2003

The effects of composition and processing of milk on foam characteristics as measured by steam frothing

Michael Levy
Louisiana State University and Agricultural and Mechanical College, mlevy@lsu.edu

THE EFFECTS OF COMPOSITION AND PROCESSING OF MILK ON FOAM CHARACTERISTICS AS MEASURED BY STEAM FROTHING

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

In

The Interdepartmental Program in
Animal and Dairy Sciences

By
Michael Levy
B.S., University of Illinois, 1996
May 2003

ACKNOWLEDGEMENTS

I would like to express my eternal gratitude to my loving wife, Mercedes Levy, for all the love, patience, and support she has shown!

I also wish to thank Dr. Johnny McGregor and Dr. Witoon Prinyawiwaktul for their exceptional patience during my education and in the writing of this thesis, as well as all the guidance and support they offered.

Much appreciation goes to Chuck Boeneke and Dr. Ronald Gough for their assistance and time while using the LSU Dairy Science Creamery.

I would also like to send thanks to my good friend and fellow student Luis Fernando Osorio.

Thanks are also extended to Louisiana State University, Agricultural and Mechanical College for its education and financial support and to Dairy Management Inc. for the funding of this research.

Finally, I would like to extend a special thanks to my parents, Charles and Nancy Levy for all the support they have given me over the years. In addition to all the people who have contributed in one form or another to the realization of this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Steam frothing of milk is required to produce an acceptable foam for many espresso coffee drinks. Specific aspects of composition and processing may affect the foaming properties of milk. The aim of this study was to determine the effect of fat content, heat treatment, free fatty acid addition and storage time on the frothing properties of milk. The four treatments included: fat content (0.08% and 3.25%), pasteurization temperatures (171°F for 15 seconds and 210°F for 45 seconds), pre and post-pasteurization addition of lauric acid solution (0.0% and 2.0% of 0.5 M concentration) and storage time (1 and 10 days). For this experiment, 3 replicates were performed. For each treatment, 250 ml of milk was frothed with a Feama Espresso machine (model c85/1) using a 7.5-cm diameter graduated beaker for 25 seconds. For each treatment, frothing was repeated 5 times. Froth characteristics were observed and the steam froth value (SFV), amount of dissipation and foam volume were determined after 5 minutes. The free fatty acid level (µ equiv./ml) for all treatments were also determined prior to frothing. There was no interaction found between day and treatments. There was no significant difference ($P=0.05$) found between day 1 and day 10 for SFV, foam volume, or dissipation based on fat level, pasteurization temperature, or free fatty acid addition. When all treatments over time were observed, there was a significant difference ($P<0.05$) in SFV and FFA level (µ equiv./ml). There was a significant difference ($P<0.05$) in SFV, foam volume and percent dissipation between all free fatty acid levels when all other factors were applied.

CHAPTER 1

INTRODUCTION

The specialty coffeehouse industry is the fastest growing retail food industry in America today. In 1999 there were 108,000,000 coffee consumers in the United States spending approximately $9.2 billion in the retail sector and $8.7 billion in the foodservice sector every year (National Coffee Association, 1999). Results of the 1998 National Coffee Association survey revealed that 54% of the adult population of the United States drinks coffee daily. Of these, 29 million American adults drink gourmet coffee beverages every day, whether specialty coffee, espresso-based beverages (latte, espresso, café mocha, cappuccino) or frozen and iced coffee beverages. The average per capita consumption is around 4.4 Kg per year and among coffee drinkers the average consumption is 3.1 cups of coffee a day. Over 70% of espresso coffee drinks incorporate milk, creating one of the dairy industry's largest markets for fluid milk (National Coffee Association, 1999).

The foaming of milk is an important quality characteristic in the manufacture of dairy based espresso drinks. The quality of these products depends on the ability of the milk to form a stable foam. Over the past several years, many coffee house owners and baristas have revealed that they have been unable to properly froth milk with no explainable reason (National Coffee Association, 1999).

The principal constituents of milk are water, fat, proteins, lactose, and minerals. Milk also contains trace amounts of other substances such as pigments, enzymes, vitamins, phospholipids, and gases. Table 1 shows the typical composition of milk.

Milk fat, which is completely liquid at 40°C and completely solid at -40°C, exists as a mixture of crystals and liquid. The fat globules are the largest particles in milk. The average

size is 3 to 4 µm, and there are 3 to 4 million fat globules in a milliliter of whole milk. Milk fat is a mixture of different fatty-acid esters called triglycerides, which are compounds of an alcohol called glycerol and various fatty acids. Fatty acids make up about 90% of milk fat (Dairy Handbook, 1996).

Table 1: Quantitative composition of milk.

Main constituent	Limits of variation %	Mean value %
Water	85.5 – 89.5	87.5
Total solids	10.5 – 14.5	13.0
Fat	2.5 – 6.0	3.9
Proteins	2.9 – 5.0	3.4
Lactose	3.6 – 5.5	4.8
Minerals	0.6 – 0.9	0.8

(Source: Dairy Handbook, 1996)

Milk fat plays an important but imperfectly understood role in the structural properties of many dairy products. The stability of a foam containing emulsified fat particles may depend on both the size and composition of the dispersed lipid particles. The presence of solid fat, to promote fat globule rupture and of liquid fat, to promote clumping, may be necessary for the formation of a stable dairy foam. Milk fat with altered triglyceride composition may act to promote or, alternatively, to inhibit foam formation and stability (Pilhofer et al, 1994). Additionally, the inability of some milk to form a stable foam is attributed to lipolytic activity in milk (Deeth and Smith, 1983).

Lipolysis is caused by the action of lipase enzymes. These enzymes are not always completely inactivated at normal pasteurization temperatures and therefore continue to

breakdown the fat and release free fatty acids during the milk's lifespan (Dairy Handbook, 1996). When lipase acts on milk fat triglycerides, free fatty acids and mono- and diglycerides are formed. These compounds have surface active properties and can cause milk to exhibit poor steam frothing properties and difficulties in cream separation (Deeth and Fitz-Gerald, 1995). Table 2 lists the most important fatty acids in milk fat triglycerides.

Table 2: Principle fatty acids in milk fat.

Fatty Acid	% of total fatty acid content	Melting point °C
Saturated		
Butyric acid	3.0 – 4.5	- 7.9
Caproic acid	1.3 – 2.2	- 1.5
Caprylic acid	0.8 – 2.5	+ 16.5
Capric acid	1.8 – 3.8	+ 31.4
Lauric acid	2.0 – 5.0	+ 43.6
Myristic acid	7.0 – 11.0	+ 53.8
Palmitic acid	25.0 – 29.0	+ 62.6
Stearic acid	7.0 – 13.0	+ 69.3
Unsaturated		
Oleic acid	30.0 – 40.0	+ 14.0
Linoleic acid	3.0 – 3.0	- 5.0

(Source: Dairy Handbook, 1996)

Milk contains many hundred protein types, most of them in very small amounts. According to their abundance, their chemical or physical properties or their biological functions, the proteins can be classified in various ways. Table 3 shows an abridged list of the major milk proteins (Dairy Handbook, 1996). The intrinsic properties of a protein are governed by the content and disposition of amino acids, molecular size, shape, conformation, net charge and protein/protein interactions. However, even though the properties of a single component are significant, it is the manner in which they interact with other components, for example, water,

proteins, and lipids, in foods, that ultimately determine their functionality and applications (Kinsella, 1981).

Table 3: Different major proteins in milk.

Protein Class	Approx. % in skim milk	Approx. % of protein	Approx. % of whole milk protein
Caseins	2.6		80
a_s-caseins		50	
?-caseins		12	
ß-caseins		30	
Milk serum proteins	0.6		19
Bovine albumins		1	
ß-lactoglobulins		10	
a-lactoglobulins		4	
Immunoglobulins		3	
Fat-globule (membrane)			5

(Source: Dairy Handbook, 1996)

Lactose is the sugar in milk which is part of the organic chemical compounds called carbohydrates. It is a disaccharide made up of glucose and galactose. Lactose is water soluble, occurring as a molecular solution in milk (Dairy Handbook,1996).

Milk also contains a number of minerals; however, the total concentration is less than 1%. Mineral salts occur in solution in milk serum or in casein compounds. The most important salts are those of calcium, sodium, potassium and magnesium (Dairy Handbook, 1996).

The inability of some milk to form a stable foam when injected with steam has been previously reported by Buchanan in 1965 and Kitchen & Cransten in1969. Such milk is unsuitable for making Cappuccino style coffee and is the subject of numerous complaints each year from restaurant and café proprietors (Deeth and Smith, 1983).

In research performed by Nanua, Osorio, & McGregor (2001), it was found that addition of FFA did significantly reduce the SFV of milk ($P < 0.05$). Although it is generally accepted that impaired foaming results from lipolysis, measures of these two do not always show a good correlation (Deeth and Smith, 1983).

CHAPTER 2

LITERATURE REVIEW

A foam can be defined as a two-phase system in which a distinct gas bubble phase is surrounded by a continuous liquid lamellar phase. Because of its large liquid-gas interfacial area, a foam requires energy to be produced and is fundamentally unstable (Britten and Lavoie, 1992). A foam is mostly air and is characterized by high viscosity, low density, high surface area and high surface energy. Foams are metastable and with time the liquid between the lamellae drain; gas diffuses from the small to large bubbles (disproportionation), the film tends to thin and become fragile, causing rearrangement, and ultimately stresses and shocks may cause localized rupture (Kinsella, 1984).

The ability of a protein to form a multi-molecular matrix which can withstand minor physical perturbations will determine the resistance to coalescence and collapse of the air bubbles (Britten and Lavoie, 1992). In studies performed by Cumper, 1953; Graham and Phillips, 1976; Halling, 1981; and Kinsella, 1981; it was found that proteins enhance film formation in foams by concentrating at the interface, reducing interfacial tension and partially unfolding and associating with neighboring protein molecules to form continuous films (Phillips et al, 1989).

