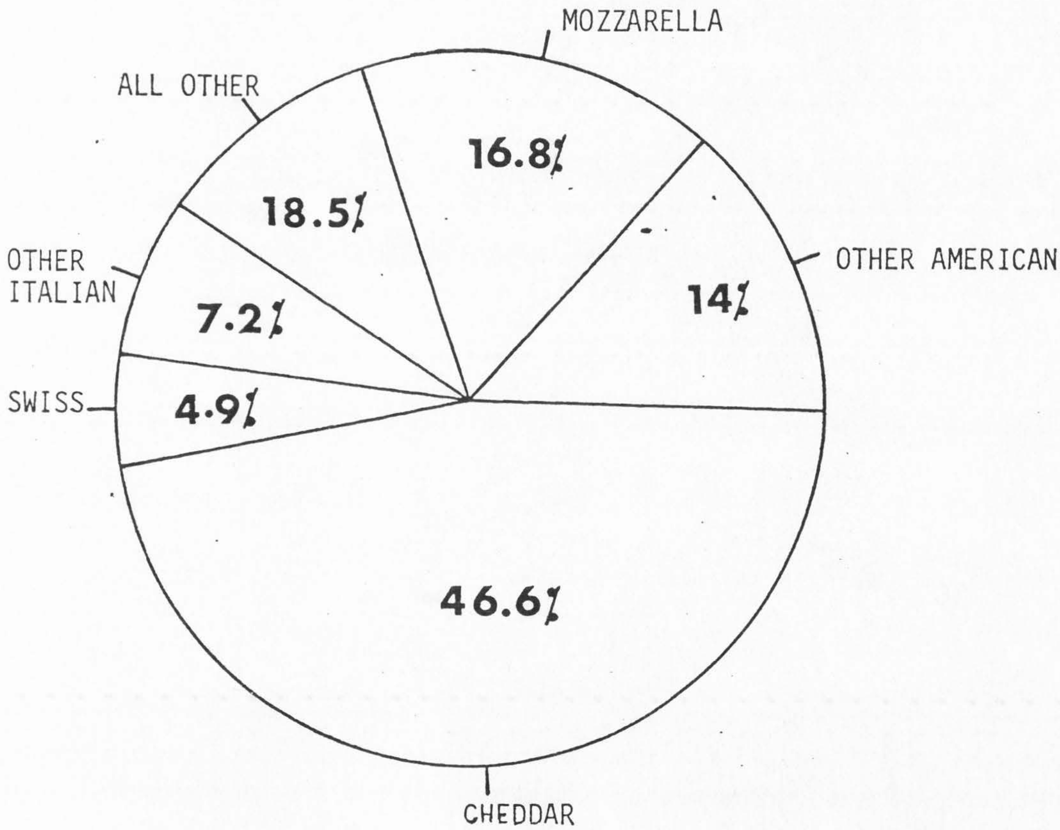
Milk fat and protein are the most variable of all milk constituents, and they are the most important milk constituents for cheese making. Cheese is a complex food product consisting mainly of casein (which is the main part of the milk protein), fat and water (8). Factors that affect the fat and casein in milk also affect the cheese yielding capacity of the milk.

Factors Affecting Total Protein, Casein and Fat Content of Milk

The factors affecting total protein, casein, and fat content of milk are: the breed of cow, individuality of the cow, feeding, season, mastitis, management intervals between milking, physiological conditions of the cow, and weather (14). The most important factors affecting the protein and fat percentages in milk are season, breed of cow, individual cows in the same breed, stage of lactation, feeding, and age of the cow.

Figure 2. Cheese production in the United States of America, 1982 (52).

CHEESE PRODUCTION



Seasonal Effect

Many researchers have found significant seasonal variations in fat and protein in the milk (6, 10, 11, 28, 33, 35, 38, 40, 42, 43, 45, 47). As a general rule, most of them found that the fat content was higher in winter months than in summer months (6, 10, 11, 38, 40, 42, 43).

Using monthly samples of milk from 326 tagil and varal black pied cattle, Tuerdokhleb and Zarkh (47) found that the fat ranged from 3.3 to 6.9% and the protein from 3.3 to 5.8% with minimum percentages of both fat and protein in the spring months and maximum percentages in autumn (47).

From 1971-1972, Szijarto et al. (45) analyzed samples from twenty-four selected dairy plants in Ontario, Canada for twelve months. They found significant differences in the amounts of casein, whey protein, and total protein according to production area and season. Casein as a percentage of total protein was highest in January and February, 77.08% and 77.19% of the milk protein with the lowest standard deviation (±2.36 and ±2.28). Casein percentages fluctuated most in May with a standard deviation of ±5.89%. The lowest casein percentages were in August, September, and October, 73.41%, 73.03% and 73.09%.

Overmann (40) tried to find the effect of season on the composition of the milk by using 2,426 samples from 1,482 individual cows of six breeds (Table 1). He found that the highest fat content was in December and January and the lowest was in June and July (ranging from 3.9% to 4.31% fat). The highest protein was in November and the lowest in June and July (Table 1). Table 1 shows

Table 1. Influence of season on gross composition of milk (40).

Month	Fat %	Protein %	Lactose %	Ash %	Total Solids %
January	4.31	3.67	4.87	0.72	13.57
February	4.22	3.62	4.89	0.72	13.45
March	4.16	3.56	4.98	0.71	13.41
April	4.10	3.54	5.01	0.71	13.37
May	4.10	3.53	5.04	0.71	13.37
June	3.96	3.45	5.02	0.70	13.13
July	3.95	3.46	5.02	0,70	13.12
August	3.95	3.54	5.00	0.69	13.18
September	4.10	3.62	4.96	0.70	13.38
October	4.24	3.66	4.92	0.71	13.53
November	4.27	3.69	4.88	0.72	13.55
December	4.30	3.65	4.92	0.72	13.59

Note: All units are in percentages

that the fat decreased from January until July; then increased from August until December. Protein decreased from November until July, then increased from July to November.

Nakae et al. (38) estimated the fat and protein percentages from 110 samples of raw milk collected monthly from April 1976 to February 1977 in ten regions of Okayama Prefecture. They found that fat ranged from 3.25% to 3.7% and the protein from 2.95% to 3.35%. Fat percentage was less in spring and summer than in autumn and winter.

McGann and Keane (35) found that the fat and protein was maximum in November (approximately 4.5% and 3.9%) and minimum in April through June and February through March (approximately 3.25% and 3%).

Breed of Cow

Many studies have shown that milk composition is affected by the breed of cow (2, 12, 15, 18, 25, 27, 40, 43). Guernsey and Jersey have the highest fat and protein content and the Holstein breed the lowest.

Overmann (40) (Table 2) reported Jersey and Guernsey milk with a fat content of 5.05% and a protein content of 3.78-3.9%. Holstein fat content was 3.41% and the protein was 3.32%.

Cerbulis and Farrell (12) analyzed milk from commercial dairy herds in southeastern Pennsylvania for total protein, casein, and whey protein. They found that Jersey milk protein was 4.07% ± .45%, Brown Swiss 3.84% ± .47%; Guernsey 3.56% ± .53%, Ayrshire, 3.3% ± .52%, Shorthorn 3.17% ± .47%, and Holstein 3.07% ± .43%. Table 3

Table 2. Representative gross composition of milk of cows of different breeds (40).

Breed	Water %	Fat %	Protein %	Lactose %	Ash %	Total Solids %
Guernsey	85.35	5.05	3.90	4.96	0.74	14.65
Jersey	85.47	5.05	3.78	5.00	0.70	14.53
Ayrshire	86.97	4.03	3.51	4.81	0.68	13.03
Brown Swiss	86.87	3.85	3.48	5.08	0.72	13.13
Holstein[a]	87.72	3.41	3.32	4.87	0.68	12.28

Note: All units are in percentages

[a]Represents predominant dairy breed in the United States

Table 3. Percentage of the kinds of protein, fat, and lactose in the milk from seven breeds (12).

