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Prediction of Mozzarella Cheese Yield from Milk Composition

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PREDICTION OF MOZZARELLA CHEESE

YIELD FROM MILK COMPOSITION

by

Hamzah M. Abu-Tarboush

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

of

MASTER OF SCIENCE

in

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UTAH STATE UNIVERSITY
Logan, Utah

1982

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ABSTRACT

Prediction of Mozzarella Cheese

Yield From Milk Composition

by

Hamzah M. Abu-Tarboush, Master of Science

Utah State University, 1982

Major Professor: Rodney Jay Brown
Department: Nutrition and Food Sciences

This study was conducted to develop and evaluate several formulas
which predict Mozzarella cheese yield from fat and protein content of
milk and moisture content of cheese. During a one month period, 107
samples of milk and cheese were collected at Olympia Cheese Company,
Olympia, Washington. Milk samples were analyzed for fat and protein
content. Cheese samples were analyzed for fat, protein and moisture
content.

Three models were derived to predict the yield of Mozzarella
cheese. The three models were statistically fitted to the data by
applying the Gauss-Newton non-linear least squares method of itera-
tion. The differences among the three models in predicting cheese
yield were insignificant. Any of the three formulas can predict yield
of Mozzarella cheese reasonably well.

(54 pages)

INTRODUCTION

Cheese yield is defined as the amount of cheese manufactured from a given weight of milk. Cheese yield is of great interest to milk producers, cheese makers and dairy economists (18). The influence of milk fat and casein on the amount of cheese produced suggests using fat and casein as a base for milk payment by the cheese industry.

In 1948, and again in 1952, Van Slyke and Price published a formula for predicting Cheddar cheese yields from milk on the basis of its fat and casein content (45). A number of other yield formulas that have been proposed by many workers are listed by Davis (12), but the Van Slyke formula (45) has received the widest acceptance.

The Van Slyke formula is:

$$Y = \frac{[0.93\ F + (C - 0.1)]\ 1.09}{1 - W}$$

where:

Y = Kg Cheddar cheese per 100 Kg milk.

F = Percent fat in the milk.

C = Percent Casein in the milk.

W = Kg moisture per Kg cheese.

This formula assumes that 93% of milk fat is recovered in the cheese, 0.1 Kg of milk casein per 100 Kg of milk is lost in the whey, other milk solids (not fat and casein) plus salt added represent 9% of cheese fat and casein.

The Van Slyke formula is the basis of the program suggested by Ernstrom (14) which uses the Cheddar cheese yielding capacity of milk

as a means of payment. It is possible to derive a yield formula for any varieties of cheese which fits the form of the Van Slyke formula. However, the factors 0.93, 0.1 and 1.09 will differ from cheese to cheese (18).

The objective of this study was to develop a formula to predict Mozzarella cheese yield based on milk compositions. This formula could then be used to determine the value of milk for making Mozzarella cheese.

REVIEW OF LITERATURE

Cheese Making

In the conversion of milk to cheese curd, a partition of milk
constituents occurs which is dependent upon the characteristics of
each component (27, 45). During milk clotting, casein, which exists
as a suspension of micelles in milk, aggregates and forms a network
that entraps some of the water and most of the milk fat. Fat globules
are held within the protein network (12, 27, 45). Table 1 shows the
typical separation of milk constituents into cheese and whey (45).

Table 1. Milk constituents and their distribution in cheese
and whey (45).

Constituent	Milk (Kg)	Cheese (Kg)	Whey (Kg)
Water	87.0	3.90	83.10
Lactose	5.1	0.20	4.90
Fat	4.0	3.70	0.30
Casein	2.5	2.40	0.10
Whey protein	0.7	0.05	0.65
Mineral	0.7	0.35	0.35
Total	100.0	10.60	89.40

Mozzarella Cheese

Mozzarella cheese belongs to the pasta filata or pulled curd category. Mozzarella cheese originated in Italy where it was made from the high fat milk of the water buffalo. People in southern Italy still use the milk of water buffalo to manufacture this kind of cheese while in northern Italy cows' milk has been used to produce Mozzarella cheese (18, 31).

Four types of Mozzarella cheese are recognized by the United States Food and Drug Administration. Table 2 shows fat and moisture levels required for each type to meet the standard of identity (15).

Table 2. Standards of identity for Mozzarella cheese (15).

Type of Cheese	Fat* (%)	Moisture (%)
Mozzarella cheese	$F \geqslant 45$	$52 < W \leqslant 60$
Part skim Mozzarella cheese	$30 \leqslant F < 45$	$52 < W \leqslant 60$
Low moisture Mozzarella cheese	$F \geqslant 45$	$45 < W \leqslant 52$
Low moisture part skim Mozzarella cheese	$30 \leqslant F < 45$	$45 < W \leqslant 52$

*Calculated on the solid basis.

The popularity of Italian cheese in the United States began in 1952, and is still increasing (18). Total cheese production in the United States in 1980 increased seven percent over the previous year. Mozzarella registered the second largest increase in production in 1980, behind only Cheddar cheese. Production of Italian varieties of cheese increased six percent above 1979 production, and Mozzarella alone accounted for 70% of the Italian varieties (39, 44). Figure 1 shows cheese production in the United States in 1980.

Per capita consumption of cheese in the United States has also increased for both American and Italian cheese. During the period of 1969 to 1979 per capita consumption of cheese increased by 60% (40, 41, 42, 43). Figure 2 shows per capita consumption of Italian and American cheese in the United States between 1972 and 1979 (41).

Factors Affecting Cheese Yields

Four main factors determine the yield of all types of cheese (12, 18, 45):

1. Composition of the milk

2. Amounts of milk constituents lost in the whey

3. Amount of salt added in the cheese making process

4. Amount of water retained in the cheese

Factors Affecting Milk Composition

Table 3 shows the average gross composition of cows' milk (17).

Figure 1. United States cheese production in 1965 (39).

Figure 1. United States cheese production in 1980 (39).
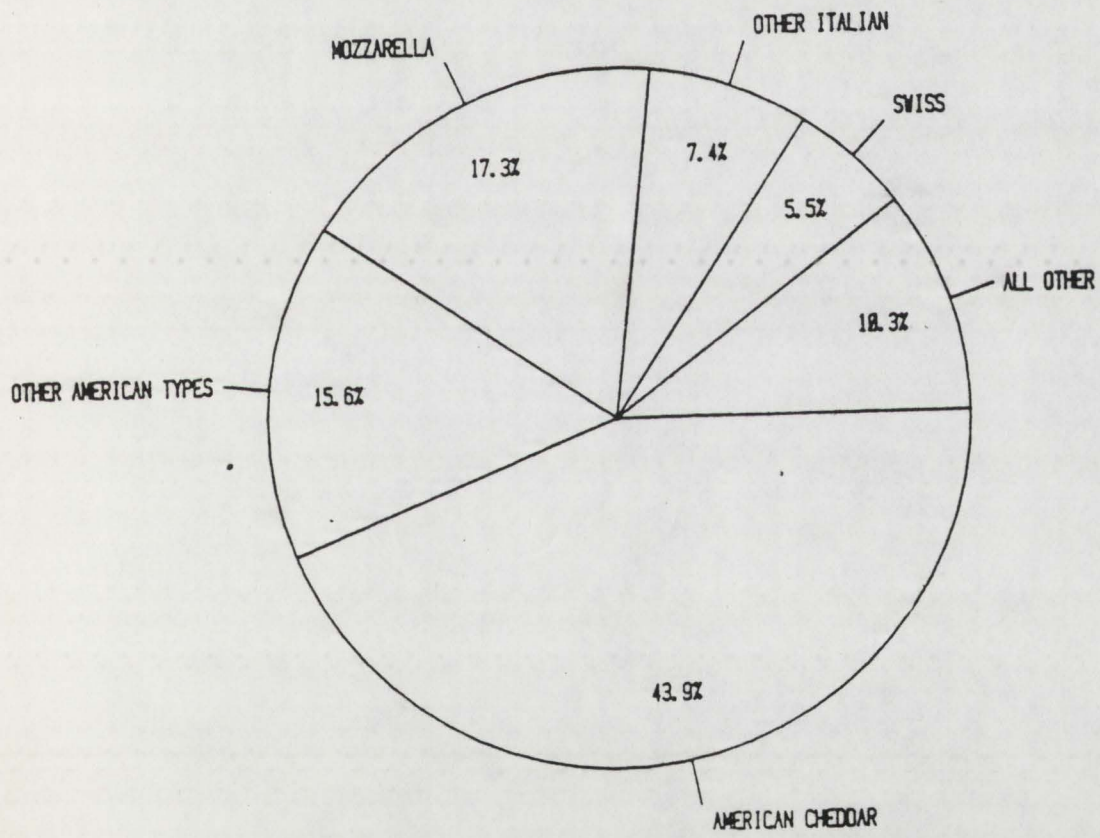
Figure 2. Per capita consumption of Italian and American cheese
          in the United States, 1972-1979 (42).
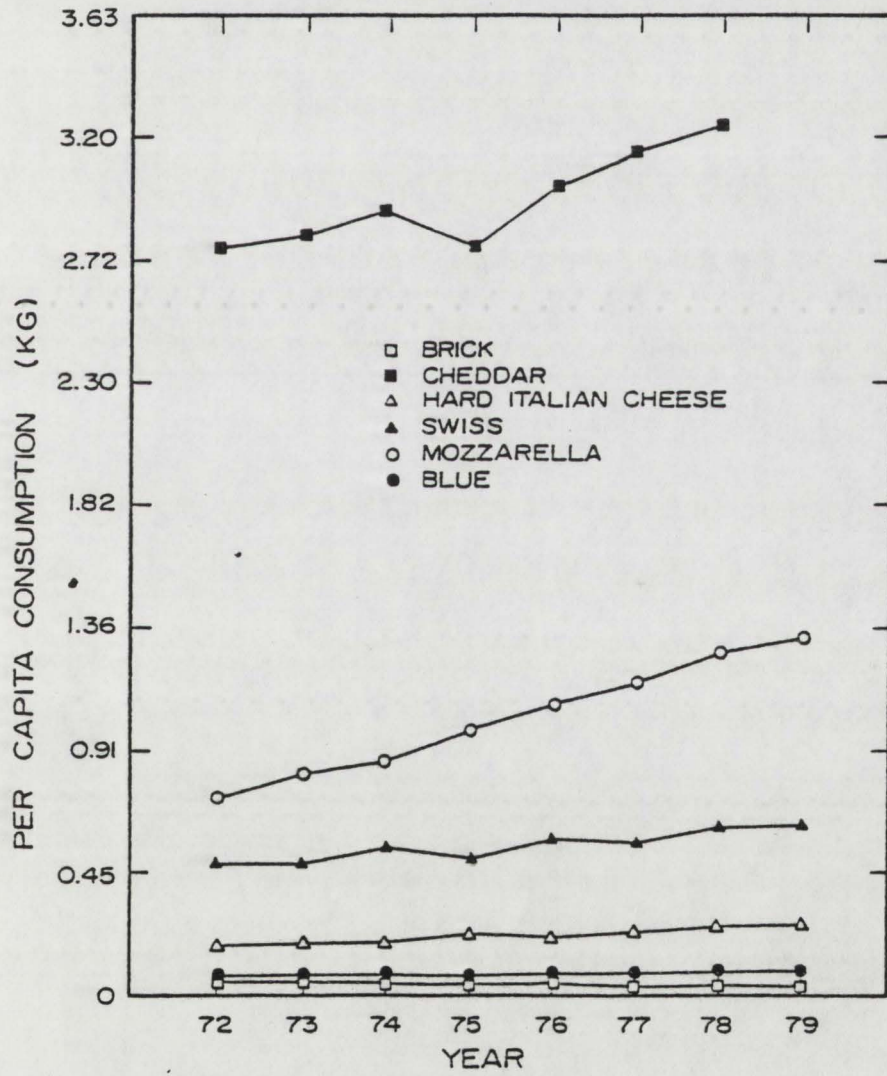
Table 3. Average gross composition of cows' milk (17).