Milk proteins are surface active, that is, at relatively low concentrations they adsorb at the surface or interface of liquids and reduce surface and interfacial tension (Leman and Kinsella, 1989). Factors such as pH, heat treatment and ionic environment, which effect properties of proteins, influence the foaming properties of milk (Ward et al., 1997). The degree to which whey proteins are denatured in milk depends on the heating procedures. In the native state, whey proteins have a definite conformation, which when exposed to heat above certain critical levels, is disrupted, and characteristic properties of the protein are altered. This is important because the

extent of whey protein denaturation has important consequences on the functional properties of many milk products (Manji and Kakuda, 1987).

Raw milk is typically stored before collection and again before processing for periods of up to 48 hours at 5° to 7°C. The fat and proteins in milk undergo chemical changes due to storage over time. Theses changes are normally of two kinds: oxidation and lipolysis. Oxidation of fat and proteins usually causes off flavors such as metallic or "sun" flavors. However, lipolysis, which is the breakdown of fat into glycerol and free fatty acids, produces a rancid taste and smell (Dairy Handbook, 1996). Storage also favors the growth of gram negative psychrotrophic bacteria (i.e *pseudomonus sp*.). Even though most gram negative psychrotrophic bacteria are killed during pasteurization, the extracellular lipase and protease produced during growth are thermostable and main remain active during the storage of finished products (Blake et al, 1996). Celestino, Iyer and Roginski (1996) found that the effect of refrigerated storage at 4°C for 48 hours was enough to significantly increase the number of lipolytic and proteolytic bacteria. The bacterial and enzyme action in the stored raw milk resulted in increased free fatty acid contents and lower pH (Celestino et al, 1996).

Milk is heat treated (pasteurized) to kill any pathogenic microorganisms that may be present. However, the higher the temperature and the longer the time exposed to heat, the greater the changes that will occur to its components. Milk fat is not affected by temperatures below 100°C; however, some coalescence occurs at higher temperatures. Casein proteins do not undergo any detectable changes at temperatures below 100°C, but any temperatures above 65°C affect the casein micelles. The milk-serum proteins (whey proteins) begin to denature at 65°C and are almost completely denatured when the milk is heated to 90°C for 60 seconds. After heating the milk to 75°C or more and holding the temperature for even less than a minute, the milk will start to smell and taste "cooked". This is due to the release of sulphur-containing

compounds from ß-lactoglobulin and other sulphur-containing proteins (Dairy Handbook, 1996). The sulphydryl (-SH) groups of milk are located chiefly in ß-lactoglobulin. In unheated milk they are masked, but they become free and highly reactive when milk is heated and are then involved in changes in flavor and heat stability of milk (Lyster, 1964).

Kintner and Day (1965) found that the heating of milk had a pronounced effect upon the quantity of free fatty acids. Most of the FFA of milk was distributed in the fat and the fat globule membrane fraction. Hence, milk with higher fat content contains more FFA. However, they found that as the heat treatments increased, the FFA decreased (Kintner and Day, 1965). In a study by Burton (1988), it was found that an increase of FFA concentrations in Ultra High Temperature (UHT) pasteurized milk during storage was almost certainly a consequence of the survival of heat-resistant lipases of natural milk origins or produced by psychrotrophic bacteria during cold storage or raw milk (Choi and Jeon, 1993).

The lipases which cause problems in milk and dairy products are of two main types- milk lipase which occurs naturally in all raw milk and bacterial lipase which are produced by contaminating bacteria. Surveys of raw and pasteurized milk have found varying degrees of lipolysis. Under certain conditions, lipase can act on the milk fat globule resulting in the release of free fatty acids (FFA). Some of the possible factors contributing to lipolysis in raw milk are excessive agitation, alternate warming to about 32°C and cooling after that, excessive air incorporation, and leaving raw milk sitting unrefrigerated for an extended period of time. Lipase may also be produced by bacteria and somatic cells present in the milk (Christen and Lee, 1994). Table 4 shows some of the main causes of spontaneous lipolysis in milk.

Milk contains relatively large amounts of lipoprotein lipase (LPL). In spite of this, little lipolysis occurs in normal milk. Milk lipids are efficiently packaged in milk fat globules so that LPL binds and acts on them only to a limited degree. However, if the organization of the

globules is disrupted, rapid lipolysis ensues (Sundheim and Bengtsson-Olivecrona, 1987). This can occur through pumping, agitation (mechanical or air) or excessive mixing of air in the milk. In all these cases, the incorporation of air is essential for disrupting the milk fat globule membrane. As in the case of spontaneous lipolysis, induced lipolysis also involves attachment of the lipase to the milk fat globule membrane. Once attached to the fat globule membrane, the enzyme has enhanced heat stability and hence cream from the milk which has been severely mechanically abused may retain some milk lipase activity after high temperature short time (HTST) pasteurization (Deeth and Fitz-Gerald, 1995).

Table 4: Characteristics of spontaneous lipolysis.

- It is initiated by cooling milk to < 10°C soon after secretion from the cow and develops during cold storage. Most of the lipolysis occurs in the first 12 hours of storage.
- It tends to occur most in the milk of cows late in lactation and cows on a poor plane of nutrition.
- It is largely caused by an imbalance in lipase "activators" and lipase "inhibitors".
- A necessary precondition for lipolysis is attachment of some of the lipase from the skim phase of the milk to the milk fat globule membrane. In milk which undergoes a high level of lipolysis, the amount of lipase redistributing to the cream phase from the skim phase can be a significant proportion of the total lipase present. The nature of this attachment is not well understood.

(Deeth and Fitz-Gerald, 1976)

With some milk, cooling below 15°C starts lipolysis. This is called cold-induced lipolysis. In this milk, time-dependent changes occur during cooling that allow binding of LPL to the milk fat globule. The reason milk fat globules are more sensitive in some milk is not known. However, Sundheim did find that cold-induced lipolysis of milk fat globules could be prevented by the addition of normal skim milk (Sundheim and Bengtsson-Olivecrona, 1987). An influence of the skim milk fraction on milk lipolysis is suggested by interchanging cream and skim milk from normal and susceptible milk. This could be due to some physicochemical

properties of skim milk, to the presence of certain activators in susceptible milk, or the presence of certain inhibitors in normal milk (Cartier and Chilliard, 1990).

Lipolysis caused by bacterial lipases has become most significant since the widespread introduction of cold storage on milk farms. This change has caused the levels of the lactic acid bacteria to decline and the psychrotrophic bacteria to increase. During growth at low temperatures, many of the latter produce extracellular lipases which can cause lipolysis. One of the most important properties of these microbial lipases is their heat stability. Most of them retain at least some of their activity after pasteurization and even after UHT processing. In contrast to the natural milk lipase, most microbial lipases are not prevented from attacking the fat in milk fat globules by the milk fat membrane. The milk fat globules do not have to be disrupted before these bacterial lipases can act on the fat (Deeth and Fitz-Gerald, 1995).

Steam frothing of milk is required to produce an acceptable foam for many espresso coffee drinks. Specific aspects of composition and processing may affect the foaming properties of milk. The frothing capacity of milk, as determined by steam frothing value (SFV), decreases with degree of lipolysis (Deeth and Smith, 1983). Milk with a FFA above 1.5 µ equiv./ml was unsuitable for making cappuccino froth. Deeth and Smith also reported that the SFV improved with heat treatment up to 74°C, homogenization, and the addition of nonfat milk powder (Nanua et al. 2002). Levy & McGregor (1998) found an increased frothing capacity with the addition of whey protein concentrate and a decrease if frothing capacity with increased fat content. The objective of this study was to identify if fat content, free fatty acid addition (before or after pasteurization), storage time up to 10 days and pasteurization temperature affect the froth created by steaming milk.

CHAPTER 3

MATERIALS AND METHODS

Milk Preparation

All the milk for this experiment was obtained from the Louisiana State University Dairy Farm. The University Dairy has a milking herd of approximately 120 Holstein cows which are milked twice a day. The milking parlor is Grade A and meets all state and federal regulations. After the cows are milked, the milk is stored in the dairy farm's bulk tank (<4°C ± 1°) and any milk not used by the University is picked up by the local CO-OP for processing and sale to the public.

All the milk for this experiment was obtained from the morning milking and was stored no more than 12 hours before being received. The milk was placed in cleaned and sanitized stainless steel 10 gallon milk cans, transported to the LSU creamery, and immediately placed in bulk coolers with temperatures below 4°C ± 1°.

Standardization of Fat Level

Immediately after receiving the milk, the milk was separated into raw skim milk and raw cream using a De Laval model 342 cold milk separator. After all the milk was separated and the fat removed, the Babcock fat test was performed on the skim milk and cream to obtain accurate fat levels.

Once the exact fat levels were determined, the cream was recombined with the skim milk, using the Pearson Square method, to obtain the desired fat levels. These included fat contents of skim (0.08%) and whole milk (3.25%).

Pasteurization

All the milk was pasteurized using a CPV Crepco model S/S Jr. Lab scale plate heat exchanger system with a 2 stage homogenizer at 2000 psi. The homogenizer acted as the timing

pump for this system. The milk samples were pasteurized at 171° F for 15 seconds (HTST) or 210°F for 45 seconds (UHT). After pasteurization, milk temperature was checked and the milk was immediately placed back into the cooler to insure that the milk was maintained below 4°C (±1°C).

Free Fatty Acid Fortification

Skim milk and whole milk samples were fortified with 0.5 M Lauric acid (C:12) at 0.0% or 2.0% w/w concentrations. One half of the samples received the FFA one hour before pasteurization, while the other samples received the FFA immediately after pasteurization.