		Holstein 26[a]	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average 151
Crude Protein, %	$\bar{X} \pm S$	3.22±.45	4.22±.51	3.70±.55	3.47±.55	4.05±.50	3.42±.51	3.72±.63
	range	1.94-4.09	3.41-5.11	2.72-4.74	2.60-5.02	3.15-4.68	2.61-4.67	1.94-5.11
True Proteins, %	$\bar{X} \pm S$	3.07±.43	4.07±.49	3.56±.53	3.30±.52	3.84±.47	3.17±.47	3.54±.60
	range	1.83-3.94	3.26-4.95	2.61-4.59	2.43-4.78	2.96-4.46	2.36-4.38	1.83-4.95
Casein, %	$\bar{X} \pm S$	2.53±.40	3.39±.40	2.88±.44	2.73±.43	3.14±.42	2.56±.40	2.89±.51
	range	1.53-3.30	2.68-4.15	2.07-3.60	2.10-3.99	2.37-3.80	1.81-3.37	1.53-4.15
True Whey Proteins, %	$\bar{X} \pm S$	.541±.111	.684±.094	.681±.121	.571±.127	.691±.117	.600±.143	.632±.132
	range	.29-.82	.50-.89	.48-.87	.33-.79	.43-.91	.45-1.01	.29-1.01
β-lactoglobulin %	$\bar{X} \pm S$	.184±.051	.281±.074	.222±.047	.163±.051	.222±.062	.168±.034	.208±.068
	range	.07-.29	.19-.46	.14-.31	.10-.30	.08-.35	.10-.23	.07-.46
Other Whey Proteins, %	$\bar{X} \pm S$	.361±.091	.404±.053	.459±.095	.410±.096	.470±.089	.432±.130	.424±.102
	range	.23-.59	.28-.65	.33-.59	.18-.56	.32-.62	.29-.78	.18-.78
Fat, %	$\bar{X} \pm S$	3.73±.32	5.42±.53	4.76±.44	4.12±.22	4.28±.39	3.58±.26	4.34±.71
	range	3.4-4.6	4.0-6.6	4.0-5.4	3.7-4.8	3.3-4.9	3.2-3.9	3.2-6.6
Lactose, %	$\bar{X} \pm S$	4.93±.61	4.99±.34	4.66±.34	4.67±.34	5.15±.46	4.80±.31	4.89±.45
	range	3.51-6.22	4.25-5.79	3.82-5.29	4.12-5.52	3.96-5.89	4.32-5.35	3.51-6.22

[a]Number of cows

(12) shows the percentage of the kinds of protein and fat in the milk from seven breeds. The casein percentage in Jersey milk was the highest at 3.39% ± .4% of the milk which is 80.33% of the total protein, and the lowest in Shorthorn milk (2.56% ± .4%) which is 74.85% of the total protein. The highest fat content was in Jersey milk (5.42% ± .53%) and the lowest in Shorthorn milk (3.58% ± .26%). Table 4 (12, 25, 30) compares data from different researchers concerning the casein and serum protein contents in different breeds of cow.

Table 5 (27) compares the fat content of milk from several breeds of cows in the United States with the fat content of the same breeds in the United Kingdom. The United States breeds have milk with a higher fat content than United Kingdom breeds.

Many researchers (1, 2, 15) found differences in milk composition among individual cows of the same breed as well as between breeds.

Armstrong (2) concluded that the average fat and solids not fat in United States milk increased between 1900-1957. He also concluded that the percentage of fat, solids-not-fat, lactose, ash, and protein are slightly lower in herd samples than in individual cows samples of the same breed.

Davis et al. (15) showed (Table 6), the maximum and minimum values for milk constituents of individual cows in three breeds. The highest fat content was Jersey between 7.8% to 3.45% fat. Guernsey had lower fat content 6.7% to 3.1%, and Holstein had from 7.8% to 2.6%.

Vander Have and Rinske (53) analyzed milk composition from separate milkings of ten cows from the Friesian breed during normal and prolonged lactation. They noted variations in the composition of

Table 4. Published composition of milk proteins in milk from different breeds of cows.

Source	Breed	Protein Fractions		
		Casein %	Serum Protein %	Nonprotein Nitrogen %
Larson et al. (30)	Ayrshire	79.3	15.3	
	Guernsey	78.7	15.8	
	Holstein	76.5	18.0	
	Jersey	76.2	18.5	
Cerbulis (12)	Ayrshire	78.67	16.46	
	Guernsey	77.84	18.41	
	Holstein	78.57	16.8	
Harland et al. (25)	Mean of all Breeds	76.2	18.4	5.5

Table 5. Mean fat contents of the milk of different cattle breeds (in percent) in the United States and United Kingdom (27).

	Fat Percent	
Breed	United Kingdom %	United States %
Ayrshire	3.8	4.1
Dairy Short Horn	3.6	3.6
Guernsey	4.5	4.9
Holstein	3.6	3.6
Jersey	5.0	5.4

Table 6. Maximum and minimum values for milk constituents of individual cows in three breeds (15).

	Breed					
	Jersey		Guernsey		Holstein	
Number of Cows	11		11		12	
Number of Samples	160		139		207	
	Max	Min	Max	Min	Max	Min
Percent Butter Fat	7.8	3.4	6.7	3.1	7.8	2.6

milk from the same breed. During 10 months of lactation, the fat percentage in evening milk varied from 4.42 ± .76% to 3.81 ± 56%, the total protein varied from 3.67 ± .32% to 3.03 ± .33% and the casein from 2.94 ± .32% to 2.32 ± .26% of the milk which is 80.11% to 76.57% of the total protein. In the morning milking the variation in the fat was from 4.12 ± .6% to 3.38 ± .59% the total protein from 3.58 ± .39% to 2.93 ± .26%, and the casein from 2.86 ± .32% to 2.25 ± .19% of the milk which is 79.88% to 76.79% of the total protein. During prolonged lactation calculated over the eleventh and following months of lactation, they found in the evening milk that the fat percentages were from 6.14 ± 1.08% to 4.51 ± .61%, the total protein were from 4.81 ± .77% to 4.01 ± .38%, and the casein percentages were from 4.08 ± .57% to 3.04 ± .19% of the milk which is 84.82% to 75.81% of the total protein. In the morning milking in the prolonged lactation they found that the fat varied from 5.72 ± .99% to 4.16 ± .77%, the protein varied from 4.98 ± .70% to 3.89 ± .32%, and the casein varied from 3.97 ± .51% to 3.08 ± .19% of the milk which is 79.72% to 79.17% of the total protein.

Stage of Lactation

Many investigators found that a change in composition of milk takes place during lactation (4, 6, 7, 9, 15, 17, 18, 26, 30, 34, 48, 55, 56, 61). As a general rule, (4, 7, 17, 26, 34, 38, 55, 56, 61), fat decreased until the second and third months after parturition, then rose continuously.

After calving colostrum has a different composition from normal milk (57). The total protein, casein and fat start very high, then decrease rapidly.

As a general rule from the time of calving until dry time, milk composition undergoes gradual changes. The change during this period is regular. Table 7 (57) shows that the fat percentage decreased in the second month compared with the first, and then increased, continuing to increase from month to month during the entire period of lactation. The rate of increase is more rapid during the last two or three months. Such behavior appears to be the general rule (57).

After parturition the solids-not-fat, is high and then drops to a lactation low at two to three months, then increases slowly to six months, and then to the end of lactation increases rapidly (6, 61). Two to five months after successful service, pregnancy effects were noticeable and in the later stage of lactation, account for most of the increase in solid not fat (6, 61). During lactation, total protein varies in the same manner as the solids not fat (17).

The change in percentage of casein is very close to that of the fat change (Table 8). During the second month of lactation, the percentage of casein decreased (57) and then increased month by month until the end of the lactation period.

Feed

This factor was studied by many researchers (1, 21, 22, 23, 24, 31, 37, 46, 61).