Milk Constituent	Percent
Water	87.2
Fat	3.7
Protein	3.5
Lactose	4.9
Ash	0.7

Many workers have reported factors which may affect the composition of milk. These factors are:

1. Season of year (12, 16, 17, 23, 27, 35, 37, 47).

2. Age of cow (4, 6, 17, 47, 49).

3. Breed of cow (7, 10, 11, 21).

4. Feeding (11, 12, 21, 29, 36).

5. Stage of lactation (4, 8, 20, 21, 49).

6. Disease (32, 47, 48).

7. Heat treatment of milk (1, 13, 25).

8. Cheese manufacturing (12, 27, 46).

Season of year

Irvine (16), in studying the composition of milk in Ontario, Canada, indicated that milk fat reached a minimum in August and a maximum in October. He found that variation in protein content paralleled that of fat except for an unexpected increase in June. The Canadian study showed that the concentration of lactose varied also

and appeared to compensate for variations in protein since the level
of solid-not-fat was fairly stable throughout the entire period
(Figure 3).

Irvine also indicated that cheese yield varied directly with
deviations in the amounts of fat and protein according to seasonal
variation. However, the relationship was not consistent at certain
times of the year (Figure 4). Olson (27) attributed these yield changes
to the variation of milk protein.

Steinsholt and Ystgaard (37) found that the smallest yield was
from May to August, but they excluded June because during this period
the milk had the lowest content of fat, total solids and casein nitro-
gen. Waite, et al. (47), in studying the effect of season of the year
on milk composition, concluded that seasonal variations caused the yield
of milk to increase from January to the May-June period, and then
decrease to a minimum during October-November. Fat content decreased
to a minimum in June, then increased to a maximum in October. Crude
protein and casein contents rose to a peak in May-June and again in
September while the lowest values were observed from January to March.
The range of variation in the values for lactose was less than those
for protein and fat. Davis (12) indicated that there is a relationship
of fat and casein in milk with cheese yield. Maximum cheese yield
occurs during the period from October to December when fat and solids-
not-fat in milk reach their maximum. Minimum cheese yield occurs from
March to April when fat and solids-not-fat in milk decrease to their
minimum. However, he indicated that maximum and minimum yield may be
obtained at other times of the year. Szijarto, et al. (38) found an
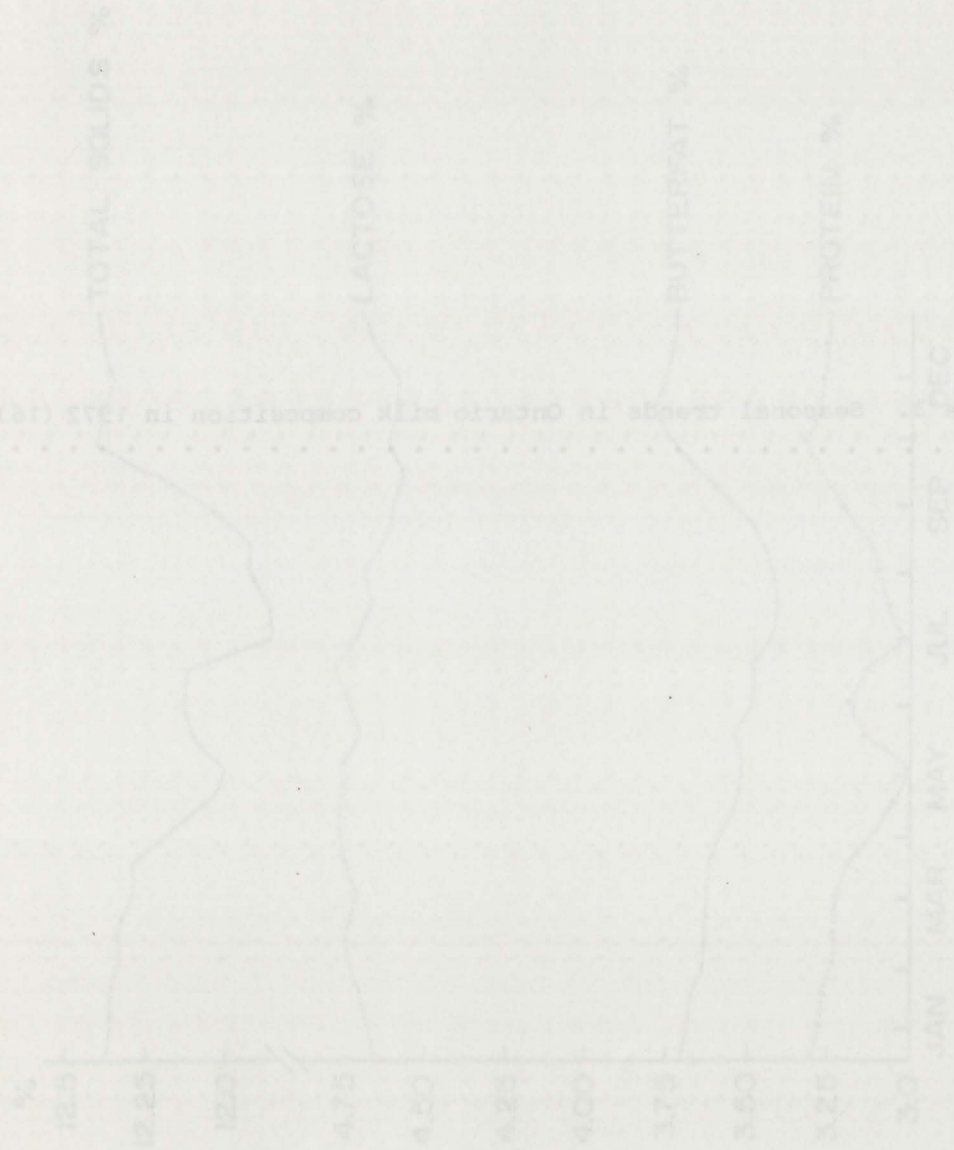
TOTAL SOLIDS %

LACTOSE %

BUTTERFAT %

PROTEIN %

Figure 3. Seasonal trends in Ontario milk composition in 1977 [18].