Frothing Procedure

For each sample, 250 ml of milk (4°C ± 1°C) was placed in a 7.5 cm diameter graduated beaker with a centimeter height scale (0.2 increments) measuring 0.0 to 15.0 cm. The beaker was placed under the steam valve of a commercial Feama Espresso machine (model c85/1, at a pressure of 1 – 1.2 KPa) and held in place so that the tip of the steam arm was just below the surface of the milk (~ 5mm). The steam was turned on and the tip remained just below the surface of the milk until the milk started to froth, at which time the beaker was slowly lowered so as to allow the steam tip to remain just below the surface of the foam. This process continued for 25 seconds, the steam was turned off and final temperature was recorded. The cylinder was then placed on a level surface and allowed to settle for 5 minutes. Froth characteristics were observed and the initial heights of the froth (IF), the height of the froth after 1 minute (FH_1) and 5 minutes (FH_5) were recorded. The liquid volume of the milk (LV), the total volume (TV) of milk and froth, and the milk/foam interface (FI) were also recorded after 1 minute and 5 minutes of dissipation. The Steam Froth Value (SFV) after 5 minutes dissipation was calculated using the equation SFV=100(TV-LV)/LV. Each treatment was frothed 5 times and means for all values were determined.

Effect of Storage

After all treatments were applied to the milk, it was stored at 4°C (± 1°C) for 1 day (24 hours) and 10 days (240 hours) from the time of pasteurization. The samples were then frothed as described.

Determination of Free Fatty Acids

FFA was determined by a variation of the method of Deeth, Fitz-Gerald, and Wood (1975).

1. Pipette 3 ml of milk into a 35-ml test tube
2. Add 10 ml extraction mixture (isopropanol: petroleum ether:4N H_2SO_4, 40:10:1) and mix
3. Add 6 ml petroleum ether and 4 ml water, shake vigorously for 15 sec.
4. Allow to settle for about 10 min for the two layers to separate and record the volume of the upper layer
5. Transfer a portion of the upper layer into a 50 ml conical flask and add 2 drops of 1% methanolic a-naphtholphthalein
6. Titrate with 0.002 N methanolic KOH
7. Make blank determination by replacing the milk with water

Free fatty acid (µ equiv./ml) = $TN/(PV)x10^3$, where T is the net titration volume, N is the normality of the methanolic KOH, P is the proportion of the upper layer titrated and V is the volume of milk (Nanua et al, 2001). The value was determined on each sample prior to frothing

Foam Volume

The foam volume was calculated by taking the foam height after 5 minutes dissipation (FH_5) and subtracting the foam interface (FI_5). If the foam was not evenly distributed across the beaker, an average height was determined visually.

Foam Dissipation

The percent of foam dissipation was determined by the formula: % dissipation = (IF – FF_5) / (IF – FMI) X 100, where initial foam (IF) is foam height immediately after beaker was

removed from steam, final foam height (FF_5) is foam height after 5 minutes dissipation and, final milk interface (FMI) is the final milk-foam interface in beaker.

Statistical Analysis

The experiment had 24 treatments each with 5 trials and 3 replications. General linear model procedures were carried out using the SAS® software for windows, version 8.0 (SAS Institute, Cary, NC). Sample means were compared for significance of difference using Tukey's procedure with an alpha value of 0.05.

CHAPTER 4

RESULTS

There were 24 treatments in the experiment. Table 5 identifies the treatment variables used. All results represent the mean value of five trials of three replicates Steam Froth Value (SFV), Free Fatty Acid (FFA), Foam Volume (FV), and Percent Dissipation tests results for day*treatment are shown in each respective column of appendix. The appendix identifies that there was no interaction between treatments (Pr=F).

Table 5: Identification of treatment variables.

HS - HTST SKIM
US - UHT SKIM
HW - HTST WHOLE
UW - UHT WHOLE
HS FFA - HTST SKIM FFA PRE PASTEURIZATION
US FFA - UHT SKIM FFA PRE PASTEURIZATION
HW FFA - HTST WHOLE FFA PRE PASTEURIZATION
UW FFA - UHT WHOLE FFA PRE PASTEURIZATION
HS FFA PP - HTST SKIM FFA POST PASTEURIZATION
US FFA PP - UHT SKIM FFA POST PASTEURIZATION
HW FFA PP - HTST WHOLE FFA POST PASTEURIZATION
UW FFA PP - UHT WHOLE FFA POST PASTEURIZATION

There was no significant difference (P=0.05) between day 1 vs. day 10 for the same treatment for all test results of steam frothing value, foam volume, and percent dissipation when

all other factors not considered. Also, all results for the free fatty acid test for the same treatment over storage time (day 1 vs. day 10) were not significantly different except for the HS treatment (Table 6).

Table 6: Mean free fatty acid value (µ equiv./ml) for HTST skim vs. storage time.

Tukey Grouping	FFA (µ equiv./ml)	Day	Treatment
A	0.84	1	HS
B	0.96	10	HS

(Alpha 0.05, DF=4, Minimum Significant Difference = 0.096)
Means with the same letter are not significantly different.

Table 7: Model analysis of pasteurization temperature*fat level*lauric acid treatments between day 1 vs. day 10 by test type.

Test type	Tukey Grouping	Mean	Day
SFV			
	A	49.08	1
	B	45.54	10
(Alpha 0.05, DF=47, Minimum Significant Difference = 3.05) Means with the same letter are not significantly different.			
FFA (µ equiv./ml)			
	A	3.74	1
	B	3.96	10
(Alpha 0.05, DF=47, Minimum Significant Difference = 0.17) Means with the same letter are not significantly different.			
Foam Volume			
	A	2.47	1
	A	2.30	10
(Alpha 0.05, DF=47, Minimum Significant Difference = 0.17) Means with the same letter are not significantly different.			
Dissipation			
	A	42.40	1
	A	42.23	10
(Alpha 0.05, DF=47, Minimum Significant Difference = 5.18) Means with the same letter are not significantly different.			

For the model results of all treatments between day 1 vs. day 10, there was a significant difference ($P<0.05$) for SFV and FFA test procedures but not for foam volume or percent dissipation tests (Table 7).

For the steam frothing value (SFV) test, significant differences ($P<0.05$) due to lauric acid treatments both at day 1 (Table 8) and day 10 (Table 9) can be observed. As the level of free fatty acid (lauric acid) addition increases, the SFV significantly ($P<0.05$) declines.

Table 8: Mean steam frothing value (SFV) by treatment - Day 1.

Tukey Grouping		SFV	Treatment
	A	76.02	HS
	A	73.86	US
B	A	66.15	HW
B	A	65.68	UW
B	A	65.57	HW FFA
B	A	61.11	US FFA
B		51.07	HW FFA
B		49.58	UW FFA
	C	27.28	HS FFA PP
D	C	19.64	US FFA PP
D	C	10.96	UW FFA PP
D		8.44	HW FFA PP

(Alpha 0.05, DF=23, Minimum Significant Difference = 18.33)
Means with the same letter are not significantly different.

Table9: Mean steam frothing value (SFV) by treatment - Day 10.

Tukey Grouping		SFV	Treatment
	A	72.61	HS
	A	71.63	US
B	A	62.41	US FFA
B	A	61.35	HS FFA
B	A	58.16	UW
B	A	57.11	HW
B		50.68	UW FFA
B		47.02	HW FFA
	C	25.20	HS FFA PP
	C	21.33	US FFA PP
	C	11.46	UW FFA PP
	C	7.59	HW FFA PP

(Alpha 0.05, DF=24, Minimum Significant Difference = 19.67)
Means with the same letter are not significantly different.

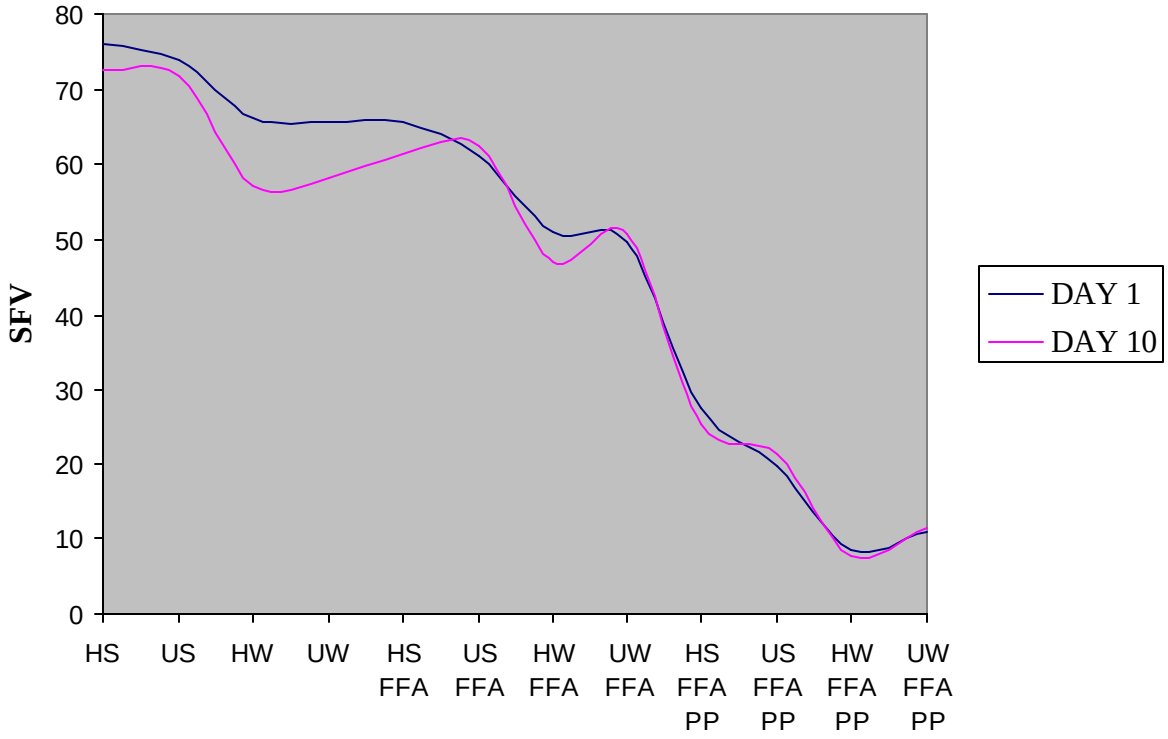


Figure 1. Mean steam frothing value by treatment.