Fisher et al. (22) used different treatments of propylene glycol and glycerol for the first eight weeks of lactation on a total of 120 Holstein-Friesian and Ayrshire cows. They found that at the 3%

Table 7. Variation in percentage of fat in milk with advance of lactation (57).

Month of Lactation	Fat in Milk %	Comparison With First Month %
1	4.30	100.0
2	4.11	95.6
3	4.21	97.9
4	4.25	98.8
5	4.38	101.9
6	4.53	105.3
7	4.57	106.3
8	4.59	106.8
9	4.67	108.6
10	4.90	114.0
11	5.07	118.0

Table 8. Variation in percentage of casein in milk with advance of lactation (57).

Month of Lactation	Casein in Milk %	Comparison With First Month %
1	2.54	100.0
2	2.42	95.3
3	2.46	96.8
4	2.52	99.2
5	2.61	102.8
6	2.68	105.8
7	2.74	108.0
8	2.80	110.2
9	2.90	114.2
10	3.01	118.5
11	3.13	123.2

and 6% level of propylene glycol supplementation increased milk yield and caused a slight decrease in milk fat.

Legates (31) found that reducing feed rations about 25% from normal energy requirements caused a decrease in solids-not-fat, and this change was due to a decrease in the protein content in the milk.

Thomas (46) found that the fat content in milk changed from 3.6% to 3.2% by feeding the animals sunflower instead of alfalfa-grass silage, which contained more neutral detergent fiber and acid detergent fiber but less ether extract than the sunflower silage ration.

Many studies (21, 23, 24, 37) showed that feeding cows a high roughage diet results in a lower milk yield than that of cows fed a low roughage diet. The cows which were fed a low roughage diet gave milk of a higher fat and protein percentage than the cows fed on a high roughage diet.

Evans, et al. (21) fed six lactating Holstein Friesian heifers a low roughage diet, containing 20% legume hay or a high roughage diet containing 67% legume hay, for 18 days in each of three 21-day periods. They fed the cows an intermediate diet for one week before the experiment and for the first three days of each period. They found that the cows which were fed low roughage had daily milk yields of 19 kilograms and the fat percentage in the milk was 3.11%, the protein 3.44% and the lactose 5.19%. The cows which were fed high roughage diets had daily milk yields of 17.5 kilograms, fat percentage in the milk was 3.99%, protein 2.78%, and lactose 4.94%.

Gordin and Birk (23) studied 32 cows throughout lactation to observe the effects of a low roughage diet high in concentrates on milk yield and milk constituents. They found that the cows which were fed high levels of concentrates had increasing in the milk yield and milk protein percentage, but decreasing in the percentage of the milk fat.

Gordin and Birk (24) studied the effect of the roughage level on the composition of milk of Israeli Friesian cows. Two levels of roughage; 3 FU (feed units) and 5 FU were fed to the cows daily. For 12 weeks following parturition, the milk yield and milk composition were studied. During the first 8 weeks, the cows on 5 FU of roughage produced a higher milk yield. There was no effect on milk composition with cows fed the normal diet. For cows with the high diet, the milk yield was higher than with the normaldiet. The milk of cows on a 3 FU diet had a decrease in fat percentage, and an increase in protein percentage.

Age of the Cow

Many studies (7, 31, 61) found that the average solids not fat percentage of milk decreased slightly with the age of the cow. Wilcox et al. (61) noted decreases in solids not fat percentage with the age of the cow. Legates (31) found declines in solids not fat ranging from .21% to .45% during the first seven years of lactation. Bartlett (7) noted that the solid not fat was higher (0.2%) in the first year of lactation than in the second year of lactation. Then the following lactations have lower solids not fat content.

Factors Affecting the Yield of Cheese

The factors which affect cheese yield are (14, 29):

1. The chemical composition of the milk.

2. The losses of constituents in whey.

3. The type of cheese and particularly its moisture content.

4. The heat treatment of the milk.

<u>The Composition of the Milk</u>

Cheese makers know that Jersey milk yields more cheese than Holstein milk. The relation between composition of milk and cheese yield is of highest practical interest and importance to cheese makers. The factors that affected the fat and casein percentage of the milk were mentioned earlier.

As a general rule, yield of cheese increases in proportion to increase of fat and casein in milk (54, 58). Table 9 (58) clearly shows the difference between the yield of cheese made from milk with a low fat and casein content and a high fat and casein percentage. For example from Table 9 it is shown that for cheese with 37% moisture, one hundred pounds of milk which has 3% fat and 2.1% casein yields 8.3 pounds of cheese, but one hundred pounds of milk which has 5% fat and 2.9% casein gives 12.9 pounds of cheese.

<u>The Losses of Constituents in the Whey</u>

During cheese making, most of the milk fat and casein are retained in the curd with a small percentage going to the whey (56). The finished green Cheddar cheese contains (56):

1. Over 90% of the milk fat and casein.

2. A small amount of calcium salts, phosphoric, lactic and citric acids.

3. The salt added in cheese making.

Table 9. Ratio of fat to cheese yield in normal milk containing different amount of fat. The cheese yield is based on a uniform percentage of water in the cheese, 37%. (58).

Fat in Milk	Casein in Milk	Cheese Made from 100 Pounds of Milk	Cheese Made for Each Pound of Fat in Milk
%	%	lbs.	lbs
3.00	2.10	8.30	2.77
3.25	2.20	8.88	2.73
3.50	2.30	9.45	2.70
3.75	2.40	10.03	2.67
4.00	2.50	10.60	2.65
4.25	2.60	11.17	2.63
4.50	2.70	11.74	2.61
4.75	2.80	12.31	2.59
5.00	2.90	12.90	2.58

4. Some of the milk whey proteins.

5. Some of the milk sugar which mostly disappears in a few days.

The percentages of fat and casein that go to the whey depend on many factors, including the type of cheese, the heat treatment (cooking the curd), and manufacturing steps (14). Fat losses during manufacturing are caused by the following (59):

1. Cutting the curd when too soft.
2. Careless and rapid motions of the knife in cutting the curd.
3. Careless handling of curd in the soft stage.
4. Removal of whey before the curd is formed.
5. Salting the curd at a high temperature (over 90°).
6. Pressing when the cheese is too warm.

Casein losses may be caused during manufacturing by the following (59):

1. Careless cutting of the curd.
2. Handling the cheese when the curd is soft.
3. Agitation while removing whey from the curd.
4. Imperfect strainers.

Moisture Content of Various Kinds of Cheese

Whey is lost in all kinds of cheese making. The more whey that is lost, the smaller the cheese yield will be (14, 32, 29). The moisture in cheese varies from about 20% to 55% and the corresponding yield varies from about 10.47 to 17.44 pounds per 100 pounds of milk (14). Table 10 shows the relationship between yield and moisture in Cheddar cheese (32).

Table 10. Yield of Cheddar cheese as affected by moisture (32).

Number of Experiments	Fat in Milk	Cheese Yield		Water in Cheese	Cheese Yield Containing 37% Moisture
	%	%		%	%
22	3.00-3.49	Lowest:	8.47	34.77	8.43
		Highest:	9.68	39.09	9.46
59	3.50-3.74	Lowest:	9.25	33.75	9.32
		Highest:	10.42	40.47	10.60
51	3.75-3.99	Lowest:	9.60	32.69	9.76
		Highest:	11.00	40.17	10.76
43	4.00-4.19	Lowest:	10.24	34.15	10.38
		Highest:	12.44	42.90	10.93
25	4.20-4.40	Lowest:	10.64	33.53	11.03
		Highest:	13.17	43.89	12.03

Heat Treatment of Milk

The heat treatment of milk increases the yield of Cheddar cheese (14, 16, 19, 39). El-Sadek and Abd Elmottleb (19) found that heating buffalo milk to 170°C for 15 min. before making into Karish cheese gave higher yield than the yield of the cheese made from raw buffalo milk.