%
12.5
12.25
12.0
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.0

JAN MAR MAY JUL SEP DEC

Figure 3. Seasonal trends in Ontario milk composition in 1972 (16).
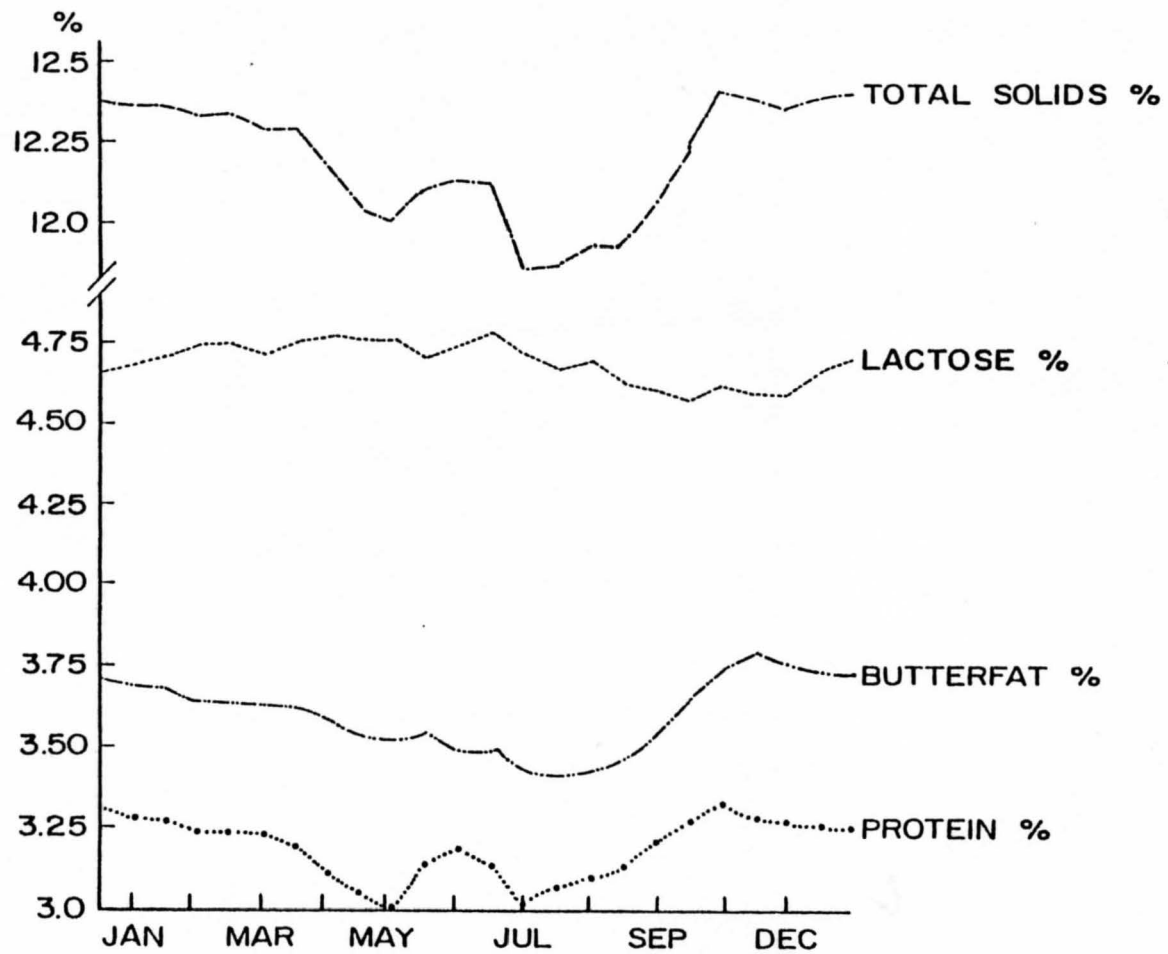
Figure 4.   Correlation between cheese yield and milk fat plus protein content in Eastern Ontario in 1972 (16).
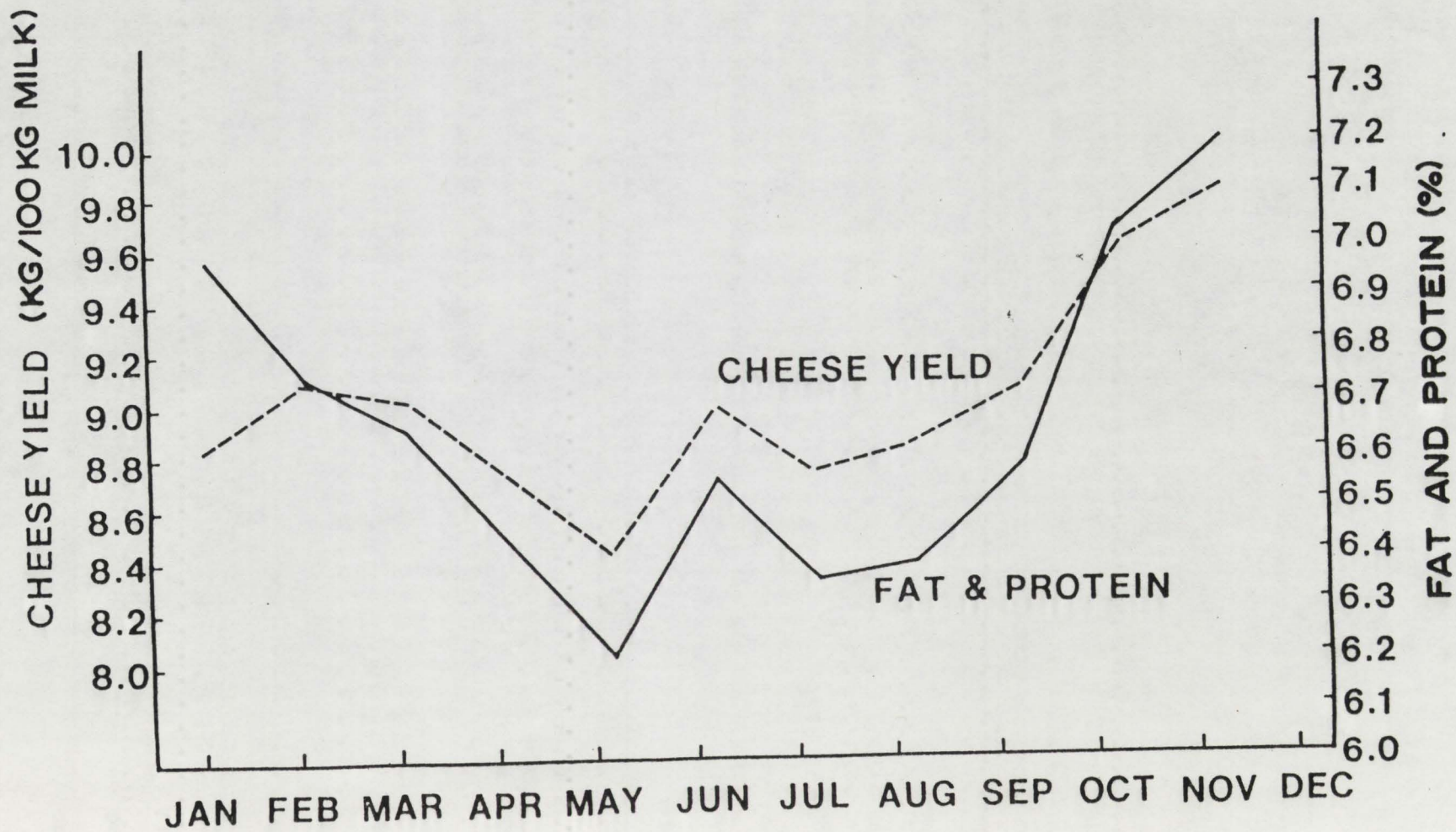
increase in percent casein in milk during May, June and July
and a decrease during August, September and October. Johnson
(17) indicated that the percentage of total solids in milk
decrease sharply from May to June. He attributed this to change
in feed or temperature. Schinckel (35) observed that seasonal
variation affects the amount of cheese which can be manufactured from a
given quantity of milk. They noticed a decline in the cheese yield dur-
ing the late summer period.

Age of cow

Johnson (17) found that both average fat and solids-not-fat per-
centages of milk decline with the age of cow, but lactose and casein
are affected most. Bartlett (6) showed that age of the cow has an
influence on the lactation curve. Many workers have indicated that there
is a decline in solids-not-fat percentages with the age of a cow or
advancing lactation which is almost twice the magnitude of the decline
in fat percentage (4, 6, 47, 49). They reported declines in solids-
not-fat from 0.21 to 0.45% during the first seven years of lactation.
Most of this decrease was due to a decline in lactose content. While
the crude protein did not change much with age, the casein percentage
declined during the first seven lactations almost as much as the lactose,
suggesting that the whey protein and non-protein nitrogen fractions in-
creased with advancing lactation number.

Breed of cow

Cerbulis and Farrell (10) stated that cheese should be made from
milk which has high casein content without concern for whey protein
and lactose content because casein is the principal protein component

of cheese. They also indicated that yield of cheese depends directly on the amount of casein in milk. In a study involving 26 Holstein, 25 Jersey, 24 Guernsey, 25 Ayrshire, 33 Brown Swiss and 18 Milking Shorthorn cows, they found that the largest protein percentage is in milk from Jersey and Brown Swiss cows and the lowest is in milk from Holstein and Milking Shorthorn cows. The percent casein (as percent of protein) is highest in Jersey and Ayrshire milk while lowest in Holstein and Guernsey milk (Table 4). Therefore, milk from Jersey or Ayrshire cows would be better for cheese making than milk from other breeds. Chapman (11) claimed that Ayrshire milk is most suitable for cheese making due to its small even-sized fat globules. Blake et al. (7) found that the percent casein (as percent of protein) is higher in Jersey's milk than in Holstein's milk. Armstrong (2) found that the highest fat content was in Jersey milk.