Figure 1 depicts a graph of tables 8 and 9. As treatments go from no FFA addition to FFA addition prior to pasteurization to FFA addition post-pasteurization the mean SFV significantly decreases ($P<0.05$).

Table 10: Mean free fatty acid level (µ equiv./ml) by treatment - Day 1.

Tukey Grouping			FFA (µ equiv./ml)	Treatment
	A		7.32	UW FFA PP
	A		6.93	HW FFA PP
	B		5.48	UW FFA
	B		5.12	HW FFA
C	B		4.98	HS FFA PP
C	B	D	4.70	US FFA PP
C		D	3.76	HS FFA
		D	3.67	US FFA
	E		1.20	HW
	E		1.08	UW
	E		0.88	US
	E		0.84	HS

(Alpha 0.05, DF=23, Minimum Significant Difference = 18.33)
Means with the same letter are not significantly different.

Table 11: Mean free fatty acid level (µ equiv./ml) by treatment - Day 10.

Tukey Grouping	FFA (µ equiv./ml)	Treatment
A	7.42	UW FFA PP
A	7.24	HW FFA PP
B	5.62	UW FFA
B	5.34	HW FFA
B	5.26	HS FFA PP
B	4.82	US FFA PP
C	3.74	US FFA
C	3.68	HS FFA
D	1.28	HW
D	1.28	UW
D	0.96	HS
D	0.92	US

(Alpha 0.05, DF=24, Minimum Significant Difference = 0.85)
Means with the same letter are not significantly different.

For the FFA test (µ equiv./ml), both day 1 (Table 10) and day 10 (Table 11) showed similar significant differences ($P<0.05$) and trends (Figure 2). As the treatments went from no FFA addition to FFA addition post-pasteurization, the µequiv./ml of free fatty acid significantly increased ($P<0.05$). Table 10 also identifies the initial µ equiv./ml of FFA for all milk treatments before any additional free fatty acid treatments were applied (HS - 0.84, US - 0.88, UW – 1.08, HW – 1.20).

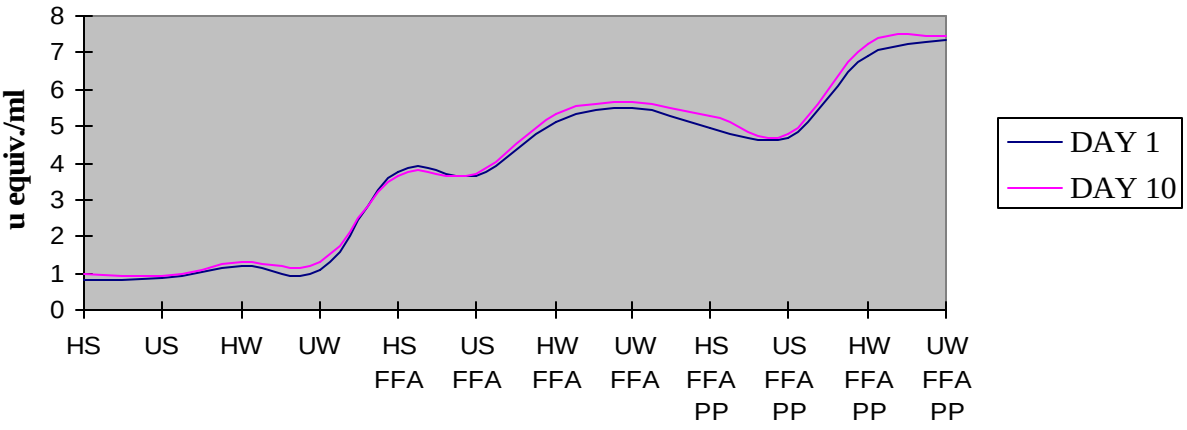


Figure 2. Mean free fatty acid level (µ equiv./ml) by treatment.

Table 12: Mean foam volume (FV) by treatment – Day 1.

Tukey Grouping			FV	Treatment
	A		3.81	HS
B	A		3.70	US
B	A	C	3.30	HW
B	A	C	3.29	UW
B	A	C	3.29	HS FFA
B	A	C	3.10	US FFA
B		C	2.60	HW FFA
	D	C	2.52	UW FFA
E	D		1.39	HS FFA PP
E			1.05	US FFA PP
E			0.57	UW FFA PP
E			0.45	HW FFA PP

(Alpha 0.05, DF=23, Minimum Significant Difference = 1.14)
Means with the same letter are not significantly different.

Table 13: Mean foam volume (FV) by treatment – Day 10.

Tukey Grouping			FV	Treatment
	A		3.63	HS
B	A		3.58	US
B	A	C	3.16	US FFA
B	A	C	3.09	HS FFA
B	A	C	2.92	UW
B	A	C	2.85	HW
B		C	2.59	UW FFA
		C	2.40	HW FFA
	D		1.33	HS FFA PP
	D		1.14	US FFA PP
	D		0.61	UW FFA PP
	D		0.40	HW FFA PP

(Alpha 0.05, DF=24, Minimum Significant Difference = 1.03)
Means with the same letter are not significantly different.

For the foam volume test, similar significant differences ($P<0.05$) appear for both day 1 (Table 12) and day 10 (Table 13). While there are observable differences between treatments, milk treatments with FFA addition post-pasteurization had significantly less foam volume compared to the other treatments (Figure 3).

The percent foam dissipation due to treatment shows similar significant differences ($P<0.05$) at both day 1 (Table 14) and day 10 (table 15). While there was no significant

difference over time (P=0.05), there are observable trends due to treatments. As the treatments moved from no FFA addition to FFA addition to FFA addition post-pasteurization, there is a significant increase in percent foam dissipation (Figure 4).

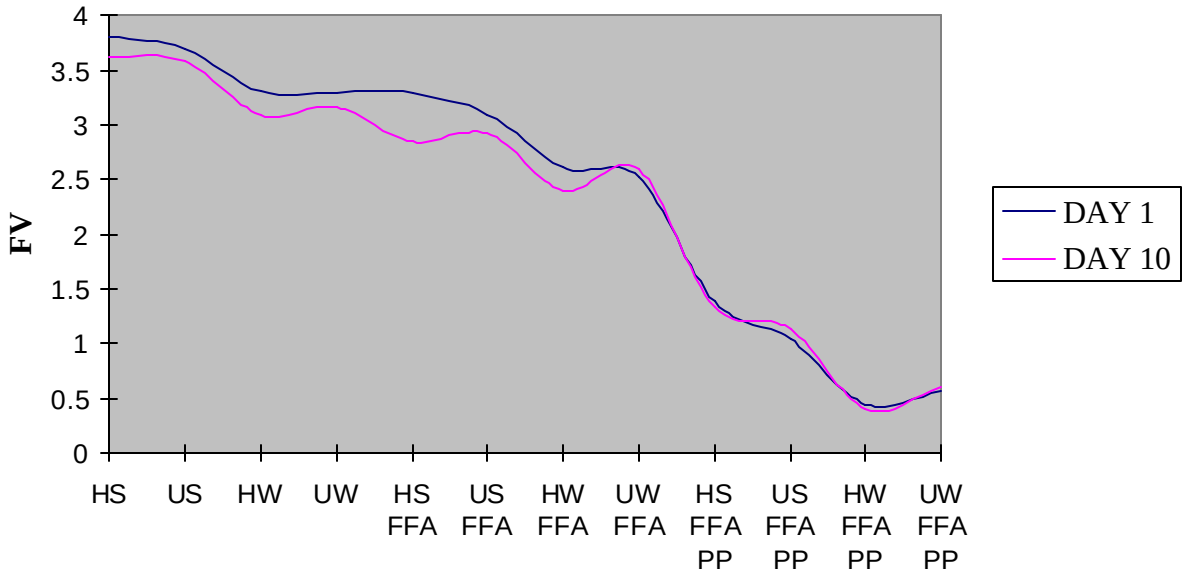


Figure 3. Mean foam volume by treatment.

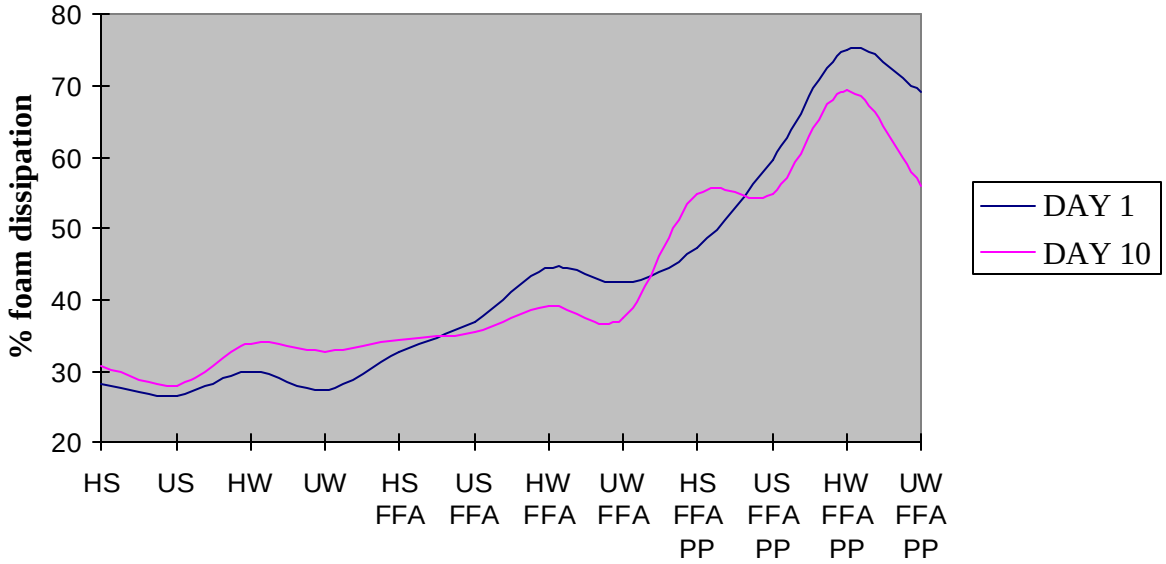


Figure 4. Mean percent foam dissipation by treatment.