Narasimhan (39) found that increasing the pasteurization temperature of skim milk from 61.8 to 79.4°C for 30 minutes resulted in 15.6% increase of cultured cottage cheese yields. Although pasteurization causes this increase in cheese yield, it is also related to other factors such as (14):

1. The time and temperature of treatment.
2. The type of the cheese.
3. The age of the cheese when the yield is calculated.

Formulas for Estimating Cheese Yield

Because cheese yield depends on the chemical composition of milk, many researchers have tried to find accurate formulas for predicting cheese yield. Some of them are as follows: Van Slyke (58) developed the formula Cheddar cheese yield = 1.63 (Casein + Fat). Babcock et al. (5) used Yield = 1.1 fat + 2.5 casein.

A simple formula involving only fat and casein is not adequate because other factors are involved. The factors complicating the matter are (14):

1. Variations in moisture content of the cheese.
2. Difficulty in determining casein.
3. Complex nature of casein.

4. Variable losses of fat in whey due to breed, method, etc.

5. Variable losses of casein due to breed, etc.

6. Specific water binding effect of casein.

Van Slyke and Price (59) tried to estimate the yield of Cheddar cheese in two ways, by calculating the cheese solids and by calculating the water in cheese. He gave the following equation for Cheddar cheese yield.

$$y = \frac{(0.93\ \text{Fat} + \text{Casein} - 0.1)\ 1.09}{1 - \text{water}}$$

The formula (0.93 Fat + Casein - 0.1) x 1.09 is based upon:

1. Seven percent of the milk fat (0.07 pounds for each pound of milk fat) being lost in whey and 93% (0.93 pounds for each pound of milk fat) remaining in the cheese.

2. About 0.1 pounds of the milk casein for 100 pounds of milk being lost in the whey and the rest going into the cheese.

3. The other solids in the cheese, including the added salt, forming about 9% of the fat and casein present in cheese. To obtain the total amount of cheese solids (fat, casein, salts, etc.), 1.09 is multiplied by the amount of fat and casein in cheese. The formula

$$\text{Yield} = \frac{(0.93\ \text{Fat} + \text{Casein} - 0.1)\ 1.09}{1 - \text{water}}$$

came from subtracting from 1.00 the percentage of water in the cheese and then dividing the results into the cheese solids. Ernstrom (20) has modified the above formula by assuming that casein in the protein is 78% of the total milk protein and the fat which goes to the cheese is 90% of the milk fat. The resulting formula is:

$$\text{Yield} = \frac{[0.9\ \text{Fat} + (0.78\ \text{Protein} - 0.1)]\ 1.09}{1 - \text{W}}$$

By applying the general principles of this modified formula, Majeed (33) gave a formula for Swiss cheese.

$$\text{Yield} = \frac{[0.77\ \text{Fat} + (0.78 - 0.2)]\ 1.1004}{1 - \text{W}}$$

The constants in the equation were determined from known fat and protein percentages in the milk and actual cheese yields of known moisture levels. The iteration method was used with the computer until the residual sum of squares was minimized.

Whey Fat and Fat Recovery

The percentage of fat in the whey depends on the percentage of the fat in the milk from which the cheese is made and on the type of the cheese that the whey comes from (14).

Many researchers (7, 9, 55, 56) have tried to estimate the fat percentage in the whey from Cheddar cheese. In the United States, Van Slyke (55) found that fat in the whey ranges from 0.22% to 0.55% with an average of 0.34%. He also (56) found values of 0.24% to 0.51% and averaged 0.38%. In England, Berry (9) found values of 0.12% to 0.36%, with an average of 0.21%.

METHODS AND PROCEDURES

Swiss Cheese Making

Swiss cheese making in this study was at Cache Valley Dairy Association in Smithfield, Utah. Fresh, raw milk at 95°F was standardized to approximately 2.8% fat. However, there was some variation in standardization. Casein to fat ratios varied from 0.84 to 0.98 (see Table 11). The milk was clarified at the same temperature. The standardized and clarified milk was pasteurized at 157°F for 15 sec. After pasteurization, the milk was pumped into the cheese making vats. Swiss cheese starter cultures were added to the milk at 91°F. They included 1.2% of _Streptococcus thermophilus_, about 0.08% _Lactobacillus bulgaricus_, and 0.02% _Propioni bacterium_.

After 55 min., the milk was stirred, and the rennet added to the milk and stirred for 5 minutes. After 25 minutes, the curd was cut into cubes using Swiss cheese wire knives. After cutting the curd, the curd and the whey were agitated for 40 minutes. The agitation was stopped, and about 8 inches of whey from the original milk level was predrawn. After that, the heat was turned on by introducing the stem into the jacket of the vat. The curd was heated slowly to 127°F in approximately 35 minutes. The steam was turned off, and the curd continued to be stirred. After about 60 to 65 minutes, when the titrable acidity of the whey was about 0.113%, the stirring was stopped and the curd dipped by pumping the curd and the whey to the pressing vats called universals. In this vat the whey was drained from the curd and the curd pressed for about 12 hours. On the second day, the pressed curd was cut into 120 pound blocks. The cheese blocks were trimmed and then transferred to the brine. The pH of the cheese blocks when put in the brine was 5.2 to 5.3. After 14 to 18 hours of brining, the cheese blocks are packaged and transferred to the cold room at 40°F.

After 14 to 18 days in the cold room, the cheese is transferred to the curing room at 70°F for 6 to 8 weeks. Then the cheese is transferred to the cold room and stored in it until shipping time.

Sample Collection

Milk from 2 to 3 cheese vats plus the corresponding cheese trimmings and salted cheese were sampled each week from August 23, 1981 to August 23, 1982. Samples were collected as follows:

1. Five minutes after the starter was added to the standardized milk.

2. After cooking the curd and before transferring it to the vat for pressing (the universal) the whey samples were collected.

3. The cheese curd trimmed from the blocks were weighed and sampled after pressing and before transferring to the brine.

4. Samples of Swiss cheese were collected after the cheese blocks were removed from the brine and before packing. Four samples were taken from the ends and middle of each block.

5. Some samples were taken from the top of the brine in the brine vat in order to see if there is any fat in the brine.

An outline of cheese making and sample collection is given in Figure 3.

Milk and Cheese Weights

The amount of milk in each cheese vat was measured in gallons by a calibrated dip stick just before agitation for taking the milk samples. It was then converted to pounds by multiplying by a factor of 8.6. The cheese weight was taken before and after salting. The unsalted trim weight was taken and converted to salted weight according to the difference between unsalted and salted cheese weight. By adding the weight of salted cheese plus the corrected weight of the trim, actual yields of Swiss cheese were calculated.