Legates (21) indicated that breed affects milk composition and that fat content varies more than any other constituent. He also indicated that there is a variation in solids-not-fat due to breed of cow and that most of the variation in solids-not-fat is accounted for by variation in protein content.

Feeding

Davis (12) claimed that prolonged feeding of cows without green fodder of any kind may lead to the cows secreting a milk which clots poorly with rennet or even not at all. He thought that grass, hay, dried grass and silage may have a special significance for the cheese making farmer. He said that some feed like linseed cake and sunflower seed cake may adversely affect milk for cheese making when fed in large

Table 4. Fat, protein, casein and lactose in milk from
          different breeds of cows (10).

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

quantities. Chapman (11), however, indicated that the high nutritional
value of spring grass causes a rise in milk solids-not-fat and a
decrease in fat when compared to winter feed.

Schingoethe et al. (36) concluded that adding dried whole whey
to the grain ration of cows may prevent the drop in milk fat tests
which is experienced on high-grain rations. He attributed that to the
minerals in the whey as well as lactose. Banks, et al. (5) reported
that the addition of fat to a fat-deficient diet may result in milk
with a different protein to fat ratio.

Legates (21) indicated that a decrease in solids-not-fat occurs
when cows are fed rations with 25% less than normal energy requirements
and most of this change is due to protein. Patchell (29) and Rook,
et al. (33) found that underfeeding may decrease the solids-not-fat
percentage by 0.3 to 0.4%. The decrease in protein content is somewhat
more than the decrease in the lactose content.

Stage of lactation

Legates (21) indicated that after the first test of a cow's lactation total solids, solids-not-fat and protein drop to reach a low value by the second month of lactation. Lactose content is highest at the beginning of the lactation and declines linearly during the remainder of the lactation while solids-not-fat rises toward the end of lactation.

Many workers (4, 8, 20, 21, 22, 24, 28, 30, 49) have indicated that stage of lactation influences milk components. The percentage of fat and protein are high in colostrum, drop to a low around the second month, then rise at slightly different rates, increasing most rapidly at the end of lcatation. Lactose is low in colostrum then rises to normal in the first week and remains steady until mid-lactation. Then it decreases slowly at first and then more rapidly at the end of lactation. They have also concluded that there is a small increase in protein and solids-not-fat after the sixth month of lactation due to pregnancy.

Disease

Weaver and Kroger (48) found that as somatic cell count in milk increases, total protein content is also increased. The increase in total protein is due to the leak of serum albumin and immunoglobulins from damaged cells into the milk. However, they also found that as the somatic cell count increases casein content in the milk decreases.

Waite, et al. (47) observed a decrease in lactose and solids-not-fat by 0.38% and 0.25%, respectively, as the total leucocyte count

increased to 500,000 per ml. They also observed a negative correlation between casein and cell counts.

The Wisconsin Dairies study as shown by Rhodes (32) attributed the losses in yield of cheese made from mastitic milk to its low casein content and alkaline pH. Moreover, the increase in sodium chloride and pH adversely affect rennet coagulation and cause losses of casein in the whey. Rhodes also concluded that a loss of 0.31 Kg of cheese per 100 Kg of milk was observed above 640,000 cells per ml.

Heat treatment of milk

El-Sadek and Motteleb (13) found that pasteurization of buffalo milk increased the yield of cheese over that made from raw milk. They found that heating milk to 170°C for 15 minutes before making the cheese resulted in a higher yield when compared to the yield of cheese made from raw milk. Angevine (1) indicated that higher temperature or longer holding (or a combination of both) can affect the yield of Cottage cheese. He also concluded that higher temperature may incorporate some of soluble protein into the cheese curd. Narasimhan (25) found that the yield of Cottage cheese was increased by 15.6% when the heat treatment temperature of skim milk was increased from 61.8° to 79.4°C for 30 minutes due to the retention of whey proteins in the curd.

Cheese manufacturing

Olson (27) mentioned that loss of fat and casein may occur at any stage during cheese making. Pumping with inadequately sized pumps and cutting prior to the formation of a good coagulum are examples of things which cause fat and casein loss. Davis (12) attributed the

loss of fat and casein to violent agitation of milk and curd and the temperature employed.

Van Slyke and Publow (46) indicated that loss of fat in the manufacture of Cheddar cheese may occur due to the failure to keep fat well distributed in milk, cutting the curd when it is too soft, heating the curd too rapidly or to too high temperatures, excessive piling of curd and putting curd into the press while still too warm. Loss of casein is due to violence in cutting the curd, agitation while removing the whey from the curd and any condition which interferes with the complete coagulation of the milk casein by rennet.

The Relationship of Fat and Casein

to Yield of Cheese

There is a relationship between fat and casein percentages in milk as found by Van Slyke and Price (45). Van Slyke and Publow (46) also reported a positive correlation between fat and casein. An increase in fat content of 1% is accompanied by an increase in casein of 0.4%. However, this relationship is reliable only for an average of a very large number of cows and is not reliable for predicting the relationship between fat and casein in milk from individual cows or herds. Van Slyke and Price (45) also found an increase in the yield of cheese in proportion to the increase of fat and casein. they observed that 50% of milk solids were recovered in the cheese, and the remainder went into the whey. They also indicated that 90% of cheese solids are fat and casein.

Many workers have mentioned the relationship between yield of cheese and milk fat and casein (12, 16, 27, 45, 46). Olson (27)

indicated that there was a direct linear relationship between the
amount of fat and casein in milk and the yield of Cheddar cheese.
Mickelsen (24) found that cheese yield depends on fat as well as casein
of the milk. Steinsholt and Ystgaard (37) concluded that there is a
positive correlation between the yield of cheese and the casein frac-
tion, fat content and total solids of milk.

Relation of Water to Cheese Yield

Van Slyke and Price (45) indicated that estimating the yield of
cheese depends on the fat and casein of milk as well as the moisture
content of the cheese. The higher the moisture in the cheese the more
the yield and vice versa. The water content of cheese is independent
of water content of the milk. Cheese making operations can determine
the amount of water required in cheese to meet the standards of
identity.

Predicting Cheese Yields

Many formulas have been derived by many workers to predict cheese
yield as listed by Davis (12):

A. Formulas based on fat and casein:

    1. Babcock, et al. (1910):

        Cheese yield = 1.1 fat + 2.5 casein

    2. Van Slyke and Price (1932):

        Cheese yield = 1.63 (casein + fat)

    3. McDowall (1936) (using Van Slyke's data):

        Cheese yield = 1.4 (casein + fat) + 1.04

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4.   McDowall formula (1936) (using his data):

   a.   Cheese yield = 1.22 (casein + fat) + 2.32

   b.   Cheese yield = 1.07 fat + 2.35 casein

5.   Shelton and Meaney (1937, 1938):

Yield = $F - \frac{4F}{100} + C - \frac{4C}{100} + \frac{22C}{100} \times 2.26$

   This formula makes the following assumptions:

   a.   Four percent of the milk fat lost in the whey.

   b.   Four percent of the milk casein lost in the whey.

   c.   A retention in the cheese of non-casein solids-not-fat

        equivalent to 22% of the casein.

   d.   A cheese moisture content equivalent to 126% of the

        solids-not-fat retained.

6.   The above formula was simplified by McDowall in 1939 to:

        Yield = 0.96 fat + 2.67 casein.

B.   Formula based on total solids or fat plus solids-not-fat:

Yield = fat + 1/3 solids-not-fat.

The above formula was derived by VanDam and Janes in 1931.

C.   Formula based on milk fat and protein in milk and on water and salt

in the cheese:

Bergman and Joost in 1953 suggested the following formulas:

   a.   Yield = $0.91\ F + 0.77P + 0.48 + \frac{W(0.77P + 0.48)}{(100 - W)}$

   b.   Yield = $\frac{91F + 77P + 40}{100 - S + W}$

where:

F = Represents the percentage of fat in milk.

P = Percentage of protein in milk.

W = Percentage of water in cheese.

S = Percentage of salt in water.

D. Formula based on fat and total nitrogen (or total protein):

Schulz and Kay in 1957 proposed the following formula:

$$\text{Yield} = \text{net fat} + 0.75 + \frac{0.825 \ Wff}{100 - 1.1 \ Wff} \ P$$

where:

net fat = milk fat - whey fat.

Wff = moisture content of the fat-free cheese.

P = protein content of the milk, assuming 75% of this goes into the cheese.

This formula was simplified to:

Yield = net fat + F(P)

where:

F = a factor which varies with the moisture content of the fat-free cheese.

Shultz and Kay gave values of F for different varieties of cheese according to change in the moisture percent in fat-free cheese.

E. Formula based on fat and casein in milk and moisture content of cheese:

Formula derived by Van Slyke and Price (45) to predict the yield of Cheddar cheese:

$$Y = \frac{[0.93F + (C - 0.1)] \ 1.09}{1 - W}$$

where:

Y = Kg Cheddar cheese per 100 Kg milk.

F = Percent fat in the milk.

C = Percent casein in the milk.

W = Kg water per Kg cheese.