Table 14: Mean percent foam dissipation (FD) by treatment after 5 minutes – Day 1.

Tukey Grouping			FD	Treatment
	A		75.00	HW FFA PP
B	A		69.10	UW FFA PP
B	A	C	59.69	US FFA PP
B	A	C	47.37	HS FFA PP
B	A	C	44.49	HW FFA
B	A	C	42.35	UW FFA
B	A	C	36.96	US FFA
B		C	32.77	HS FFA
B		C	29.89	HW
		C	28.15	HS
		C	27.30	UW
		C	26.60	US

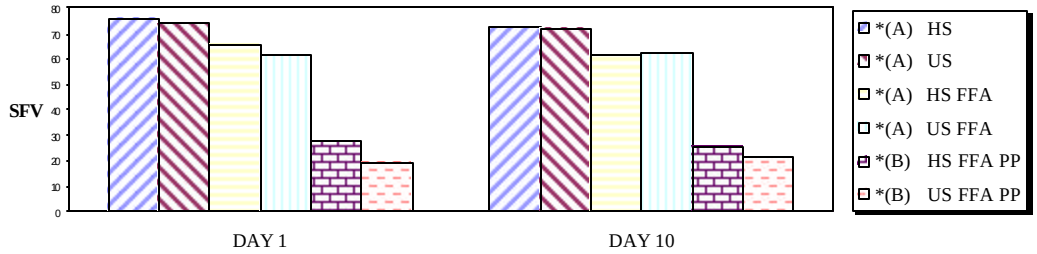
(Alpha 0.05, DF=23, Minimum Significant Difference = 39.89)
Means with the same letter are not significantly different.

Table 15: Mean percent foam dissipation (FD) by treatment after 5 minutes – Day 10.

Tukey Grouping			FD	Treatment
	A		69.27	HW FFA PP
B	A		56.01	UW FFA PP
B	A		54.88	US FFA PP
B	A		54.76	HS FFA PP
B		C	39.14	HW FFA
B		C	37.45	UW FFA
B		C	35.51	US FFA
B		C	34.50	HS FFA
B		C	33.84	HW
B		C	32.76	UW
		C	30.62	HS
		C	28.06	US

(Alpha 0.05, DF=24, Minimum Significant Difference = 23.471)
Means with the same letter are not significantly different.

When the SFV of the skim milk treatments was calculated, there was no significant differences (P=0.05) between pasteurization levels (HTST vs. UHT) and FFA addition pre-pasteurization, at either day 1 or day 10. There was also no significant difference (P=0.05) over time. However, both the HTST and UHT treatments with FFA addition post-pasteurization at day 1 and day 10 had significantly lower SFV than all other skim milk treatments (Figure 5).



* Treatments with the same letter are not significantly different.

Figure 5: Mean steam frothing value for skim milk by treatment.

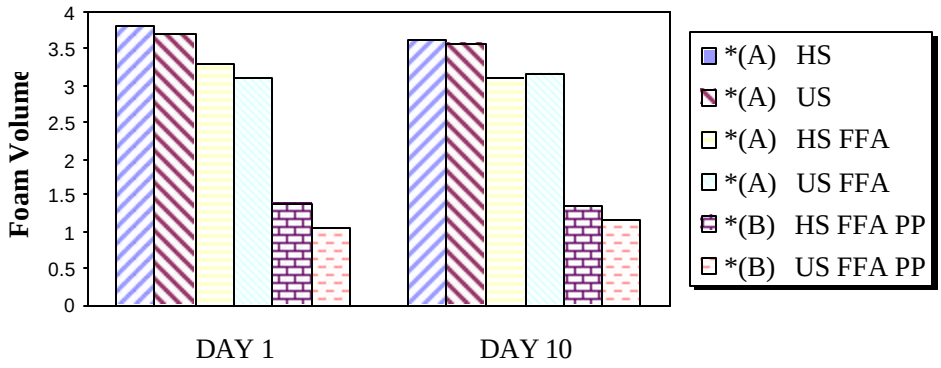
Skim milk treatment was significant (P<0.05) for µ equiv./ml of FFA based on FFA addition (Table 16). There was no significant difference (P=0.05) over time between the same treatments. The skim milk with no FFA addition was significantly lower (P<0.05) than all other treatments. While there was not a significant difference (P=0.05) between US FFA PP and HS FFA treatments, as the skim milk treatments went from no FFA addition to FFA addition pre-pasteurization to FFA addition post-pasteurization, the µ equiv./ml of FFA greatly increased.

Table 16: Mean FFA level (µ equiv./ml) for skim milk by treatment over time.

Tukey Grouping		FFA (µ equiv./ml)	Day	Treatment
	A	5.26	10	HS FFA PP
	A	4.98	1	HS FFA PP
	A	4.82	10	US FFA PP
B	A	4.70	1	US FFA PP
B	C	3.76	1	HS FFA
B	C	3.74	10	US FFA
	C	3.68	10	HS FFA
	C	3.67	1	US FFA
	D	0.96	10	HS
	D	0.92	10	US
	D	0.88	1	US
	D	0.84	1	HS

(Alpha 0.05, DF=24, Minimum Significant Difference = 0.96)
Means with the same letter are not significantly different.

Foam volume of skim milk by treatment is shown in Figure 6. There was no significant difference (P=0.05) over time for the same treatments, and no significant difference (P=0.05) between skim milk with no FFA addition and FFA addition pre-pasteurization. However, there was a significant lowering (P<0.05) of foam volume at both day 1 and 10 of skim milk with FFA addition post-pasteurization.



* Treatments with the same letter are not significantly different.

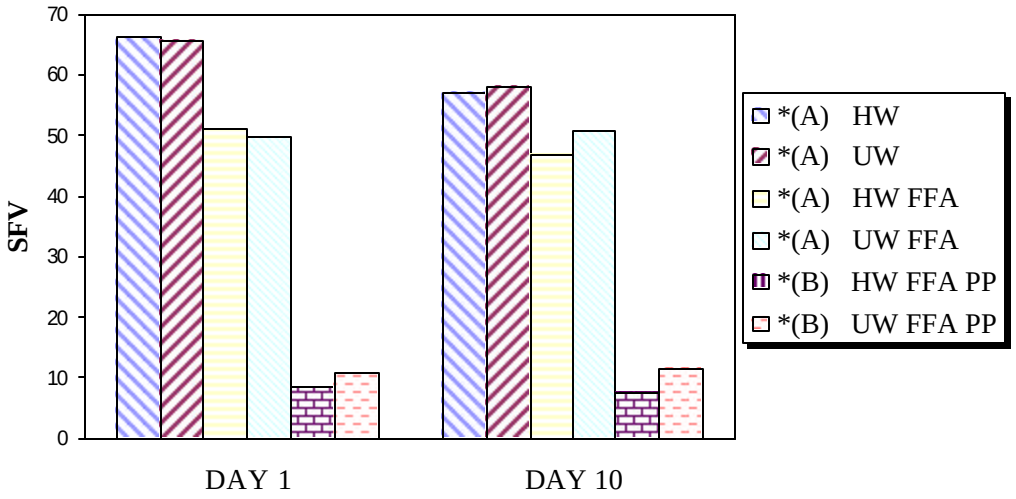
Figure 6: Mean foam volume of skim milk by treatment.

Table 17: Mean percent foam dissipation (FD) for skim milk by treatment over time.

Tukey Grouping			FD	Day	Treatment
	A		59.69	1	US FFA PP
B	A		54.88	10	US FFA PP
B	A		54.76	10	HS FFA PP
B	A	C	47.37	1	HS FFA PP
B	D	C	36.96	1	US FFA
B	D	C	35.51	10	US FFA
	D	C	34.50	10	HS FFA
	D	C	32.77	1	HS FFA
	D	C	30.62	10	HS
	D	C	28.15	1	HS
	D	C	28.06	10	US
	D		26.60	1	US

(Alpha 0.05, DF=24, Minimum Significant Difference = 20.23)
Means with the same letter are not significantly different.