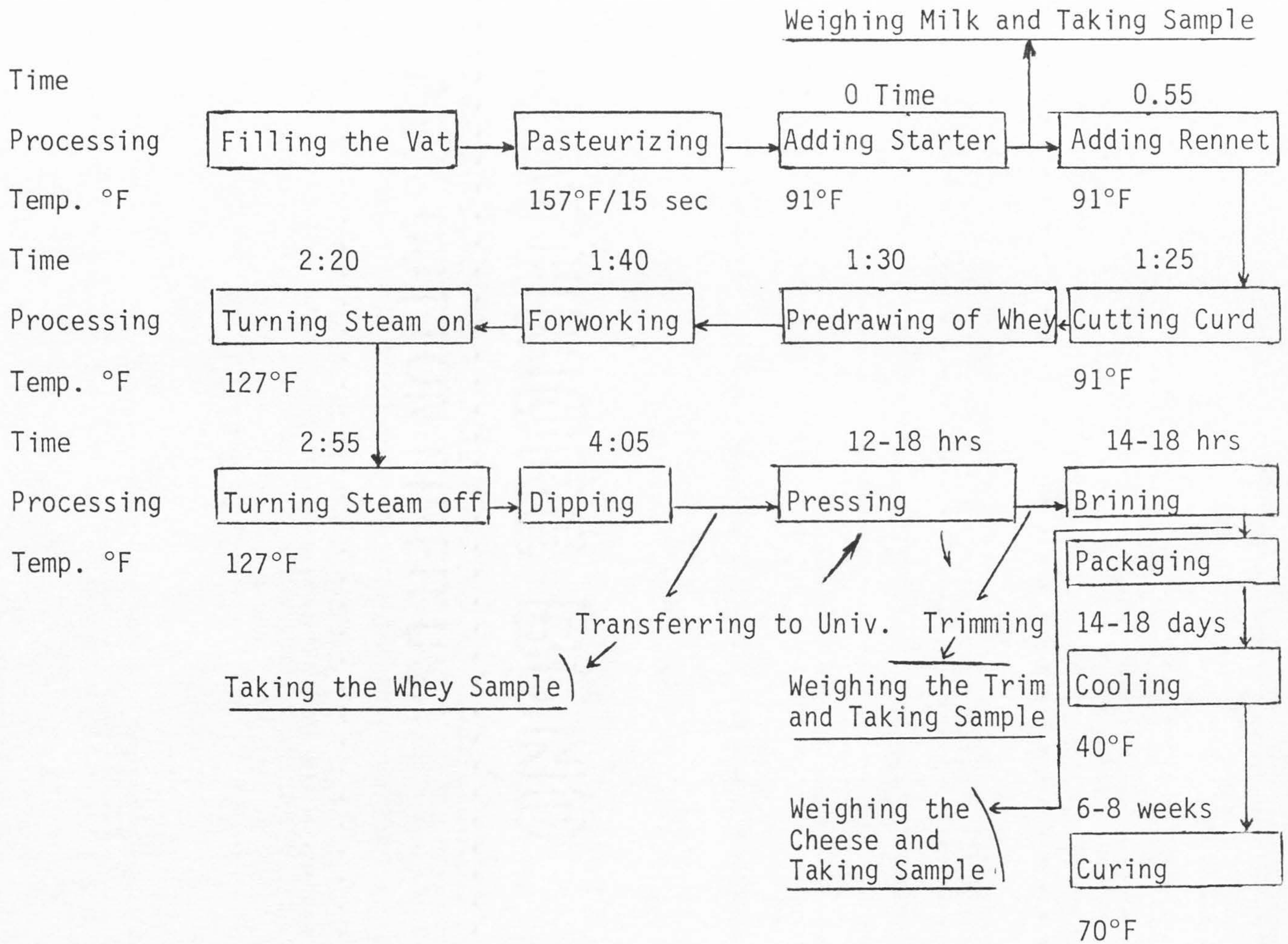
Milk, Cheese and Whey Analysis

The milk fat and protein percentages were determined for each milk sample by a Milk-o-Scan 300 (A/S N. Foss Electric, Denmark). The cheese moisture test according to Price et al. (41) was run on all trim samples. Cheese fat was determined by a modified Babcock test (29). Cheese protein was by the Kjeldahl method (3). The cheese moisture was estimated by the procedure of Price et al. (41). The "Mojonnier" test was used to estimate whey fat (36).

Statistical Analysis

By using Tektronix Laboratory Computer 4051 (Tektronix, Beaverton, Oregon, U.S.A.), the data were analyzed by applying the Gauss-Newton nonlinear least squares method of iteration (44).

Figure 3. Cheese making procedure and schedule of sample collection.


Weighing Milk and Taking Sample
Time
Processing
Temp. °F
Time
Processing
Temp. °F
Time
Processing
Temp. °F
0 Time
0.55
Filling the Vat
Pasteurizing
Adding Starter
Adding Rennet
157°F/15 sec
91°F
91°F
2:20
1:40
1:30
1:25
Turning Steam on
Forworking
Predrawing of Whey
Cutting Curd
127°F
91°F
2:55
4:05
12-18 hrs
14-18 hrs
Turning Steam off
Dipping
Pressing
Brining
127°F
Packaging
Transferring to Univ.
Trimming
14-18 days
Taking the Whey Sample
Weighing the Trim and Taking Sample
Cooling
40°F
Weighing the Cheese and Taking Sample
6-8 weeks
Curing
70°F

After the starting values for the parameters were put into the models below, the computer modified these values by iteration until the residual sum of squares was minimized.

The models used were the same as those used by Majeed (33), and the modified Van Slyke's equation for the yield of Cheddar cheese (20).

Model 1

$$Y = \frac{[a\text{Fat} + (0.78\ \text{Protein} - b)]\ d}{1 - \text{Water}}$$

where:

a = percent milk fat that goes to cheese

b = percent of milk casein that is lost in the whey

d = one plus the fraction of salts and solids other than fat and casein as a percentage of cheese fat and casein.

Model 2

$$Y = \frac{(a\text{Fat} + b \times .78\ \text{Protein})\ d}{1 - \text{Water}}$$

where:

a = percent milk fat that goes to cheese

b = percent milk casein that goes to cheese

d = one plus the fraction of salts and milk solids other than fat and casein as percentage of cheese fat and casein.

Model 2 differs from Model 1 in that Model 2 assumes that the milk protein lost to the whey is a function of the protein content in the milk. Model 1 assumes that a constant amount of casein is lost from the milk regardless of the amount of casein in the milk.

RESULTS

The Seasonal Effect on Milk Composition

By analyzing the samples of milk for fat and protein content, the average percentage of protein and fat are shown in Figure 4. The figure shows that the highest protein content in the milk was in the months of October, 3.36%; November, 3.43%; February, 3.47%; and January 3.38%. The lowest protein was in June, 3.18% and July 3.14%. Figure 4 shows also the fat percentage in the standardized Swiss cheese milk. The highest contents were in July, 2.9% and August, 2.84% and the lowest in October, 2.67%, and December, 2.69%. Figure 5 shows the yield of Swiss cheese (corrected to 39% moisture) and percent protein in standardized milk throughout one year. Table 11 shows the average monthly percent fat and protein in standardized milk for Swiss cheese and the actual and corrected (39% moisture) cheese yield throughout one year at Cache Valley Dairy Association.

Whey Fat and Fat Recovery

By using the Mojonnier test for estimating fat in the whey of Swiss cheese, the whey fat was from 0.13 to 0.32%, but the average was 0.23%. All of the whey samples were taken after cooking the curd and before transferring it to the universal. The fat percentage in the brine were from 0.5% to 1.6%.

Figure 4. Percent fat and protein in standardized milk for Swiss cheese making throughout one year.

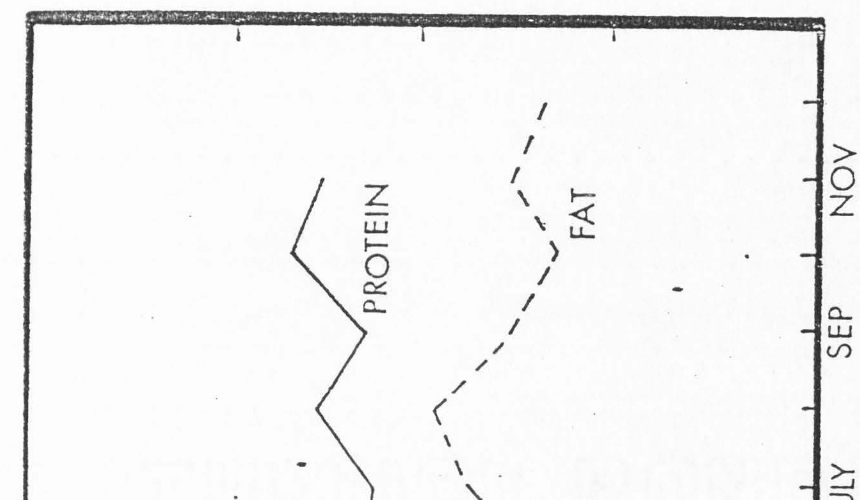

PERCENT
3.5
3.0
2.5
JAN
MAR
MAY
JULY
SEP
NOV
PROTEIN
FAT

Figure 5. Yield of Swiss cheese (corrected to 39% moisture) and percent protein in standardized milk throughout one year.

