Federal Order Hearing on Milk Pricing
Docket No. 23-J-0067; AMS-DA-0031

EXPERT REPORT OF NANA Y FARKYE, Ph.D.

Submitted in Support of Proposal 10 – Butterfat Retention Factor

INTRODUCTION

1. I am Nana Y. Farkye, Ph.D. My business address is 2929 Floyd Ave. #330, Modesto, CA 95355.
2. I have been retained by Select Milk Producers Inc., to provide a written report expressing my independent expert opinion on milkfat recovery in cheesemaking.
3. I have a B.Sc. (Hons) degree double major degree in Biochemistry and Nutrition from the University of Ghana, a Master of Science degree in Nutrition and Food Science from Utah State University and a Ph.D. degree in Nutrition and Food Science from Utah State University.
4. I worked as a postdoctoral research scientist at the University College, Cork, Ireland and was on the faculty at California Polytechnic State University for 25 years where I rose through the ranks of assistant professor, associate professor and full professor in the Dairy Products Technology Center, Dairy Science Department where I taught classes in Dairy Chemistry, Dairy Processing, and in Cheese and Fermented Dairy Foods at both undergraduate and graduate levels.
5. My research focuses on dairy technology with special emphasis on cheese technology and ripening.
6. I served as a judge at the U.S. and World Championship Cheese Contest hosted by the Wisconsin Cheesemakers Association, and American Cheese Society Cheese Contest. I am an author or co-author of over 100 peer-reviewed research papers, industry presentations, book chapters and encyclopedia articles related to dairy chemistry, microbiology, and cheese technology.
7. In 1995, I took an early retirement from the university and since then, I am a consultant to dairy foods industry where I advise, troubleshoot, and find solutions to problems and develop new products and streamline processes.
8. My CV is attached in Appendix 1.

Steps in Cheesemaking

Cheesemaking involves the conversion of milk from its fluid state to a semi-solid mass. The general process involves the following steps:

1. Standardization of milk
2. Pasteurization
3. Addition of cheesemaking ingredients (i.e., color, starter, calcium chloride, rennet)
4. Cut Curd

5. Stir and Cook
6. Whey Drainage*
7. Matt and Cheddar Curd
8. Mill curd
9. Salt
10. Hoop/Mold
11. Package and Storage

Efficient manufacture of cheese involves efficient recovery of the major components of milk (i.e., casein and fat) into cheese along with moisture and salt added during cheesemaking. Most of the fat losses during cheesemaking occur during whey drainage (step 6, above). Whey contains about 0.35% milk fat. Milkfat in the whey is termed "whey fat" and occurs as whey cream. In cheese making, whey fat and whey proteins can be recycled to increase cheese yield (Brown and Ernstrom, 1982; Hinrich, 2001) and plant revenue (Peters, 2005). Although whey fat (as whey cream) may be recycled into cheese during manufacture, the potential for bacteriophage attack of starter cultures discourages the use of whey cream unless the whey cream is highly heated to inactivate any possible introduction of bacteriophage into the cheese vat. When the whey cream is highly heated before use, it addition has significant economic benefits.

Milk composition.

U.S. dairy cows are mostly Holsteins (or Holstein-Friesian). Other breeds of dairy cows are Jersey, Brown Swiss, Guernsey, Ayrshire, Milking Shorthorn and crossbreed cows. These breeds have gained popularity in recent years, as milk from these breeds tends to contain relatively high proportions of milk fat and other milk solids compared with Holstein cows. Table 1 shows variability in the composition of milk among breeds.

Table 1. The average composition of milk from the different breeds of dairy cattle.

Component (%)	Holstein	Brown Swiss	Ayrshire	Jersey	Guernsey
Fat	3.50	3.86	4.03	5.05	5.03
Protein	3.20	3.48	3.51	3.79	3.89
Lactose	4.87	5.09	4.81	5.00	4.97
Ash	0.67	0.72	0.68	0.70	0.74
Total solids	12.26	13.14	13.03	14.54	14.63
Water	87.74	86.85	86.97	85.46	85.37
Protein/Fat Ratio	0.91	0.90	0.87	0.75	0.77

The protein to fat (P/F) ratio in raw milk ranges from about 0.75 in Jersey milk to about 0.91 in Holstein milk – with a mean of 0.84. The calculated mean P/F ratio in USDA standard milk containing 2.99 pounds protein and 3.5 pounds fat per hundredweight is 0.85.