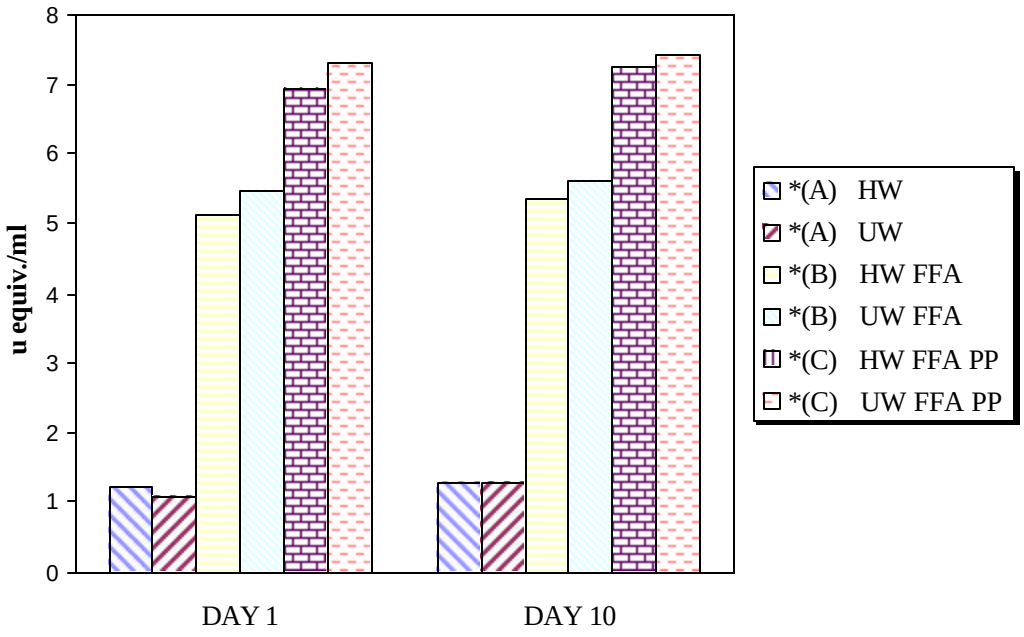
The percent foam dissipation of skim milk by treatment shows both observable significant differences ($P<0.05$) and trends (Table 17). While there was no significant difference ($P=0.05$) between percent dissipation of skim milk treatment US FFA and HS FFA PP, the treatments with FFA addition post-pasteurization had greatly increased mean percentages of dissipation over the other FFA treatments.



* Treatments with the same letter are not significantly different.

Figure 7. Mean steam frothing value of whole milk by treatment.

The SFV of whole milk showed almost identical results as that of skim milk (Figure 5). There was no significant difference ($P=0.05$) due to time between the same treatments and no significant difference ($P=0.05$) between SFV of whole milk with out FFA addition and FFA addition pre-pasteurization. There was also no significant difference ($P=0.05$) between the HTST and UHT treatments of whole milk for SFV with FFA addition post-pasteurization. However, at both day 1 and day 10, the SFV for whole milk with FFA addition post-pasteurization was significantly lower ($P<0.05$) than all other treatments (Figure 7).

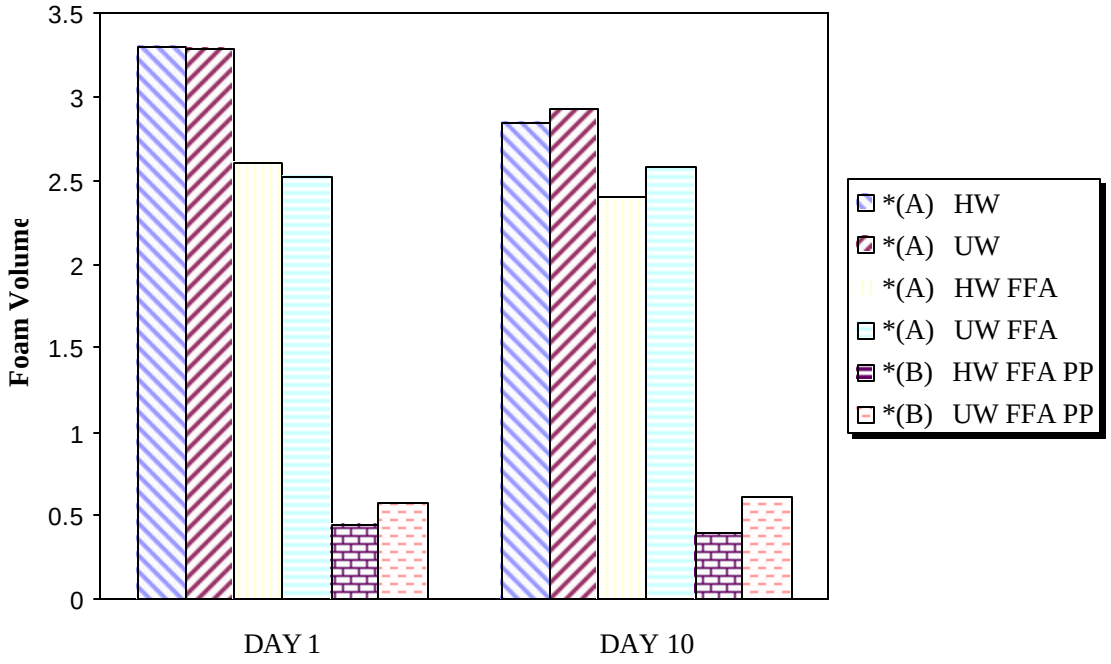


* Treatments with the same letter are not significantly different.

Figure 8. Mean free fatty acid level (µ equiv./ml) of whole milk by treatment.

The free fatty acid level (µ equiv./ml) of whole milk by treatment was not significantly different (P=0.05) over time when looking at the same treatments. However, there was a significant difference (P<0.05) of FFA level of whole milk when FFA addition treatment was applied. There was a significant difference (P<0.05) between whole milk with no FFA addition, FFA addition pre-pasteurization and FFA addition post-pasteurization (Figure 8).

The foam volume of whole milk by treatment over time showed similar results to that of skim milk (Figure 6). There was no significant difference for the same treatments over time (P=0.05), and there was no significant difference (P=0.05) between foam volume of whole milk without FFA addition and with FFA addition pre-pasteurization. However, at both days 1 and 10, there was a significant difference (P<0.05) between foam volume of whole milk with FFA addition post-pasteurization and all other treatments (Figure 9).



* Treatments with the same letter are not significantly different.

Figure 9. Mean foam volume of whole milk by treatment.

There were significant differences ($P<0.05$) in percent dissipation of whole milk due to treatment (Table 18). As with the percent dissipation of skim milk (Table 17), there was no significant difference over time when looking at the same treatments. Table 18 shows that while there are significant differences ($P<0.05$) in percent dissipation by treatments, there is also an observable trend in increased dissipation from whole milk treatments with no FFA addition to FFA addition pre-pasteurization to FFA addition post-pasteurization.

Table 19 identifies the test results when the pasteurization treatment is applied. No significant difference ($P=0.05$) in any of the testing procedures was observed when day*lauric acid*fat level treatments were applied.

Table 18: Mean percent foam dissipation (FD) for whole milk by treatment over time.

Tukey Grouping			FD	Day	Treatment
	A		75.00	1	HW FFA PP
B	A		69.27	10	HW FFA PP
B	A		69.10	1	UW FFA PP
B	A	C	56.01	10	UW FFA PP
B	A	C	44.49	1	HW FFA
B	A	C	42.35	1	UW FFA
B	A	C	39.14	10	HW FFA
B	A	C	37.45	10	UW FFA
B	A	C	33.84	10	HW
B		C	32.76	10	UW
B		C	29.89	1	HW
		C	27.30	1	UW

(Alpha 0.05, DF=23, Minimum Significant Difference = 41.79)
Means with the same letter are not significantly different.

Table 19: Mean values of all tests when day*fat level*lauric acid treatments for pasteurization are applied.

Test type	Tukey Grouping	Mean	Treatment
SFV			
	A	48.22	HTST
	A	46.38	UHT
(Alpha 0.05, DF=47, Minimum Significant Difference = 3.05)			
FFA (μ equiv./ml)			
	A	3.91	UHT
	A	3.79	HTST
(Alpha 0.05, DF=47, Minimum Significant Difference = 0.17)			
Foam volume			
	A	2.43	HTST
	A	2.35	UHT
(Alpha 0.05, DF=47, Minimum Significant Difference = 0.17)			
Dissipation			
	A	42.41	HTST
	A	42.22	UHT
(Alpha 0.05, DF=47, Minimum Significant Difference = 5.19)			

Means with the same letter are not significantly different.

The treatment of free fatty acid level and all other treatments is shown in table 20. There was a significant difference ($P<0.05$) between all three fatty acid levels (no FFA addition, FFA addition pre-pasteurization, and FFA addition post-pasteurization) for all tests used. When SFV was observed, all milk treatments with no FFA addition had the highest SFV, while all milk treatments with FFA addition post-pasteurization showed the lowest SFV. This same trend was observed for FFA addition level when using the µ equiv./ml test, foam volume and percent dissipation. The milk treatments with no FFA addition showed significantly lower levels of FFA (µ equiv./ml), the greatest foam volume, and the lowest percent dissipation. The milk treatments with FFA addition post-pasteurization had the highest levels of FFA (µ equiv./ml), the least foam volume, and the greatest percent dissipation.

Table 20: Mean test values for free fatty acid level when day*fat level*pasteurization model was applied.

Test type	Tukey Grouping	Mean	Treatment
SFV			
	A	67.65	NO FFA
	B	56.10	FFA
	C	16.84	FFA PP
(Alpha 0.05, DF=47, Minimum Significant Difference = 4.49) Means with the same letter are not significantly different.			
FFA (µ equiv./ml)			
	A	6.05	FFA PP
	B	4.55	FFA
	C	1.06	NO FFA
(Alpha 0.05, DF=47, Minimum Significant Difference = 0.25) Means with the same letter are not significantly different.			
Foam volume			
	A	3.38	NO FFA
	B	2.84	FFA
	C	0.88	FFA PP
(Alpha 0.05, DF=47, Minimum Significant Difference = 0.25) Means with the same letter are not significantly different.			

Table continued

Dissipation

A	60.14	FFA PP
B	37.90	FFA
C	29.65	NO FFA

(Alpha 0.05, DF=47, Minimum Significant Difference = 7.64)
Means with the same letter are not significantly different.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

Time Treatment

Based on the current results, the age of the milk used for frothing is not significantly critical. There was no significant difference (P=0.05) found between day 1 vs. day 10 for SFV, foam volume, or percent dissipation when comparing the same treatment over time. There was also no significant difference (P=0.05) over time based on fat level, pasteurization temperature, or free fatty acid addition. These findings were similar to those found by Deeth and Smith (1983) for SFV; however, they only looked at 0, 1, and 2 day's storage time.