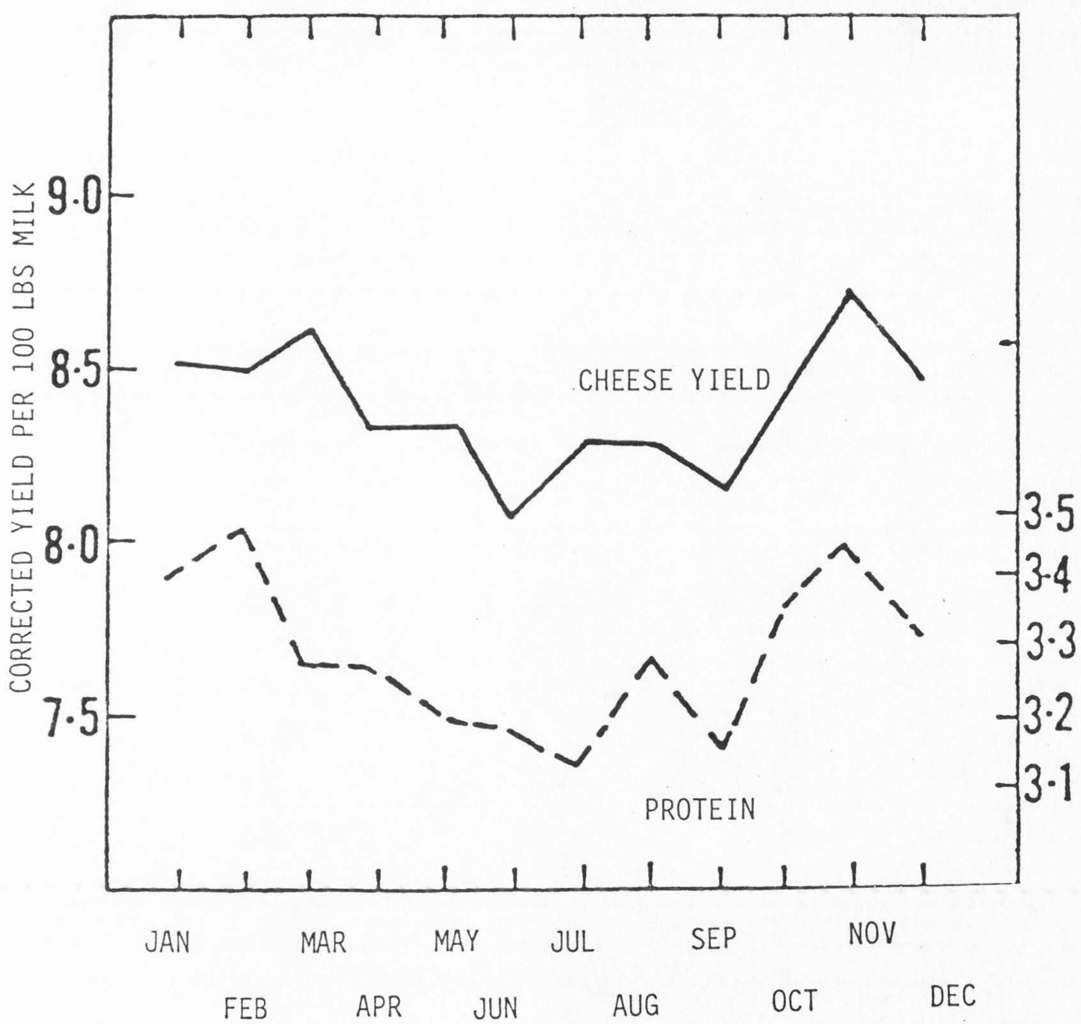

CORRECTED YIELD PER 100 LBS MILK
9·0
8·5
8·0
7·5
CHEESE YIELD
PROTEIN
PERCENT PROTEIN IN STANDARDIZED MILK
3·5
3·4
3·3
3·2
3·1
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Table 11. Average monthly percent fat and protein in standardized milk for Swiss cheese and the actual and corrected (39% moisture) cheese yield throughout one year.

	Milk Fat %	Milk Protein %	.78 Protein /Fat	Actual Cheese Yield	Corrected to 39% Moisture Cheese Yield
January	2.76	3.38	0.95	8.67	8.58
February	2.82	3.47	0.96	8.56	8.51
March	2.86	3.28	0.89	8.77	8.62
April	2.88	3.28	0.89	8.40	8.37
May	2.76	3.19	0.90	8.32	8.35
June	2.71	3.18	0.90	8.24	8.10
July	2.90	3.14	0.84	8.33	8.29
August	2.84	3.29	0.90	8.26	8.30
September	2.78	3.18	0.89	8.30	8.22
October	2.67	3.36	0.98	8.54	8.53
November	2.78	3.43	0.96	8.72	8.69
December	2.69	3.32	0.96	8.56	8.45

Table 12 shows the percentage of fat in the milk which went to the whey, the percentage of fat which went to the cheese and the total fat recovery in the cheese plus whey. Additional whey samples were taken before transferring to the universal and after pressing the curd in the universal in order to find how much the point of whey sampling affected the total fat accountability. Table 13 shows the results of those samples and gives the percentage of fat in the whey before pressing and after pressing.

Yield Models

Applying the Gauss-Newton nonlinear least squares method of iteration to Models 1 and 2 the following values were obtained:

Model 1

$$Y = \frac{[a\text{Fat} + (0.78\ \text{Protein-b})]d}{1 - \text{Water}} = \frac{[.803\text{Fat} + (.78\text{Protein} - 0.1)]1.089}{1 - \text{Water}}$$

where:

a = percent milk fat that goes to cheese

b = percent of milk casein that is lost in the whey

d = one plus the amount of salts and solids other than fat and casein as a percentage of cheese fat and casein.

The values of the three parameters 0.803, 0.1, and 1.089 did not mean that they are the actual percentages of milk fat measured in the cheese, casein lost in the whey, and the salts and solids other than fat measured in the cheese. However, by using them together, the model will give the best predicted yield for the Swiss cheese.

Table 12. Average percentage of milk fat recovered in cheese and whey from August 1981 until August 1982.

	Milk Fat Recovery		
	Cheese %	Whey %	Total %
January 1982	83.36	8.65	92.01
February 1982	79.66	10.69	90.35
March 1982	83.803	10.32	94.13
April 1982	78.776	14.77	93.55
May 1982	82.709	13.56	96.27
June 1982	80.175	17.38	97.56
July 1982	77.5	14.70	92.20
August 1981 and 1982	79.83	13.84	93.67
September 1981	78.075	16.36	95.03
October 1981	85.936	10.774	96.71
November 1981	85.84	11.58	97.42
December 1981	83.49	11.81	95.3

Table 13. Fat composition of whey and cheese and corresponding recovery of milk fat in these fractions.

		Whey Fat		Fat Recovery			Fat Recovery (Whey + Cheese)	
Date	Vat No.	Before Press %	Press Drippings %	Whey Before Press %	Whey After Press %	Fat Recovery in Cheese %	Before Press %	After Press %
2-10-82	17	0.25	0.3533	8.51	11.96	80.83	89.34	92.79
2-17-82	17	0.1837	0.2932	5.56	8.89	84.65	90.21	93.54
2-17-82	18	0.150	0.2601	5.34	9.25	86.54	91.88	95.79
2-27-82	17	0.1966	0.3461	6.62	11.66	82.20	88.82	93.86

Model 2

$$Y = \frac{[a\text{Fat} + b\ 0.78\ \text{Protein}]d}{1 - \text{Water}} = \frac{[0.75\ \text{Fat} + (0.99)(0.78\ \text{Protein})]\ 1.4}{1 - \text{Water}}$$

where:

a = percent milk fat that goes to cheese

b = percent milk casein that goes to cheese

d = one plus the amount of salts and milk solids other than fat and casein as percentage of cheese fat and casein.