The Van Slyke formula assumes that 93% of milk fat is recovered in the cheese, 0.1 Kg of milk casein per 100 Kg of milk is lost in the whey, other milk solids (not fat and casein) plus salt added represent nine percent of cheese fat and casein.

None of the above formulas have received wide acceptance except the Van Slyke and Price formula (45). Ernstrom (14) suggested the possibility of using the cheese yielding capacity of milk as a means of paying for milk in the cheese industry and used the Van Slyke and Price (45) yield formula for Cheddar cheese as a basis of this program (14). Many suggestions have been made for component pricing of milk based on fat, protein, solids-not-fat (19). The difficulty of establishing values for each component or group of components in milk has limited their success (9). Ernstrom's program (14) is being used successfully (9).

METHODS AND PROCEDURES

Milk and Cheese Source

Cheese was made at Olympia Cheese Company in Olympia, Washington during the period from June 28, 1981 to July 30, 1981. Analysis of milk fat and protein were done in the Olympia Cheese Company Laboratory. The analysis of cheese fat and protein were done in the Department of Nutrition and Food Sciences at Utah State University, Logan, Utah.

Cheese Making Procedure

Three vats of Mozzarella cheese were made daily, four days a week for five weeks. The cheese making procedure was as follows:

1. Fat in the milk was standardized as follows:

   (protein %) x (0.63) = % fat of milk used to make skim Mozzarella cheese.

   (protein %) x (0.85) = % fat of milk used to make whole milk Mozzarella cheese.

2. Setting the milk and cutting the curd:

   Lactic starter was added to the vat as milk was being pumped into it. The vat eventually contained about 9091 Kg of milk and about 38.6 Kg of lactic starter. One hour after filling began the vat weight was taken and then 0.71-0.85 Kg rennet was added. The vat was set at 34°C (93°F). Decolorizer (0.1% sodium benzoate and 1% sodium propeonate) was added just before the rennet. After 30 minutes the curd was cut.

3. Cooking the curd:

    Cooking began five minutes after cutting the curd. The tem-
    perature was raised to 41.5°C (107°F) over a 30-40 minute
    period.

4. Draining:

    Curd was drawn at one h 40 min after setting. The curd was
    separated from the whey by a screen and dropped into 49°C
    (120°F) water.

5. Agitation:

    Curd was agitated for two to three hours until pH was near 5.4
    and the proper texture was achieved.

6. Forming curd blocks:

    Curd was then dropped into a molder and extruded into 2.3 Kg
    (5 lb) blocks.

7. Cooling:

    Cheese blocks were placed in fresh water at 4.4°C (40°F) for
    15-20 min.

8. Brining:

    Cheese blocks were then transferred to brine (95-97% NaCl)
    solution at 3.5-4.4°C (38-40°F) and left for ten h (skim
    Mozzarella cheese) or 12 h (whole milk Mozzarella).

9. Package:

    Cheese blocks were pulled from the brine, drained for a short
    time and packaged in 18.2 Kg (40 lb) packages.

Milk Analysis

The percentages of fat and protein in milk samples were determined

using a Multispec M infrared milk tester at 40°C. The weight of the milk in every vat was taken by a dip stick. The dip stick reading was converted to the weight of milk by using suitable table prepared for each vat. Vats were recalibrated just prior to the beginning of this study.

Cheese Analysis

Cheese fat was determined by the Babcock method (18). Moisture in the cheese was determined by the oven method (45) with slight modifications in which beakers (50 ml) were used instead of dishes. The oven was set at 110°C. Samples of cheese were left in the oven for 16 h.

Protein in the cheese was measured by a Kjeldhal procedure (3) with some modifications. Methyl red-methylene blue indicator was used instead of methyl red indicator. Seventy milliliters of 50% NaOH was added carefully to the digestion flasks. HCl (0.1N) was used to titrate the ammonia held by the Boric acid. Total protein in the samples was obtained by multiplying percent total nitrogen by a factor of 6.38. Total protein obtained was multiplied by 0.78 (10) to estimate percent casein in the samples.

Weight of the cheese was taken separately for each vat during the packaging of the cheese.

Statistical Analysis

The data collected was used to evaluate each of three models. The models are:

Model 1   (same form as Van Slyke formula)

$$Y_1 = \frac{[aF + (0.78P - b)]c}{1 - W}$$

where:

a = Percent milk fat retained in the cheese.

b = Kg milk casein lost in the whey per 100 Kg milk.

c = Amount of other milk solids (not fat and casein) plus salt

    added as a percent of cheese fat and casein.

Model 2 (casein lost as a percent of total casein rather than as a

    constant amount) and based directly on protein rather than 0.78P.

$$Y_2 = \frac{(aF + bP)}{1 - W}$$

where:

a = Percent milk fat retained in the cheese times percentages of

    milk solids (not fat and casein) and added salt.

b = Percent milk protein retained in the cheese times percentages

    of other milk solids (not fat and casein) and added salt.

Model 3 (same as model 2 plus casein:fat ratio controls amount of fat

    recovered in cheese)

$$Y_3 = \frac{ab^{\frac{(0.78P)}{F}} F + cP}{1 - W}$$

where:

$ab^{\frac{(0.78P)}{F}}$ = percent milk fat retained in the cheese times percen-

    tages of other milk solids (not fat and casein) and

    added salt.

$\frac{(0.78P)}{F}$ = Casein to fat ratio of milk.

C = Percent milk protein retained in the cheese times per-

    centages of other milk solids (not fat and casein) and

    added salt.

In all three models:

Y = Kg cheese per 100 Kg milk.

F = Percent fat in milk.

P = Percent protein in milk.

W = Kg moisture per Kg cheese.

Gauss-Newton non-linear least squares was used to fit each model to the data. The Gauss-Newton method performs a least squares fit of data to a function. The function can depend upon any reasonable number of parameters and can be non-linear. Data can have an arbitrary number of independent variables. Optimal function papameter values are found by the Gauss-Newton iteration method, starting from a set of initial guesses, to minimize the residual sum of squares (34).

Average percent fat recovery, casein lost factor and factor of other milk solids (not fat and casein) and salt added (as a percent of cheese fat and casein) retained in cheese based on the Van Slyke formula (45) were determined with a computer program (APPENDIX). These values were used as the starting point for iteration of the first model. Starting points for the other iterations were based on these values and the average composition of all milk samples.

RESULTS

The following results were obtained by applying Gauss-Newton
iteration to the data:

Model 1

$$Y_1 = \frac{[aF + (0.78P-b)]c}{1 - W}$$

$$Y_1 = \frac{[0.88F + (0.78P - 0.02)]\,1.12}{1 - W}$$

This suggests that 88% of milk fat was retained in the cheese and
that 0.02 Kg of milk casein was lost per 100 Kg of milk. Added salt
and other milk solids (not fat and casein) account for yield equal to
12% of cheese fat and casein.

Model 2

$$Y_2 = \frac{(aF + bP)}{1 - W}$$

$$Y_2 = \frac{(0.86F + 0.97P)}{1 - W}$$

In this model 0.86 represents percent milk fat retained in the
cheese times added salt and other milk solids (not fat and casein).
The parameter b = 0.97 represents percent milk protein plus accompanying
salt and other milk solids (not fat and casein) retained in the cheese.

Model 3

$$Y_3 = \frac{ab^{\frac{(0.78P)}{F}} F + cP}{1 - W}$$

$$Y_3 = \frac{(0.89)(1.24)^{\frac{(0.78P)}{F}} F + 0.78P}{1 - W}$$

In this model $(0.89)(1.24)^{\frac{(0.78P)}{F}}$ represents percent milk fat and other milk solids (not fat and casein) and salt added as a function of cheese fat and casein. Also, 0.78 represents milk protein retained in the cheese times salt added and other milk solids (not fat and casein) as a percent of cheese fat and casein.

For all three models:

Y = Kg cheese per 100 Kg milk.

F = Percent fat in milk.

C = Percent casein in milk.

P = Percent protein in milk.

W = Kg water per Kg cheese.

The correlation coefficients (r) between the actual yields and the predicted yields for the three models were found by linear regression.

Table 5 and Figures 5, 6 and 7 show the correlation coefficients (r) between the actual yields and the predicted yields, and the residual sums of squares (RSS) for the three models.

Table 5. Correlation coefficients (r) between actual and predicted yields and residual sums of squares (RSS) of the three models.

Model	r	RSS
1. $Y_1 = [0.88F + (0.78P - 0.02)]1.12/1-W$	0.7535	40.50
2. $Y_2 = (0.86F + 0.97P)/1-W$	0.7534	39.49
3. $Y_3 = (0.89)(1.24)^{\frac{(0.78P)}{F}} F + 0.78P/1-W$	0.7533	39.50
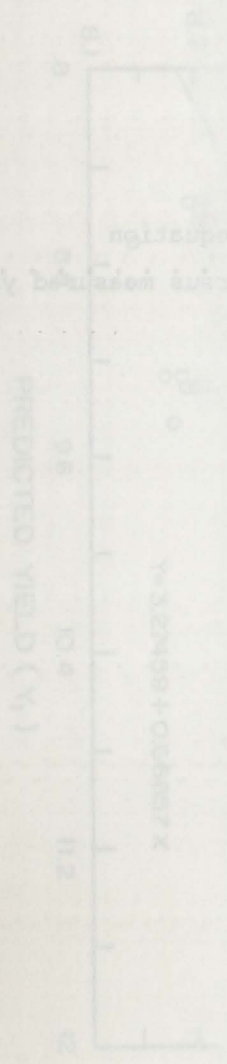
Figure 5. Regression of yield predicted by the equation

$$Y_1 = \frac{[0.88F + (0.78P-0.02)]1.12}{1 - W}$$

versus measured yield.