When all factors were applied to treatments (fat level*lauric acid*pasteurization temp) and results due to time (day 1 vs. day 10) were observed, there was a significant difference (P<0.05) in SFV and FFA level (µ equiv./ml), however, not in the foam volume or percent dissipation (Table 7). These findings are also similar to those found by Nanua et al. (2001) for SFV. He found that the SFV for skim milk increased with storage time up to 10 days, while whole milk did not change significantly. Figure 1 shows the trends observed at both day 1 and day 10. There was a slight increase from day 1 to day 10 in the SFV of both the HS FFA and US FFA treatments.

Lauric Acid Addition

When the treatment of lauric acid (free fatty acid) by all other treatments (day, pasteurization level, and fat content) were observed for all test types (SFV, FFA (µ equiv./ml), foam volume, and dissipation) a significant difference (P<0.05) was found as the level of FFA increased from no FFA addition to FFA addition pre-pasteurization to FFA addition post-pasteurization (Table 20). As the amount of free fatty acid increased, the SFV decreased, the µ equiv./ml increased, the foam volume decreased, and the percent dissipation increased. Several

factors affect the foaming properties – protein concentration, pH, temperature, salt, sugars, and lipids. The pH of the dispersing medium markedly affects foaming, particularly foam stability, by its direct effects on the net charge and conformation of the protein (Kinsella, 1981). Maximum protein-protein interaction occurs close to the isoelectric pH and consequently surface rheological properties are also at a maximum. When making protein foams close to the isoelectric pH of the protein, excessive coagulation at the interface may be accelerated, thereby reducing foam formation and stability because rupture of the lamella and protein desorption occurs (Kinsella, 1984). While the pH and isoelectric point was not observed in this experiment, the addition of lauric acid did increase the ion concentration and lower the milk's pH. These findings all correspond to similar results found by Nanua et al. (2001) and Deeth, et al (1976, 1983) in respect to increasing FFA (µ equiv./ml) decreases SFV. However, they contradict with Deeth and Smith (1983) as to the level of µ equiv./ml of free fatty acid that will still produce a stable foam. They found the effect on SFV was small in milk with natural lipase-induced lipolysis, until the FFA reached 1.6-2.0 µ equiv./ml and thereafter the steam frothing ability showed a marked decline until the FFA of 2.0 – 3.0, when the milk showed negligible frothing (SFV of 0 – 10). They did however find that with a *Candida* (bacterial) lipase, a steady decrease in SFV was observed, but negligible foaming was not observed until relatively high FFAs (4.2 µ equiv./ml.) were reached. Our results show that while there was a decline in SFV as µ equiv./ml increased, all the treatments with FFA added pre-pasteurization still had relatively high SFVs, even after 10 days (47.019 – 62.41) (Table 9). These treatments had FFA levels (µ equiv./ml) as high as 5.62 (UW FFA – day 10) (Table 12) and still maintained a significant level of foam (Table 15).

It is clear that an addition of lauric acid created a significant increase in the FFA level (Table 10 & 11) of the milk. The milk with no lauric acid treatment had significantly ($P<0.05$)

lower levels of FFA (μ equiv./ml) compared to the milk with free fatty acid added both pre and post-pasteurization. However, the effect of pasteurization, itself, on the milk, significantly affected this treatment and the SFV, foam volume, and dissipation of the milk treated with free fatty acid. The milk treated with FFA addition pre-pasteurization had a significantly higher ($P<0.05$) SFV than all the milk treated with FFA post-pasteurization at both day 1 and day 10, yet, was not significantly different ($P=0.05$) from most of the non FFA treated milk (Table 8 & 9). These same trends can be observed for foam volume and dissipation (Table 12, 13, 14, & 15).

When lauric acid addition post-pasteurization is observed due to fat level, the effect due to pasteurization is even more observable. There was no significant difference ($P=0.05$) between the HS, US, HS FFA, and US FFA treatments for skim milk at both day 1 and day 10 for SFV (Figure 5) and foam volume (Figure 6); however, the HS FFA PP and US FFA PP treatments at both day 1 and 10 were significantly ($P<0.05$) lower. These same results can be seen for the SFV (Figure 7) and foam volume (Figure 9) for whole milk. Deeth and Fitz-Gerald (1976) reported that normal pasteurization of milk inactivates the lipase enzyme but does not destroy any taint which is already present at pasteurization. Deeth and Smith (1983) did take factory raw bulk milk and heat treat it to 75°C before immediately re-cooling to deactivate the lipase. They did find a considerable enhancement of steam frothing compared to the raw, unheated samples. However, this research only looked at the free fatty acids originating due to the lipase enzyme, which is deactivated by heating.

Pasteurization

Based on the current results, the temperature of pasteurization does not appear to affect the SFV, FFA level, foam volume, or dissipation of milk by steam frothing. There was no significant difference ($P=0.05$) between the HTST treatment and the UHT treatment when all

treatments were applied (Table 19). Heat treatments and temperature affect foaming via their effects on protein structure and viscosity of the aqueous phase. Limited heating, which induces partial unfolding of globular proteins without causing thermal coagulation, facilitates foam formation (Kinsella, 1981). These findings appear to agree with those of Deeth and Smith (1983) who found only a minimal significant difference in SFV due to pasteurization temperature ranges of 72°C – 80°C.

Conclusions

The age, pasteurization temperature, and fat level of milk do not appear to have a significant affect on the overall ability of the milk to form a stable foam due to steam frothing. However, there were noticeable trends in the frothing characteristics due to the different treatments.

There was no significant difference between the fat level treatments for all tests applied, however, the characteristics of the foams varied. As previous research has shown, skim milk tends to produce a lighter, "airier" foam over whole milk. It also tends to produce greater foam volume. These characteristics can be important in the coffeehouse when certain foam qualities are desired for specific applications.

While the age of the milk over ten days did not significantly affect the froth, there was a decrease in the SFV and an increase in percent dissipation. Since the typical shelf life of pasteurized milk is approximately 14 days, it may be necessary to look at the frothing characteristics over this time frame.

The origins of the free fatty acids present in the milk and the heat treating of those free fatty acids do appear to significantly affect the frothing characteristics. The results of this study found that adding Lauric acid (which is naturally present in milk at levels of 2% – 5 %) still

allowed for a stable foam to be formed. It is possible that the origin or type of free fatty acid that is present in the milk has different effects on the milk's ability to form a stable foam.

Previous research has shown that the levels of free fatty acids can greatly vary and still produce a stable foam when different origins of free fatty acid were applied. Future research should therefore look at the different types of free fatty acids that occur naturally in milk. These free fatty acids levels could change over the lactation period of the cow as well as what the cow digests. Future research should determine if a specific free fatty acid is present at the time when milk does not properly foam and at what concentration. This research could be extremely important for the coffee industry because it could allow processors to identify when the milk may be unsuitable for use in coffeehouses.

Another significant observation from this study is the effect of pasteurization on the free fatty acids present in the milk. Pasteurization did have a significant effect on the frothing characteristics of the milk due to free fatty acid addition. Heat treatment deactivates the lipase enzymes that initiate the production of free fatty acids. It has been previously shown that milk frothed after heat treatment improved frothing ability. While heat treatment does not eliminate the free fatty acids present in the milk, it does affect their ability to further increase the free fatty acids effect on frothing. However, what effect heat treatment has on the natural free fatty acids present in milk has not been determined by this study.

It is possible that the effect of homogenization and not heating, alone, improved frothing when the FFA was added before pasteurization. The homogenization may have formed a more stable emulsion with the added free fatty acid that helped improve the milks frothing. If the effect is related to emulsion stability, this is a fundamental discovery. New research should look at emulsion stability as the basis for frothing performance.

REFERENCES

Blake, M.R., Koka, R., and Weimer, B.C. 1996. A semi-automated reflectance colorimetric method for the determination of lipase activity in milk. J. Dairy Sci. 79: 1164-1171.

Britten, M. and Lavoie, L. 1992. Foaming properties of proteins as affected by concentration. J. Food Sci. 57: 1219-1222.

Burton, H. 1988. Properties of UHT-processed milk. Elsevier Applied Sci. 268.

Cartier, P. and Chillard, Y. 1990. Spontaneous lipolysis in bovine milk: combined effects of nine characteristics in native milk. J. Dairy Sci. 73: 1178-1186.

Celestino, E.L., Iyer, M., and Roginski, H. 1996. The effects of refrigerated storage on the quality of raw milk. Aus. J. Dairy Sci. 51: 59-64.

Choi, I.W. and Jeon, I.J. 1993. Patterns of fatty acids released from milk fat by residual lipase during storage of ultra-high temperature processes milk. J. Dairy Sci. 76: 78-85.

Christen, G.L. and Lee, C. M. 1994. Impact of raw milk quality attributes on milk lipolysis. Tenn. Farm and Home Sci. Spring: 39-43.

Dairy Handbook, 1996. Alfa-Laval. Food Engineering AB. Lund, Sweden.

Deeth, H.C. and Fitz-Gerald, C.H. 1976. Lipolysis in dairy products: a review. Aus. J. Dairy Tech. June: 53-64.

Deeth, H.C. and Fitz-Gerald, C.H. 1995. Lipolytic enzymes and lipolytic rancidity in milk and milk products. Advanced Dairy Chem. Vol. 2: 247.

Deeth, H.C. and Smith, R.A.D. 1983. Lipolysis and other factors affecting the steam frothing capacity of milk. Aus. J. Dairy Tech. S:March: 14-19.

Kinsella, J.E. 1981. Functional properties of proteins: possible relationships between structure and function in foams. Food Chemistry. 7: 273-288.

Kinsella, J.E. 1984. Milk proteins : physicochemical and functional properties. Critical reviews in food science and nutrition. 21: 197-262.

Kintner, J.A. and Day, E.A. 1965. Major free fatty acids in milk. J. Dairy Sci. 48: 1575-1581.