Same as Model 1 the values 0.75, 0.99, and 1.4 together give the best predicted yield for the Swiss cheese.

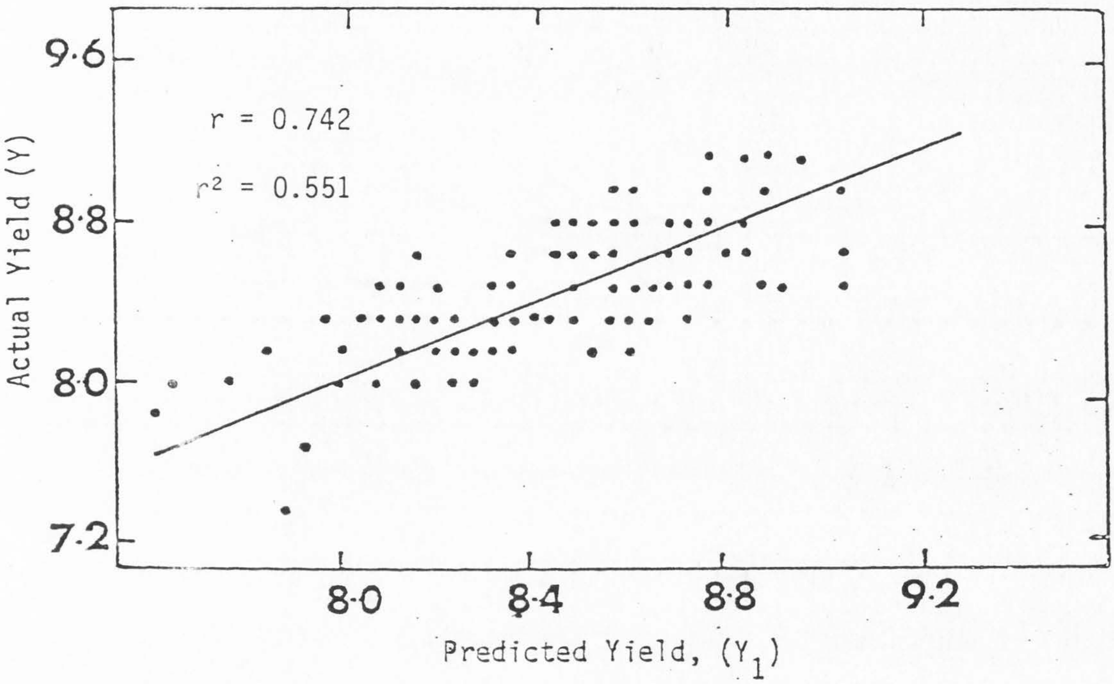
Table 14 shows the correlation coefficients (r) between the actual yields and the predicted yields and the final residual sum of squares (RSS) and the parameters for models 1, 2, and Majeed's model.

Figures 6, 7, and 8 show the regression lines obtained from plotting predicted yields by Model 1, Model 2, and Majeed's model, versus actual yields.

Table 14. The final values of parameters, residual sum of squares, and the correlation coefficients (r) of the models.

Models	Parameters	Final Values	RSS Final	r
1. $Y = \frac{[aF+(.78P-b)]d}{1-w}$	a	0.803		
	b	0.1	8.457	0.742
	d	1.089		
2. $Y = \frac{[aF+b.78]d}{1-2}$	a	0.75		
	b	0.99	10.967	0.726
	d	1.4		
3. Majeed's Model				
$Y = \frac{0.77F+(0.78P-0.2)]1.1004}{1-w}$	a	0.77		
	b	0.2	16.506	0.593
	d	1.1004		

Figure 6. The regression line obtained from plotting predicted yields by Model 1 versus actual yields.



r = 0.742
r² = 0.551
9·6
8·8
8·0
7·2
Actual Yield (Y)
8·0
8·4
8·8
9·2
Predicted Yield, (Y1)

Figure 7. The regression line obtained from plotting predicted yields by Model 2 versus actual yields.

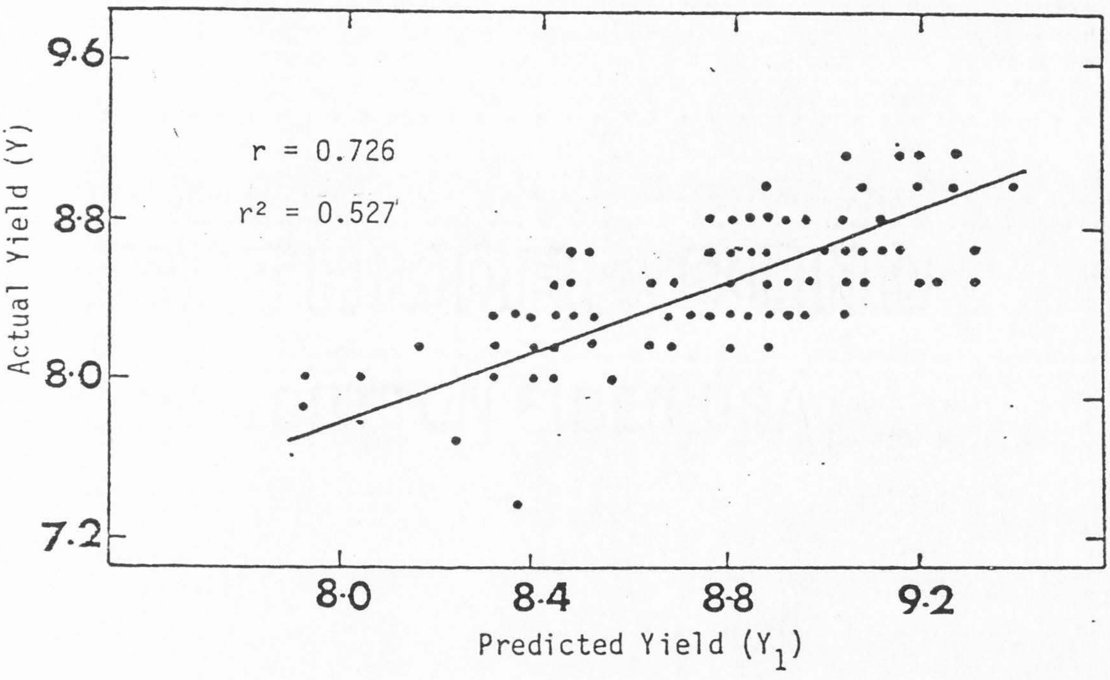
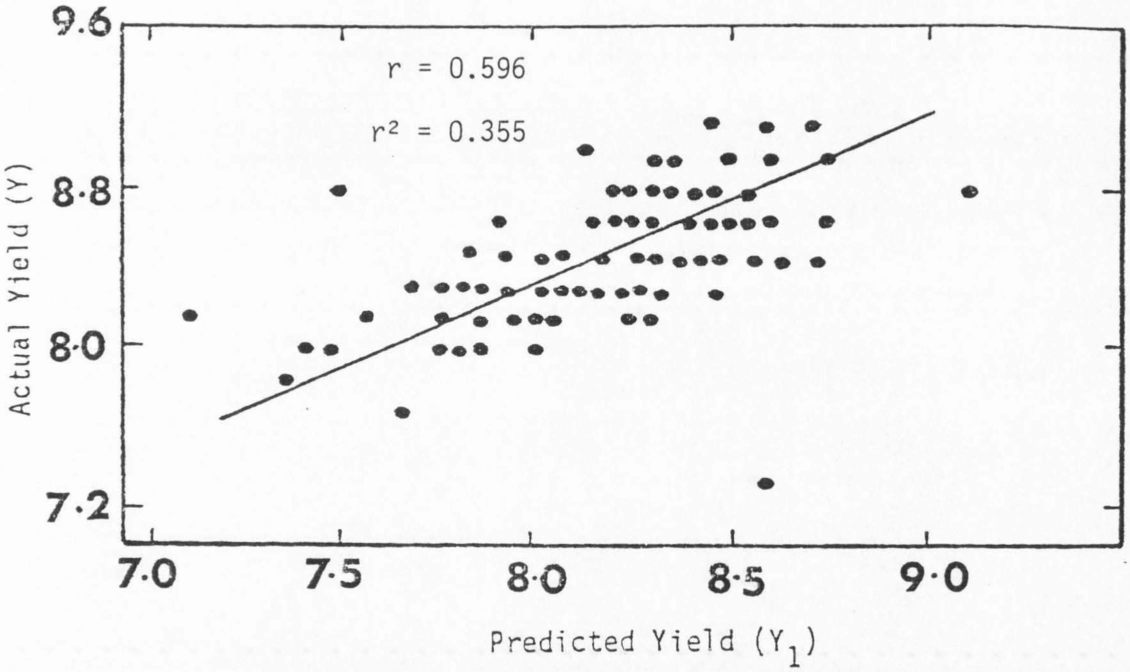

r = 0.726
r² = 0.527
9.6
8.8
8.0
7.2
Actual Yield (Y)
8.0
8.4
8.8
9.2
Predicted Yield (Y_1)