Cow milk contains two major types of proteins (i.e., caseins and whey proteins) in the ratio 80:20 respectively. Casein proteins are most important in cheese making. Hence accurate determination of casein content of milk is important. Because there is no rapid test for casein, it is approximated accurately as 78% of the total protein in milk. Therefore, multiplying 0.85 by 0.78 gives an average casein to fat (C/F) ratio of 0.66 in typical US milk.

The standards of identity specified for Cheddar cheese in the Code of Federal Regulations require a minimum of 50% fat-in-dry matter (FDM) and a maximum of 39% moisture in Cheddar cheese. To meet this requirement, the milk for Cheddar cheese manufacture must be standardized to C/F between 0.64 to 0.71. The lower the C/F ratio, the higher the FDM (Figure 1) suggesting that higher fat cheeses can be made from high fat milk. However, the casein content must increase accordingly to balance the increased fat content to maximize cheese yields.

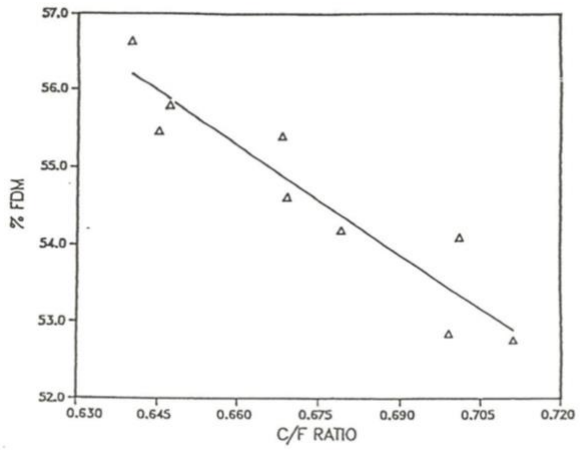

Figure 1. Effect of casein to fat (C/F) ratio on percent fat-in dry matter (FDM) in Cheddar cheese.

Cheese Yield

Van Slyke and Price (1927) developed the yield equation below for Cheddar cheese.

$$Cheese\ Yield = \frac{0.93F + C - 0.1}{1 - W}\ x\ 1.09$$

Where:

Yield = Pounds of cheese per hundred pounds of milk
F = Pounds of fat per 100 pounds milk
C = Pounds of casein per 100 pounds milk
W = Pounds of water per pound of cheese.

The yield equation indicates the following:

That 93% of the milkfat is recovered in cheese.
That one-tenth of a pound of casein from 100 pounds of milk is lost in the whey.
That the other milk constituents and salt added to cheese contribute to 9% of the fat and casein retained in cheese.

The original research leading to the development of the Van Slyke and Price cheese yield formula was reported in 1894. At that time, cheese was made in open vats. When enclosed vats were introduced, fat recoveries greater than 90% were not easily attainable. Hence, a modified Van Slyke and Proce formula was introduced. In the modified formula, the fat recovery was reduced to 90% which forms the basis of current Class III milk pricing developed by the USDA.

USDA calculations for Class III milk pricing involve the value of key components (i.e., fat and protein) and make allowances. In the calculation, the following are assumed:

1. USDA standard milk consists of 3.5 pounds milkfat and 2.99 pounds of protein per hundredweight.
2. The manufacturing cost to produce 1 pound of cheese (excluding the cost of raw milk) is $0.2003.
3. That 1.383 pounds of cheese can be made from 1 pound of protein.
4. That 1.572 pounds of cheese that can be made from 1 pound of milkfat.
5. That 90% of the milkfat is retained during cheese manufacture. The remainder is of the fat lost in the whey stream or other points in the cheese making process.

Improvements in Cheesemaking Efficiency
Advances in cheesemaking to improve cheesemaking efficiencies involve the introduction of highly efficient cheese vats and milk coagulants.