Leman, J. and Kinsella, J.E. 1989. Surface activity, film formation, and emulsifying properties of milk proteins. Critical reviews in food science and nutrition. 28: 115-138.

Levy, M.I. and McGregor, J.U. 1998. Effect of fat content and whey protein fortification on milk forthing properties. J. Dairy Sci. 81 S1:23.

Lyster, R.L.J. 1964. The free and masked sulphydryl groups of heated milk and milk powder and a new method for their determination. J. Dairy Res. 31: 41-51.

Manji, B. and Kakuda, Y. 1987. Determination of whey protein denaturation in heat-processed milks: comparison of three methods. J. Dairy Sci. 70: 1355-1361.

Nanua, J. N., McGregor, J. U., Osorio, L. F. and Traylor S. 2002. Contribution of the products of fat hydrolysis to the frothing capacity of milk. International J. of Agric. and Rural Dev. Vol. 4 (Accepted for publication).

Nanua, J.N., McGregor, J.U. and Osorio, L.F. 2001. Influence of fatty acids and glycerol on the foaming properties of milk used in the manufacture of cappuccinos. IFT Annual Meeting Technical Program Abstracts.

National Coffee Association of USA, Inc. – 1999 Coffee Study. Consumption patterns from 1960 to present.

Olivecrona, T., and Bengtsson, G. 1983. Lipases in milk. Page 206 in Lipases. B. Borgstrom and H. Brockman, ed. Elsevier, Amsterdam.

Phillips, L.G., Yang, S.T., Schulman, W., and Kinsella, J.E. 1989. Effects of lysozyme, culpeine, and sucrose on the foaming properties of whey protein isolate and ß-lactoglobulin. J. Food Sci. 54: 743-747.

Pilhofer, G.M., Lee, H., McCarthy, M.J., Tong, P.S., and German, B. 1994. Functionality of milk fat in foam formation and stability. J. Dairy Sci. 77: 55-63.

SAS User's Guide: Statistics, Version 8. 1999. SAS Inst., I. Cary, NC.

Sundheim, G. and Bengtsson-Olivecrona. 1987. Methods to asses the propensity of milk fat globules toward lipolysis and the ability of skim milk to inhibit lipolysis. J. Dairy Sci. 70: 2040-2045.

Ward, B.R., Goddard, S.J., Augustin, M., and McKinnon, I.R. 1997. EDTA-induced dissociation of casein micelles and its effect on foaming properties of milk. J. Dairy Res. 64: 495-504.

APPENDIX

STATISTICAL ANALYSIS OF TREATMENTS BY DAY

Dependent Variable: SFV

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	36504.66011	1587.15914	38.84	<.0001
Error	47	1920.61089	40.86406		
Corrected Total	70	38425.27100			

R-Square	Coeff Var	Root MSE	sfv Mean
0.950017	13.51787	6.392500	47.28927

Source	DF	Type I SS	Mean Square	F Value	Pr > F
day	1	221.40238	221.40238	5.42	0.0243
treat	11	36087.58960	3280.68996	80.28	<.0001
day*treat	11	195.66813	17.78801	0.44	0.9320

Source	DF	Type III SS	Mean Square	F Value	Pr > F
day	1	101.83816	101.83816	2.49	0.1211
treat	11	35861.47791	3260.13436	79.78	<.0001
day*treat	11	195.66813	17.78801	0.44	0.9320

Dependent Variable: FFA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	359.7425831	15.6409819	122.07	<.0001
Error	47	6.0221207	0.1281302		
Corrected Total	70	365.7647038			

R-Square	Coeff Var	Root MSE	ffa Mean
0.983536	9.287691	0.357953	3.854056

Source	DF	Type I SS	Mean Square	F Value	Pr > F
day	1	0.8733985	0.8733985	6.82	0.0121
treat	11	358.6872662	32.6079333	254.49	<.0001
day*treat	11	0.1819185	0.0165380	0.13	0.9996

Source	DF	Type III SS	Mean Square	F Value	Pr > F
day	1	0.3133388	0.3133388	2.45	0.1246
treat	11	356.1584463	32.3780406	252.70	<.0001
day*treat	11	0.1819185	0.0165380	0.13	0.9996

Dependent Variable: foamvolume

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	89.27763662	3.88163637	29.15	<.0001
Error	47	6.25840000	0.13315745		
Corrected Total	70	95.53603662			

R-Square	Coeff Var	Root MSE	foamvol Mean
0.934492	15.25012	0.364907	2.392817

Source	DF	Type I SS	Mean Square	F Value	Pr > F
day	1	0.51440678	0.51440678	3.86	0.0553
treat	11	88.26044736	8.02367703	60.26	<.0001
day*treat	11	0.50278249	0.04570750	0.34	0.9708

Source	DF	Type III SS	Mean Square	F Value	Pr > F
day	1	0.22870748	0.22870748	1.72	0.1964
treat	11	87.66543559	7.96958505	59.85	<.0001
day*treat	11	0.50278249	0.04570750	0.34	0.9708

Dependent Variable: dissipation

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	13742.64021	597.50610	5.06	<.0001
Error	47	5545.86087	117.99704		
Corrected Total	70	19288.50107			

R-Square	Coeff Var	Root MSE	dissipat Mean
0.712478	25.67018	10.86264	42.31620

Source	DF	Type I SS	Mean Square	F Value	Pr > F
day	1	0.48148	0.48148	0.00	0.9493
treat	11	13179.42938	1198.12994	10.15	<.0001
day*treat	11	562.72935	51.15721	0.43	0.9329

Source	DF	Type III SS	Mean Square	F Value	Pr > F
day	1	20.19811	20.19811	0.17	0.6810
treat	11	13153.65981	1195.78726	10.13	<.0001
day*treat	11	562.72935	51.15721	0.43	0.9329

Day - Heat - Fat - FFA	SFV (mean)	FFA (mean)	FV (mean)	Dissipation (mean)
1 HTST Skim No FFA	76.02 A	0.84 E	3.81 A	28.15 C
1 HTST Skim FFA Pre-Pasteurization	51.08 B	3.76 C D	3.29 A B C D	32.77 C
1 HTST Skim FFA Post-Pasteurization	27.28 C D	4.98 B	1.39 E F G	47.37 A B C
1 HTST Whole No FFA	66.15 A B	1.20 E	3.30 A B C D	29.89 C
1 HTST Whole FFA Pre-Pasteurization	65.58 A B	5.12 B	2.61 B C D	44.49 A B C
1 HTST Whole FFA Post-Pasteurization	10.96 D	6.93 A	0.45 G	75.00 A
1 UHT Skim No FFA	73.86 A	0.88 E	3.70 A	26.60 C
1 UHT Skim FFA Pre-Pasteurization	61.11 A B	3.67 D	3.10 A B C D	36.96 B C
1 UHT Skim FFA Post-Pasteurization	19.65 D	4.70 B C D	1.05 G	59.69 A B C
1 UHT Whole No FFA	65.68 A B	1.08 E	3.29 A B C D	27.30 C
1 UHT Whole FFA Pre-Pasteurization	49.59 B	5.48 B	2.52 C D E	42.35 A B C
1 UHT Whole FFA Post-Pasteurization	8.44 D	7.32 A	0.57 G	69.10 A B
10 HTST Skim No FFA	72.61 A	0.96 E	3.63 A B C	30.62 C
10 HTST Skim FFA Pre-Pasteurization	61.35 A B	3.68 D	3.09 A B C D	34.50 C
10 HTST Skim FFA Post-Pasteurization	25.20 D	5.26 B	1.33 F G	54.76 A B C
10 HTST Whole No FFA	57.11 A B	1.28 E	2.85 A B C D	33.84 C
10 HTST Whole FFA Pre-Pasteurization	47.02 B C	5.34 B	2.40 D E F	39.14 B C
10 HTST Whole FFA Post-Pasteurization	7.59 D	7.24 A	0.40 G	69.27 A B
10 UHT Skim No FFA	71.63 A	0.92 E	3.58 A B C	28.06 C
10 UHT Skim FFA Pre-Pasteurization	62.41 A B	3.74 C D	3.16 A B C D	35.51 B C
10 UHT Skim FFA Post-Pasteurization	21.33 D	4.82 B C	1.14 G	54.88 A B C
10 UHT Whole No FFA	58.16 A B	1.28 E	2.92 A B C D	32.76 C
10 UHT Whole FFA Pre-Pasteurization	50.69 B	5.62 B	2.59 B C D	37.45 B C
10 UHT Whole FFA Post-Pasteurization	11.47 D	7.42 A	0.61 G	56.01 A B C

For each column, means with same letters are not significantly different (P=0.05)

[1] Minimum significant difference: 20.35

[2] Minimum significant difference: 1.14

[3] Minimum significant difference: 1.16

[4] Minimum significant difference: 34.58

VITA

Michael Levy was born on July 5, 1968, in Chicago, Illinois, to Charles and Nancy Levy. He graduated from Niles West High School in 1986 and began his studies at the University of Illinois, Champaign-Urbana. He received his Bachelor of Science degree in child psychology development in December of 1996. He spent a year studying abroad at Tel Aviv University in Israel, in 1990. He remained in Israel from 1991 to 1993 where he spent a year in the Israeli army. It was during this period when he traveled throughout Israel and Europe that he was exposed to the food and dairy industry.

Michael entered the Louisiana State University Graduate School to work towards his Master of Science in dairy food technology. He studied dairy and food science including ice cream and cheese making under the guidance of his major professor, Dr. John U. McGregor and will receive his degree at the May 2003 Commencement,

Michael began working as Director of the Dairy Division for Chef John Folse in January of 2001. He has spent the last 2 years in research and development, including, traveling throughout the United States visiting University and Artisan cheese companies and learning about specialty and artisan cheese making in America. He plans to continue his work to develop, produce and distribute new varieties of specialty artisan cheeses at a national level.