$Y = 3.27459 + 0.66657 X$
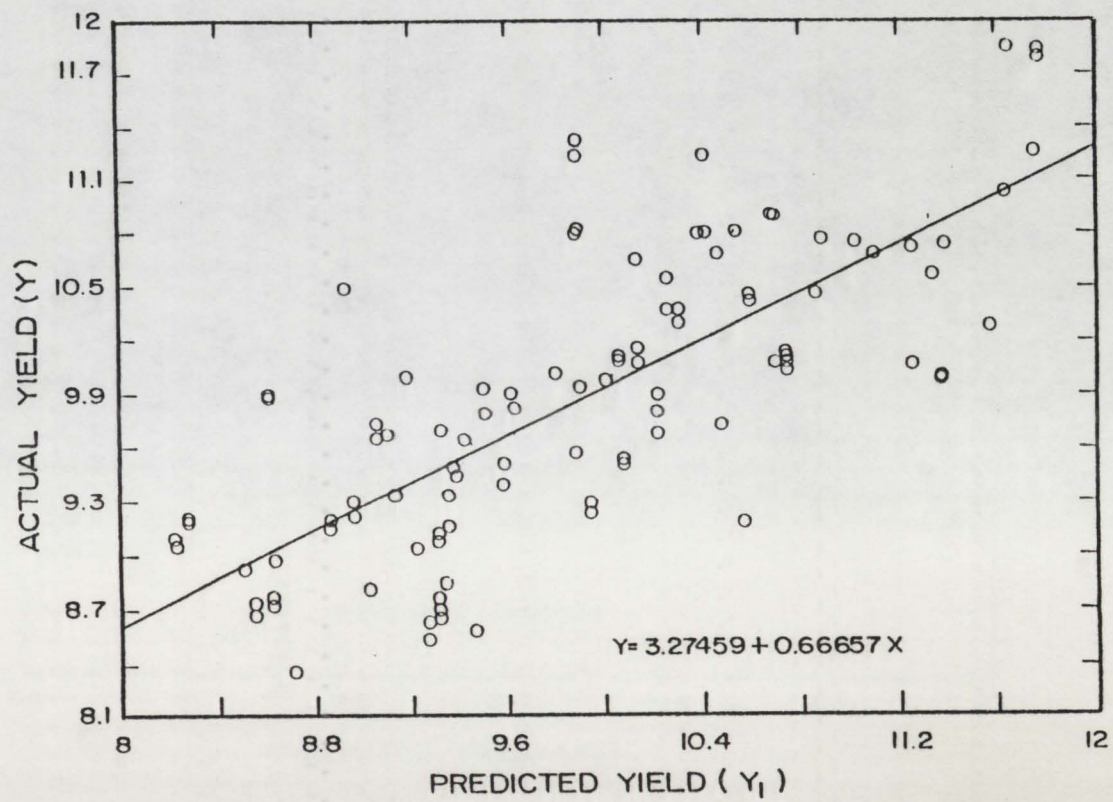
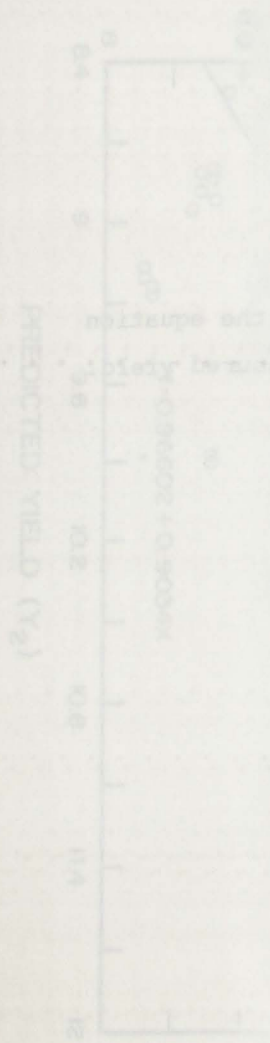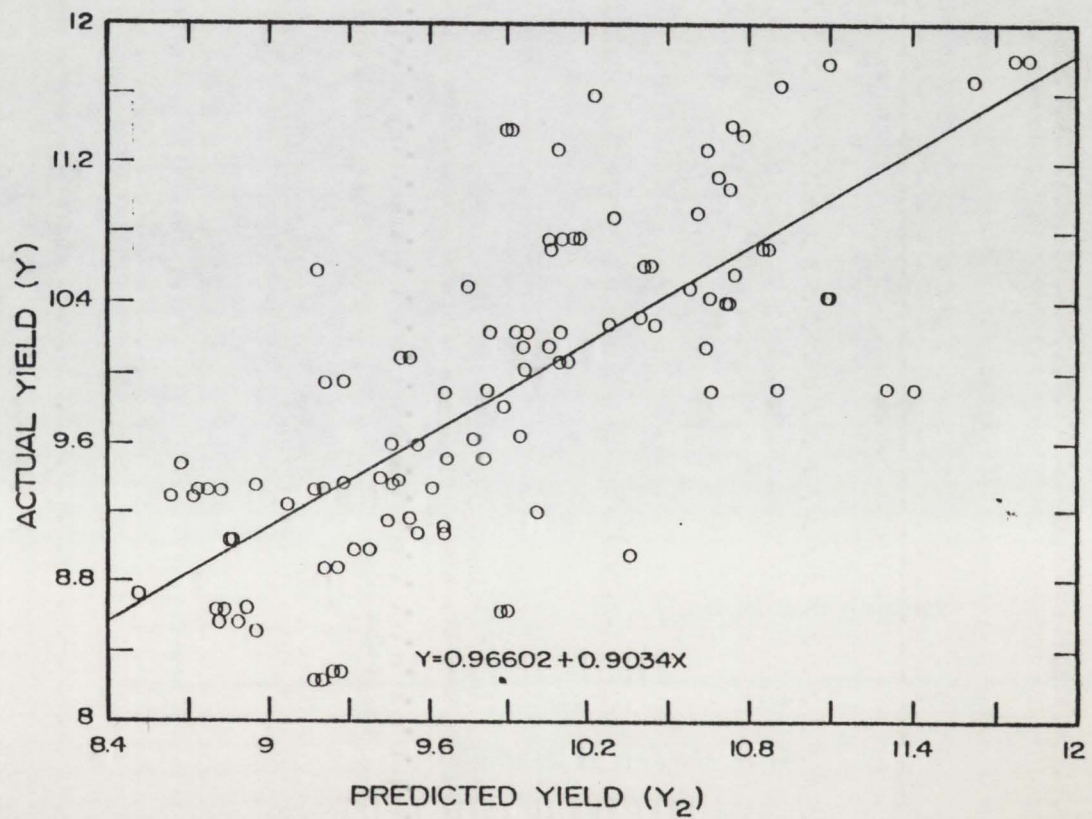Figure 6. Regression of yield predicted by the equation
$$Y_2 = \frac{(0.86F + 0.97P)}{1 - W}$$ versus measured yield.

Y=0.96602+0.9034X

ACTUAL YIELD (Y)

PREDICTED YIELD (Y$_2$)