Cheese Equipment and Curd Cutting
Cheddar cheese was traditionally manufactured in stainless steel open vats. Although open vats are still used by a minority of cheese plants, most cheese plants use enclosed vats that were introduced in the 1960s. There are different types of enclosed vats in two major cutting orientations (i.e., vertical, and horizontal). An example of a vat with vertical cutting orientation is the Double “OO” vat. This was the first style of enclosed vats introduced. Results of research on cheesemaking using the OO vats showed that fat recoveries originally reported by Van Slyke (1894) were not attainable. Most cheese plants using OO vats recovered about 90% milkfat in the cheese. Since the introduction of horizontal cheese vats (HCV) with single or double shaft (stirring mechanisms), efficiencies in cheese yields have markedly improved.

In a recent email statement regarding fat recoveries in Cheddar cheese using modern cheesemaking equipment, Mr. Mark Steffens (Cheese Technology Manager, Tetra Pak Processing Equipment Inc.) writes:

> “*Given the same vat milk composition (fat and protein); same set temperature, same milk pH/culture activity at time of rennet addition and same coagulant, we see the following vat fat retention relationships using the equation (1- (whey fat pump over/vat fat)) x 100%*
>
> *Tetra Pak Double O: 92-94% retention*
> *Tetra Pak HCV: 94-96% retention*
> *Tetra Pak YieldMaster: 96-97.5% retention*

Of course, this does not reflect the fat retention factor that needs to be used in the modified Van Slyke formula. However, we can run some back calculations and see that we can increase the Van Slyke "rFat" factor in a relational way; moving from rF= 0.90-0.91 up to 0.91-0.92. Much of our data has been based on a very large plant where 3 different style vats are located: a single shaft "OST style" vat'; our dual shaft HCV and our dual shaft YieldMaster Vat."

Therefore, using Tetra Pak HCVs and YieldMaster equipment in cheesemaking results in greater than 90% milkfat recoveries in cheese.

Milk Coagulation and Protein Recovery

During cheesemaking a specific amount of milk coagulant (rennet) is added to milk for clotting. Rennet hydrolyzes a specific bond in the kappa-casein molecule to give para-κ-casein and (glyco) macro peptide to effect milk coagulation. The para-κ-casein is trapped in the curd while the macro peptide is lost in the whey. Hence, the amount of casein loss during cheesemaking is constant.

The coagulated casein network forms a curd that traps milkfat and other soluble milk constituents. Gentle curd handling during cutting, stirring, and cooking affects the recovery of milk constituents and cheese yield. Other factors such as mode of curd formation (i.e., setting pH, time and temperature, coagulant type, and amount) and cheese equipment used for manufacture are important contributors to curd integrity that influence yield and recovery of milk constituents during cheesemaking.

Coagulant type

Different coagulant types are available to cheesemakers. A recent study conducted by the leading coagulant manufacturer (Chr. Hansen, 2021) shows that using newer coagulants increases cheese yield by at least 0.4% over traditional coagulants and up to 2% when Chy-max Supreme is used (Figure 2).

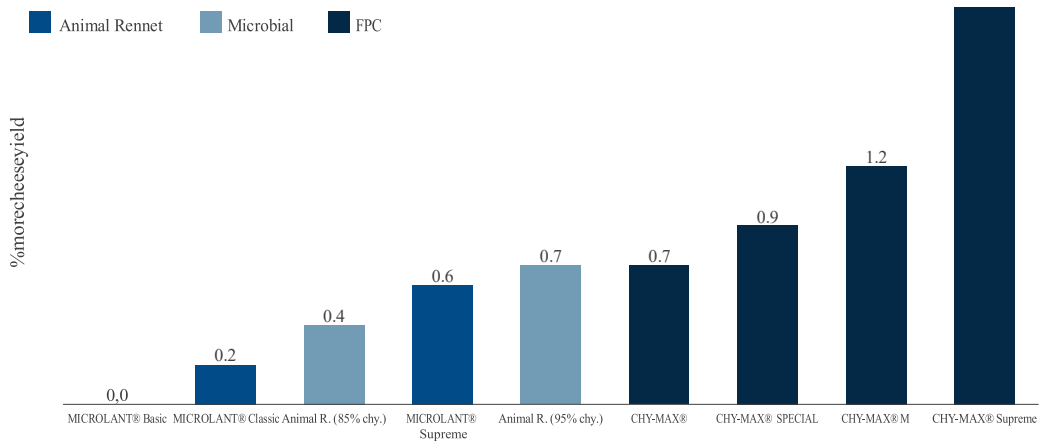

Figure 2. Effect of coagulant type on percent increase in cheese yield.