Figure 8. The regression line obtained from plotting predicted yields by Majeed's Model ($Y = \frac{[0.77\ F + (0.78\ P - 0.2)\ 1.1004}{1-w}$ versus actual yields.


9.6
8.8
8.0
7.2
Actual Yield (Y)
r = 0.596
r² = 0.355
7.0
7.5
8.0
8.5
9.0
Predicted Yield (Y1)

DISCUSSION

Results of seasonal effects in milk fat and protein between 1981-1982 are shown in Figure 4 and Table 11. The highest protein content in the milk was in November with 3.43%; February with 3.47%; January with 3.38%; and October with 3.36%. The lowest protein was in June with 3.18% and July with 3.14%. Majeed's results (33) show the same four highest months: October, with 3.44%; November, with 3.38%; December, with 3.41%; and January, with 3.41%. In this study, the highest month was November; in Majeed's study it was October. The lowest protein in Majeed's study was also July, with 3.118% and June with 3.22% and August, with 3.19%.

Table 11 shows that by comparing the cheese yield with milk fat and protein there is a relationship between the fat and protein in the milk and the actual yield of cheese. By correcting the moisture of the cheese to 39% and calculating the yield (Figure 5), the lowest yield was in June, with 8.10%, then increased until November with the exception of September which goes down a little, then increasing again until November with 8.69%. In December, the yield was 8.45%. From January until June the yield decreased again with the exception of March when the yield was higher than in February.

Figure 5 compares the yield with the protein percentage of the milk and indicates that as the protein percentage in milk increases, the yield of the cheese increases. Because the milk was standardized, the effects of the seasonal changes in the fat percentages on yield of the Swiss cheese are not apparent. Since Swiss cheese milk should be standardized to a constant casein/fat ratio, seasonal variations in casein will result in corresponding variations in fat. However, in the plant where these studies were made, fat adjustments in the milk were based on the fat in the dry matter of the cheese. Thus it was generally true that yield of moisture corrected Swiss cheese from standardized milk varied from month to month throughout the year with fat and protein variations in the standardized milk.

The monthly percentage of milk fat recovered in Swiss cheese averaged from 85.936% to 77.5% as shown in Table 12. The percentage of milk fat recovered in Swiss cheese was less than the fat recovered in Cheddar cheese because of different manufacturing steps. Loss of milk fat to the whey in Swiss cheese is higher than Cheddar cheese fat loss because Swiss cheese is cooked at a higher temperature and the curd of Swiss cheese is cut in smaller pieces after coagulation. The average fat recovery in the cheese for all samples was about 81.5% which means that about 18.5% of the fat was lost. Although it is generally assumed that this fat went to the whey, Table 12 shows that the fat which went to the whey averaged about 12.87%, with about 6% of the fat unaccounted for. Table 12 also shows the fat accounted for in cheese whey for each month. The fat accounted for in cheese plus whey ranged from 90.35% in February to 97.42 in November, with the average at 94.517%, with 5.483% unaccounted for. Table 13 shows that whey samples taken from the universals after pressing the curd had a higher fat percentage than the whey sample taken from the vat after cooking the curd. Table 13 shows that the average whey fat percentage for the four samples rose from 0.065 to 0.1044 and the average fat recovery in the cheese plus the fat in the whey rose from 0.901 to 0.94 which is 4% higher. This shows that pressing the curd causes more fat loss. Although the samples which were taken from the universals represent a small part of the total whey, they showed that some fat was lost by pressing the curd. If the whey before pressing is mixed with the whey after pressing, the fat percentage will be higher than the percentages in this study, but lower than the fat percentage after pressing. On the other hand, samples taken from the top of the brine in the brine vat showed that about 0.5 to 1.6% of the fat was in the brine. This means that salting the cheese in the brine causes some loss of cheese fat from the surface of the cheese blocks. Also fat was not uniformly distributed throughout the cheese blocks since the salt was higher on the surface of the block and not at equilibrium with the moisture when the samples were taken.

For both Model 1 and Model 2 the values of the fat coefficients which were 0.803 and 0.75 did not mean that they represented the percentage of milk fat that went to the Swiss cheese. The method of iteration minimized the residual Sum of Squares and gave the best relationship with yields. The three values of the coefficients a, b, and d together gave the best predicted yield. By looking to the correlation coefficient (r) value for Model 1 and 2 in Figures 6 and 7 which were 0.742 and .726 from the table of significance of correlation coefficient under 0.01 level of significant the table value r is .25 which means that the r values in this study were very significant. The two models seem to apply well to Swiss cheese since it gave a good predicted yield and a good correlation coefficient. By using the data of this study and applying Majeed's model (r) value was .59 (Figure 8) which is significant, but less significant than the two models of this study. But with his data Majeed had an (r) value of .734 which was more significant. From all of the results recorded in this study, the percentage of fat in Swiss cheese met the federal legal requirement of 43% fat on a dry basis (FDB) (49).

Both Model 1 and Model 2 assume that the percentage of casein in the milk protein is 78%. This percentage was based on the average casein percent reported by Cerbulis and Farrell (12), and as it was taken for modified Van Slyke and Price Cheddar cheese yield formula (20).

Model 2 can be modified as follows:

$$Y = \frac{[.75\ F + .7722\ P]\ 1.4}{1 - W}$$

The two models in this study differ from Majeed's models in the values of the coefficients. For Model 1, Majeed had 0.77, 0.2, and 1.1004 for the coefficients a, b, and d where in this study the values of the three coefficients were 0.803, 0.1, and 1.089. For Model 2, Majeed had 0.72, 0.99, and 1.095 for the parameters a, b, and d, but in this study they were 0.75, 0.99, and 1.4.

In general, differences in the number of samples, the time of taking the samples and variation between the manufacturing steps and other factors can account for differences between the two studies. The iteration method gave the best predicted yield so the most important thing is to look to the correlation coefficients between the actual and produced yields.

This study showed a relationship between the Swiss cheese yield and season. It also showed that Swiss cheese yield can be predicted by either of the following equations:

1. $$Y = \frac{[0.803\ F + (0.78\ P - 0.1)]\ 1.089}{1 - w}$$

2. $$Y = \frac{[0.75\ F + (0.99)\ (.78\ P)]\ 1.4}{1 - w}$$

Further studies are needed to improve the equations for predicting Swiss cheese yields.

1. The casein percentage should be estimated directly instead of obtaining it by multiplying the total milk protein by a factor of 0.78 because the casein fraction of milk proteins differ from one breed to another (59). Estimating the actual casein can indicate the actual percentage of casein that goes to the whey.

2. Although this study estimated the whey fat percentage in order to determine the fat recovery, more studies are needed to estimate the actual fat percentage in the whey by taking the samples of the whey after mixing the whey of the cheese vat with the whey after pressing the curd.

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