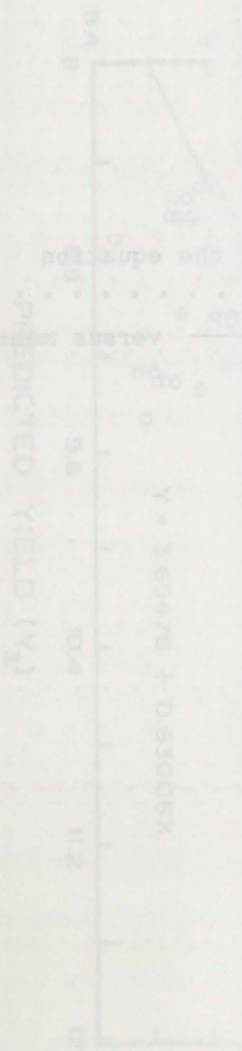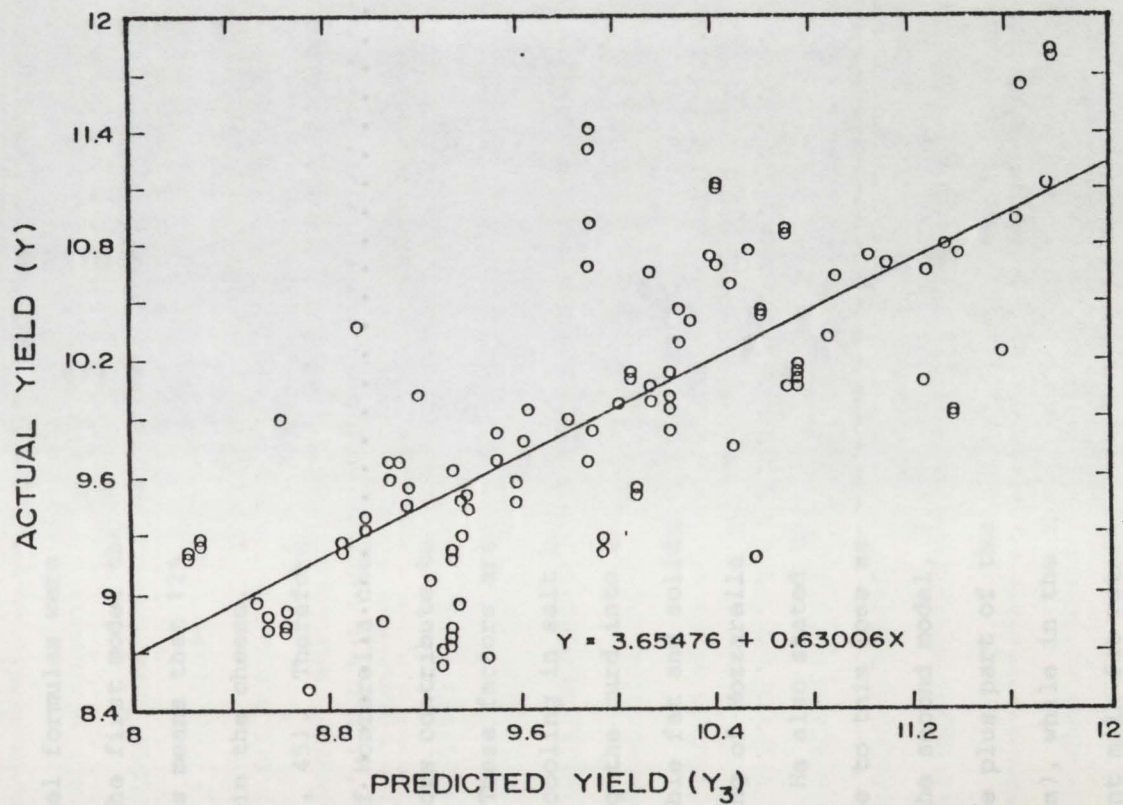Figure 7. Regression of yield predicted by the equation

$$Y_3 = \frac{(0.89)(1.24)^{\frac{(0.78P)}{F}} \quad F + 0.78P}{1 - W}$$ versus measured yield.

$Y = 3.65476 + 0.63006X$

ACTUAL YIELD (Y)

PREDICTED YIELD (Y₃)

DISCUSSION AND CONCLUSIONS

The purpose of this study was to develop an equation to predict the yield of Mozzarella cheese from milk of different compositions. Three model formulas were derived to predict Mozzarella cheese yield.

In the first model the fat lost accounted for 12% of total milk fat. This means that 12% of milk fat was lost in the whey and 88% retained in the cheese. In Cheddar cheese the fat loss factor is 7-10% (14, 45). Therefore, there is more loss of milk fat in the manufacture of Mozzarella cheese than in the manufacture of Cheddar cheese. Many factors contribute to the relatively high loss of fat in Mozzarella cheese. These factors are: 1) blending in hot water, then molding hot curd and cooling in salt brine, 2) vigorous agitation of the curd and 3) cutting the curd into small particles. Nilson (26) mentioned that considerable fat and solids-not-fat losses occur during mixing, cooking and molding of Mozzarella curd, with the greater loss occurring during molding. He also stated that the design of mechanical equipment can contribute to this loss as can fat level, curd pH and water temperature.

In the second model, 0.86 represented milk fat that remained in the cheese plus part of the added salt and other milk solids (not fat and casein), while in the third model $(0.89)(1.24)^{\frac{(0.78P)}{F}}$ represented the percent milk fat retained in the cheese times added salt and other milk solids (not fat and casein) as a function of cheese fat and casein. Casein to fat ratio (C/F) influences the percentage of fat which goes into whey (30). The more fat there is relative to casein, the more fat will be lost in the whey. One purpose of using

standardization is to minimize the loss of fat into the whey (18).
Van Slyke and Price (45) indicated that fat in low test milk was of
slightly greater value (as far as yield is concerned) than was fat in
rich milk. Since milk used for Mozzarella cheese is standardized (so
variations in casein to fat ratios are small) this concept could not
be adequately evaluated. There was not enough variation in C/F ratios
to see whether the yields were influenced or not. This model may be
more useful for other cheese varieties where variations in casein to
fat ratios are high.

In model 1, the casein lost factor was 0.02. In other words,
0.02 Kg milk casein per 100 Kg milk was lost in the whey. In Cheddar
cheese the casein lost factor is 0.1. Therefore, in Mozzarella cheese
less casein is lost in the whey. For model 2, the assumption that
casein is equal to 78% of milk protein was not taken into consideration
and 97% represented the percent milk protein retained in the cheese
plus some of the added salt and other milk solids (not fat and casein).
For model 3, 0.78 represented the percent milk protein retained in the
cheese plus added salt and other milk solids.

The recovery factor of added salt and other milk solids (not fat
and casein) was 1.12 in the first equation. Added salt and other milk
solids (not fat and casein) accounted for 12% of the cheese fat and
casein. In Cheddar cheese, added salt and other milk solids (not fat
and casein) represent 9% of cheese fat and casein. Recovery factor of
added salt and other milk solids (not fat and casein) is higher for
Mozzarella cheese than for Cheddar cheese.

Table 5 shows the residual sums of squares for the three models.
The residual sum of squares of the first equation was 40.50 that for

the second equation was 39.49, and that for the third equation was
39.50. Figures 5, 6 and 7 show the regressions of yield predicted by
equations 1, 2 and 3 versus measured yields. The correlation coeffi-
cient (r) between actual yields and the predicted yields for the three
equations were 0.7535, 0.7534 and 0.7533 respectively as shown in Table
5. The differences among the three correlation coefficients and the
residual sums of squares of three equations were insignificant. As a
result, Mozzarella cheese yields can be predicted equally well by using
any of the three equations. However, the first model is recommended
because average percent fat recovery, casein lost factor and the factor
for other milk solids and salt added (as a percent of cheese fat and
casein) retained in cheese are represented by the constants in the
formula. In both of the other models the constants cannot be explained
as having a physical meaning.

This work shows that one can easily and reasonably predict
Mozzarella cheese yields and consequently compute the value of milk
for the Mozzarella cheese making industry. Further study is recommended
to derive more reliable and accurate equations to predict Mozzarella
cheese yields by taking into consideration variations in the casein
fraction of milk protein. A direct method for casein measurement is
recommended. More accurate equations may then be developed for pre-
dicting Mozzarella cheese yields by using casein directly rather than
a constant percentage of total protein.

REFERENCES

1. Angevine, C.N. 1974. 1974 yields of Cottage cheese. Cult.
    Dairy Prod. J., 9(5):9.

2. Armstrong, T.V. 1959. Variations in the gross composition of milk
    as related to the breed of the cow: A review and critical evalua-
    tion of literature of the United States and Canada. J. Dairy Sci.,
    42:1.

3. Association of Official Analytical Chemists. 1975. Official and
    tentative methods of analysis. 2nd ed. Association of Official
    Analytical Chemists. Washington, D.C.

4. Baily, G.L. 1952. Studies on variations in solids-not-fat content
    of milk. J. Dairy Res., 19:89.

5. Banks, W., J.L. Claperton, M.E. Ferrie, and A.G. Wilson. 1976.
    Effect of feeding fat to dairy cows receiving a fat-deficient diet.
    J. Dairy Res., 43:213.

6. Bartlett, S. 1934. Variations in the solids-not-fat content of
    milk. I and II. J. Dairy Res., 5:113.

7. Blake, R.L., I.B. Nmai and R.L. Richter. 1980. Relationships
    between distribution of major milk proteins and milk yield.
    J. Dairy Sci., 63:141.

8. Brog, R.A. 1971. Proposed economic formulat (Model) for deriving
    the value of cheese milk. J. Dairy Sci., 54:1134.

9. Brown, R.J. 1981. Computerized cheese yield pricing of milk.
    2nd Biennial Marschall International Cheese Conference. Dane County
    Exposition Center, Madison, Wisconsin.

10. Cerbulis, J., and H.M. Farrell. 1975. Composition of milks of
    dairy cattle. I. Protein, lactose and fat contents and distribution
    of protein fractions. J. Dairy Sci., 58:817.

11. Chapman, R.H. 1974. The effect the chemical quality of milk has
    on cheese quality. Dairy Ind., 39:329.

12. Davis, J.G. 1965. Cheese. Vol. I. American Elsevier Publ. Co.,
    Inc., New York, N.Y.

13. El-Sadek, G.M., and L. Abd-El-Motteleb. 1958. Effect of the heat
    treatment of milk on the yield, quality and certain properties of
    standardization. J. Dairy Res., 25:480.

14. Ernstrom, C.A. 1980. A workable milk pricing system based on cheese yields. 4th Biennial Cheese Industry Conference. Utah State University, Logan, Utah.

15. Food and Drug Administration. Cheese and cheese products. Definitions and standards under the Federal Food, Drug, and Cosmetic Act, Part 19, Title 21. Code of Federal Regulations U.S. Dept. Health, Ed., and Welfare. 1976.

16. Irvine, D. 1974. The composition of milk as it affects the yield of cheese proceed. 11th Annual Marschall Invitational Italian Cheese Seminar. Madison, Wisconsin.