Thus, using the right coagulant at the desired temperature results and cutting the curd at optimal firmness results in optimal trapping of fat in the curd and minimal fat loss. Cutting the curd too firm or too soft results in high fat losses in the whey. Also, cutting too early increases curd fines and whey fat losses while delay in cutting results in increased moisture content of cheese.

Cheese Plant Experience

In my experience as a consultant, I am aware that optimize cheese yield by standardization of cheese milk by blending appropriate ratios of whole milk, UF whole milk, skim milk, nonfat dry milk and cream as appropriate to achieve C/F of 0.67-0.7. Cheese plants monitor and control the coagulant used, curd firmness at cutting and gentle stirring to minimize loss of milkfat in the whey. Typically, large commodity Cheddar cheese plants target and achieve fat recoveries of 93% or higher.

Conclusions

Consistent milk composition through effective breeding programs and improvements in cheesemaking equipment and coagulants have all contributed to increased cheesemaking efficiencies through higher recoveries of milkfat and protein resulting in high cheese yields. Hence, in my opinion, fat recoveries of 93% in the original Van Slyke and Price yield equation are achievable in current cheddar cheese plants. Not only are these yields achievable, based on my observations, knowledge, and direct observations, the majority of commodity Cheddar cheese manufactures are achieving fat recoveries at or above these levels.

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7. Van Slyke, L.L. 1984. Results of investigation relating to the manufacture of Cheddar cheese for the season of 1894. Bulleting No. 82. New York Agriculture Experiment Station. Geneva, NY.
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9. Yiadom-Farkye, N. 1984. Effect of casein to fat ratio on fat recovery in Cheddar cheese. M.S. Thesis Utah State University. Logan, UT.

Appendix 1

NANA Y. FARKYE, Ph.D.
PROFESSOR EMERITUS & DAIRY FOODS CONSULTANT

CONTACT INFORMATION:
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EDUCATION:

Degree	Year	Institution	Field of Study
Ph.D.	1986	Utah State University	Nutrition & Food Sciences
M.S.	1985	Utah State University	Nutrition & Food Sciences
B.Sc. (Hons).	1980	University of Ghana	Biochemistry & Nutrition

EMPLOYMENT HISTORY

4/1/14 – present **Dairy Foods Consultant & Professor Emeritus**, Dairy Sci. Dept., Cal Poly, San Luis Obispo. Consulting activities include:

- Dairy products development, cheese, and cultured products technologies
- Troubleshooting and development of new cheese varieties; line extensions
- Technologies for cheesemaking and ripening
- Sensory evaluation and judging dairy products.
- Dairy ingredient technologies
- Teach private cheesemaking courses for dairy and cheese companies as hired consultant
- Food Safety Audit: HACCP and SQF certification and FSMA requirements
- New dairy processing plant set up for manufacture cheese and cultured products
- Experience in cow, goat, sheep, and mixed milk dairy products.
- Expert reviewer – dairy foods litigation.

1999- 03/2014 **Professor**, Dairy Products Technology Center, Dairy Science Department. California Polytechnic State University, San Luis Obispo. 70% research 20% teaching and 10% administration (dairy plant management) appointment. [**Retired and granted Emeritus status**]

9/08 – 3/09 **Sabbatical Leave**. Rizo Lopez Foods, Inc/Don Francisco Cheese, Riverbank, CA

1995-99 **Associate Professor,** Dairy Products Technology Center, Dairy Science Department, California Polytechnic State University, San Luis Obispo. [**Granted Tenure in 1995**]

1990-94 **Research Scientist**, Dairy Products Technology Center, California Polytechnic State University, San Luis Obispo, CA.

1988-90 **Research Scientist**, National Food Biotechnology Centre, University College, Cork, Ireland.

1986-88 **Post-doctoral Fellow**, Department of Nutrition & Food Sciences, Utah State University, Logan.