17. Johnson, H.A. 1974. The composition of milk. In "Fundamentals of Dairy Chemistry:, Ed. B.H. Webb, A.H. Johnson and J.S. Alford. AVI Publ. Co., Inc., Westport, Conn.

18. Kosikowiski, F. 1968. Cheese and Fermented Milk Foods. 2nd ed. F.V. Kosikowski and Associates, Brooktondale, New York.

19. Ladd, G.W. and J.R. Dunn. 1979. Estimating values of milk components to a dairy manufacture. J. Dairy Sci. 62:1705.

20. Larson, B.L., G.D. Rolleri, and K.A. Kendall. 1957. Protein, fat, and milk production during the entire lactation period. J. Dairy Sci., 39:204.

21. Legates, J.E. 1956. Genetic and environmental factors affecting the solids-not-fat composition of milk. J. Dairy Sci., 43:1527.

22. Ling, E.R. 1956. Part II. The composition of milk and dairy products and methods of analysis. J. Dairy Res., 23:144.

23. Ling, E.R. 1958. Part II. Milk composition and analysis, and cheese ripening. J. Dairy Res., 25:132.

24. Mickelsen, R. 1974. Factors affecting yields of Cottage cheese. Report 903, Kansas State Univ., Manhattan, Kansas.

25. Narasimhan, R. 1979. An evaluation of heat treatment and ultra-filtration process on skim milk to increase Cottage cheese yield. Thesis, Utah State University, Logan, Utah.

26. Nilson, K.M. 1973. A study of commercial mixer-cooker and molders in use today. Proceed., 10th Annual Marschall Invitational Seminar, Madison, Wisc.

27. Olson, N.F. 1977. Factors affecting cheese yield. Dairy Ind. Inter., 42:(4)14.

28. Parkhie, M.R., L.O. Gilmore, and N.S. Fechheimer. 1966. Effect of successive lactations, gestation and season of calving on constituents of cow milk. J. Dairy Sci., 49:1410.

29. Patchell, M.R. The influence of undernutrition of dairy cows on the yield and milk composition. New Zealand J. Sci. Technol., 38:682. 1957.

30. Price, W.V. and L. Germain. 1931. Standardization of milk for manufacture of American cheese. Wisc. Agr. Exp. Sta. Res. Bull. 108. University of Wisconsin, Madison, Wisc.

31. Reinbold, W.G. 1963. Italian cheese varieties. Ches Pfizer and Co., Inc. New York, N.Y.

32. Rhodes, K.H. 1980. How the cheese industry can benefit from a somatic cell program. 4th Biennial Cheese Industry Conference. Utah State University, Logan, Utah.

33. Rook, J.A.F., C. Line and S.J. Rowland. 1960. The effect of the plane of energy nutrition of the cow during the late winter feeding period on the changes in the solids-not-fat content of milk during the spring grazing period. J. Dairy Res., 27:427.

34. SAS Institute. 1979. SAS users guide. SAS Institute, Raleigh, N.C.

35. Schinckel, P.G. 1946. Some observations on the seasonal variation in livestock production. J. Agr. South Australia, 49:298.

36. Schingoethe, D.J., J.G. Parson and M.J. Owens. 1974. Effect of feeding whey to dairy cows on milk fat content and composition. Cult. Dairy Products J.

37. Steinsholt, K. and O.H. Ystgaard. 1966. Seasonal variations in composition of milk for cheese making. XVII Inter. Dairy Congress D 207.

38. Szijarto, L., D.A. Biggs and D.M. Irvine. 1973. Variability of casein, serum protein and non-protein nitrogen in plant milk supplies in Ontario. J. Dairy Sci., 56:45.

39. U.S. Department of Agriculture. 1978. Dairy Product Annual Summary 1977. Da 2-1 (78).

40. U.S. Department of Agriculture. 1979. Dairy Situation. DS - 377.

41. U.S. Department of Agriculture. 1980. Dairy Situation. DS - 382.

42. U.S. Department of Agriculture. 1981. Dairy Outlook and Situation. DS - 386.

43. U.S. Department of Agriculture. 1981. Dairy Outlook and Situation. DS - 385.

44. U.S. Department of Agriculture. 1981. Dairy Product Annual Summary 1980. Da 2-1 (81).

45. Van Slyke, L.L., and W.V. Price. 1952. Cheese. Orange Judd Publ. Co., New York, N.Y.

46. Van Slyke, L.L., and A.C. Publow. 1909. The science and practice of cheese making. Orange Judd Publ. Co., New York, N.Y.

47. Waite, F., J.C.D. White, and Alan Robertson. 1956. Variations in the chemical composition of milk with particular reference to the solids-not-fat. I. The effect of stage of lactation, season of year and age of cow. J. Dairy Res., 23:65.

48. Weaver, J.C., and M. Kroger. 1977. Protein, casein and non-casein protein percentage in milk with high somatic cell counts. J. Dairy Sci., 60:878.

49. Wilcox, C.J., K.O. Pfaue, R.E. Mather and J.W. Bartlett. 1959. Genetic and environmental influences upon solids-not-fat content of cows' milk. J. Dairy Sci., 42:1132.

APPENDIX

The following basic program was used to find the starting point

for iteration of model one based on the Van Slyke and Price formula

(45). It was run on an Apple computer.

```
50   HOME
60   PRINT : PRINT
100  PRINT "ENTER THE FOLLOWING W
     ITH A RETURN AFTER
110  PRINT "EACH ENTRY - DATE, VA
     T,ORDER"
120  PRINT "%MILK,MILK,%FAT,MILK
     %PROTEIN"
125  PRINT "CHEESE %FAT,CHEESE %P
     ROTEIN"
130  PRINT "CHEESE %WATER, CHEESE
     %STARTER"
135  PRINT "%RENNIN, %CHEESE"
140  INPUT A$
150  INPUT B$
160  INPUT C$
170  INPUT D,E,F,G,H,I,J,K,L
180  M = (F / 100) * D
190  N = 0.78 * M
200  O = H / 100 * L
210  P = (N - O) / N
220  Q = E / 100 * D
230  R = G / 100 * L
240  S = R / Q
250  T = 100 / (G - H - I)
260  PR# 1: POKE 1784,80
265  L$ =  CHR$ (12)
268  PRINT L$
270  PRINT "DATE
            ";A$
280  PRINT "VAT
            ";B$
290  PRINT "ORDER
            ";C$
300  PRINT "%MILK
            ";D
310  PRINT "MILK FAT
            ";E
320  PRINT "MILK PROTEIN
            ";F
330  PRINT "CHEESE FAT
            ";G
```

APPENDIX

The following basic program was used to find the starting point
for iteration of model one based on the Van Slyke and Price formula
(45). It was run on an Apple computer.

```
50   HOME
60   PRINT : PRINT
100  PRINT "ENTER THE FOLLOWING W
     ITH A RETURN AFTER"
110  PRINT "EACH ENTRY - DATE, VA
     T,ORDER"
120  PRINT "#MILK,MILK,%FAT,MILK
     %PROTEIN"
125  PRINT "CHEESE %FAT,CHEESE %P
     ROTEIN"
130  PRINT "CHEESE %WATER, CHEESE
      #STARTER"
135  PRINT "#RENNIN, #CHEESE"
140  INPUT A$
150  INPUT B$
160  INPUT C$
170  INPUT D,E,F,G,H,I,J,K,L
180  M = (F / 100) * D
190  N = 0.78 * M
200  O = H / 100 * L
210  P = (N - O) / N
220  Q = E / 100 * D
230  R = G / 100 * L
240  S = R / Q
250  T = 100 / (G + H + I)
260  PR# 1: POKE 1784,80
266  L$ =  CHR$ (12)
268  PRINT L$
270  PRINT "DATE
            ";A$
280  PRINT "VAT
            ";B$
290  PRINT "ORDER
            ";C$
300  PRINT "#MILK
            ";D
310  PRINT "MILK FAT
            ";E
320  PRINT "MILK PROTEIN
            ";F
330  PRINT "CHEESE FAT
            ";G
```

```
340   PRINT "CHEESE PROTEIN
         ";H
350   PRINT "CHEESE WATER
         ";I
360   PRINT "#STARTER
         ";J
370   PRINT "#RENNIN
         ";K
380   PRINT "#CHEESE
         ";L
390   PRINT
400   PRINT "#PROTEIN IN MILK
         ";M
410   PRINT "#CASEIN IN MILK
         ";N
420   PRINT "#PROTEIN IN CHEESE
         ";O
430   PRINT "PROTEIN LOSS
         ";P
440   PRINT "#FAT IN MILK
         ";Q
445   PRINT "#FAT IN CHEESE
         ";R
450   PRINT "FACTOR FOR SALT/ETC
         ";T
460   PRINT
470   PRINT "THE FORMULA WOULD BE"

480   PRINT "            ("; INT (S *
      1000 + .5) / 1000;" FAT + CA
      SEIN - "; INT (P * 1000 + .5
      ) / 1000;" ) "; INT (T * 100
      0 + .5) / 1000
490   PRINT "YIELD = --------------
      --------------------
500   PRINT "                ( 1 -
      WATER)"
510   PR# 0
530   HOME : PRINT : PRINT
540   PRINT "TYPE Y TO REPEAT"
550   GET Y$
560   IF Y$ = "Y" THEN 50
1000  END
```