1983-86 **Cheese Maker & Dairy Plant Operator**, Department of Nutrition & Food Sciences, Utah State University, Logan.

1984-86 **Research & Teaching Assistant**, Department of Nutrition & Food Sciences, Utah State University, Logan.

1982-83 **Science Teacher/Dept. Head**, Orile-Imo High School, Nigeria.

1980-81 **Assistant Nutrition Officer**, Ministry of Health, Ghana.

PARTICIPATION IN PROFESSIONAL ACTIVITIES, ASSOCIATIONS AND ORGANIZATIONS

- Participated in USDEC Trade Missions to Southeast Asia (Thailand, Malaysia, Singapore, Philippines, Vietnam)- 1997-2000.
- Member, American Dairy Science Association, Institute of Food Technologists, Sigma Xi

- Member, U.S. National Committee (USNAC) Group of Experts to IDF. Group B12 - The Use of Enzyme Preparations in Cheese Manufacture; Group F32 - Chemical Indices of Maturation in Cheese.
  - Member, Editorial Board, Journal of Dairy Science 1997-2006
  - Member on FDA panel on soft cheeses food safety. 2010.
  - Guest Editor, International Dairy Journal, 2006, Volume 16, pp 499-716.
  - Member, Editorial Board, Encyclopedia of Dairy Sciences
  - Ad Hoc Reviewer – Int. Dairy J., J. Food Sci., J. Dairy Sci., J. Agric. Food Chem., J. Dairy Res., J. Am. Oil Chemists Soc., J. Sci. Food Agric., J. Dairy Res., Crit. Rev. Food Sci. Nutr., Int. J. Dairy Technol., J. Food Quality.
  - Member, Selection Committee – ADSA Richard M. Hoyt Award (2000); ADSA Graduate Student Paper Contest (Chair, 97/98); ADSA Cultor Food Science Award (1999); IFT Graduate Student Paper Contest (2002, 2008, 2009); ADSA Rhodia Int. Dairy Science Award (2003); ADSA DSM Specialty Foods Award (2006); ADSA Foundation Scholar Award (2011)
  - Selection committee chair, ADSA IAFIS Award (2004)
  - Member, Cal Poly Collaborative Agent Design Research Center (CADRC) Advisory Committee (2004-14)
  - Department representation on College of Agriculture Food and Environmental Sciences (CAFES) Committees: Library (2005- 2015; Assessment (2010 - 2014; Tenure and Post Tenure Peer Review (2010 – 2014).
  - CAFES Representation on University Committee: Academic Senate Distinguished Faculty Scholarship Awards Committee (2009 – 2011)
  - Filming of "Milk" for Modern Marvels. October 2007. TV Episode, January 2008
  - Cheese Judge. American Cheese Society Cheese Contest. 2002, 2010.
  - Cheese Judge. Riverbank Wine and Cheese Festival. August 2006
  - Cheese Judge. U.S. Championship Cheese Contest. Milwaukee, WI. 2007- 2022
  - Coach, Dairy Products Judging Team. 2007
  - Cheese Judge. World Championship Cheese Contest, Madison, WI. 2008 - 2022

AWARDS

1988 Vice President Award for Research. Utah State University.
1999 Plant Sciences Faculty Excellence Award. College of Agriculture, California Polytechnic State University.
2011 Cargill Flavor Systems Award for Contributions to Cheese Research, ADSA.

International Professional Activities:

Macedonia, Egypt, Ghana, Nigeria, South Africa, Russia, Vietnam, Thailand, Singapore, Malaysia, Philippines, China, New Zealand, Ireland, Mexico, Costa Rica, Czech Republic, Armenia, Australia, Italy, Guatemala, Nicaragua, Germany.

Research Interests

Cheese technology, cheese ripening, fermented dairy foods (yogurt, kefir, etc.), chemical and functional properties of milk proteins and products, dairy enzymology and application of enzymes in dairy foods.

Publications

Over 100 research publications including book chapters, encyclopedia articles and peer-reviewed research papers. Selected References:

Yiadom-Farkye, N.A. and C.A. Ernstrom. 1985. Effect of casein/fat ratio in milk on fat recovery in Cheddar cheese. J. Dairy Sci. 68(suppl. 1):54.
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