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Characteristics of Milk and Reduced Fat Cheddar Cheese from Cows Fed Extruded Soybeans and Niacin

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CHARACTERISTICS OF MILK AND REDUCED FAT CHEDDAR CHEESE FROM COWS FED EXTRUDED SOYBEANS AND NIACIN

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CHARACTERISTICS OF MILK AND REDUCED FAT CHEDDAR CHEESE FROM COWS FED EXTRUDED SOYBEANS AND NIACIN

This thesis is approved as a creditable and independent investigation by a candidate for the degree, master of science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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LIST OF ABBREVIATIONS

C = control diet or milk from cows fed a control diet

C+ = control diet with added niacin or milk from cows fed a control diet with added niacin

CHD = coronary heart disease

CNH = control not homogenized cheese milk treatment or cheese made from milk of that treatment

CPH = control part homogenized cheese milk treatment or cheese made from milk of that treatment

ESB = supplemental fat diet from extruded soybeans or milk from cows fed a supplemental fat diet from extruded soybeans

ESB+ = supplemental fat diet from extruded soybeans with added niacin or milk from cows fed a supplemental fat diet from extruded soybeans with added niacin

LDL = low-density lipoprotein

SNF = solids-non-fat

TC = total blood plasma cholesterol

UNH = cheese milk higher in unsaturated fatty acids not homogenized or cheese made from milk of that treatment

UPH = cheese milk higher in unsaturated fatty acids part homogenized or cheese made from milk of that treatment

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INTRODUCTION:

Today's consumers are demanding food products that are "low-fat", "reduced fat", "high in unsaturated fatty acids", and "low cholesterol". This trend in food product selection is at the advice of many health professionals. Current health recommendations are to lower the dietary intake of fat, especially saturated fat. In 1992, total dairy sales accounted for over 10% of total food sales (Milk Industry Foundation, 1993). Since dairy products are perceived as being hypercholesterolemic, a market exists for dairy products which are "lower in fat" and/or "lower in saturated fat". It is said that "consumer perception is marketing reality", and because of this the dairy industry may alter consumers views on dairy products by manufacturing perceived "healthier" products. Due to current dietary guidelines, dairy products with higher concentrations of unsaturated fatty acids could include a portion of the dairy market.

Coronary heart disease (CHD) risk factors played a major role in setting these new dietary guidelines. Greater than 500,000 deaths are blamed on CHD each year in the United States (Ney, 1991). Atherosclerosis is a disease in which lipids and cholesterol accumulate on the arterial walls causing them to thicken, resulting in CHD. It is important that the dairy industry realizes these concerns and acts on them by capturing a share of the market for foods perceived as being healthier.

Evidence suggests that only certain fatty acids are associated with increasing the risks of CHD. Milk fat from dairy cows possesses its own unique fatty acid profile. It contains approximately 66% saturated fatty acids, 30% monounsaturated, and 4% polyunsaturated. Half of the medium-chain ($C_{12:0}$ to $C_{17:0}$) and almost all of the long-chain fatty acids ($C_{18:0}$ and longer) are derived from the cow's diet (Eppard et al., 1985). This last statement suggests that dietary manipulation could be used to alter the fatty acid profile of milk fat. Other factors that may alter the fatty acid content of milk include seasonal variation, genetic variation, stage of lactation, and use of recombinant bovine somatotropin.

It has been found that feeding cows supplemental fat increases the concentration of unsaturated fatty acids in milk fat (Grummer, 1991). While this may be appealing to the consumer there are still some potential problems which should be overcome before integration into the industrial market. The first concern is producer economics for buying special feed for their dairy herd. Another potential problem would be the manufacturers economics and logistics regarding keeping the milk separate throughout and after pickup and processing. It has also been reported (Stegeman et al., 1991; Lightfield et al., 1993) that the fat content in milk higher in unsaturated fatty acids is underestimated when analyzed by the mid-infrared spectroscopic method. It is important that these concerns are realized and corrective action is taken.

The National Cheese Institute (1992) stated that total retail cheese sales were up 5% in 1991, reaching in excess of $18 billion dollars. Despite perceived health concerns the nation's cheese market has continued to grow with one-third of the milk supply going towards its manufacture. The largest growth in the cheese industry belongs to the Italian cheese market which went from 2.06 pounds (4.5 kg) per capita in 1970 to 9.36 pounds (20.6 kg) in 1991 (National Cheese Institute, 1992). American type cheeses (of which Cheddar makes up the largest portion) increased from 7.02 (15.4 kg) pounds per capita in 1970 to 11.1 pounds (24.4 kg) in 1991.

Cheeses which meet regulations for reduced fat or low-fat have steadily gained prominence on the dairy shelf. It appears that cheeses which meet both dietary recommendations of being lower in fat and saturated fat would stand an increased chance to succeed in today's marketplace. The objective of this study was to feed supplemental fat from extruded soybeans to lactating dairy cows and to manufacture a reduced fat Cheddar cheese higher in unsaturated fatty acids with acceptable sensory characteristics.

LITERATURE REVIEW

Health Concerns

Despite all of the concern for CHD, it still accounts for greater than 500,000 deaths each year in the United States. This number is greater than deaths from all of the cancer types combined (Anonymous, 1984). The increased awareness has focused health professionals into lowering total blood plasma cholesterol (TC) through dietary and medical means. Block et al. (1985) stated "Societal changes bring forth dietary changes, and foods which may have been a minor nutrient source in one era may become more important in another era."

In 1988, the National Heart, Lung, and Blood Institute published a list of guidelines and recommendations for serum cholesterol (Ney, 1991). It stated that a desirable range for cholesterol is less than 200 mg/dl TC and less than 130 mg/dl of that should be from low density lipoproteins (LDL). The moderate risk is between 200 and 239 mg/dl TC and with 130 to 159 mg/dl of that as LDL. High risk includes those with greater than 240 mg/dl TC and greater than 160 mg/dl LDL. Recommendations for those with moderate to high risks is dietary therapy, and if concentrations remain high then drug therapy is used in combination with dietary therapy (Ney, 1991).

United States dietary goals recommend that consumers decrease their dietary fat intake from 36 to 37% of total daily caloric intake to less that 30% of

total caloric intake. Milk fat comprises 11 to 15% of total dietary fat intake in adults ranging from 19 to 50 years of age (Park and Yetley, 1990). Of the recommended 30% or less total calories from dietary fat, less than one third should be from saturated fat, up to one third as polyunsaturated fat, and one third to one half as monounsaturated fat (Ney, 1991).

As a result of perceptions that milk fat is "unhealthy" and recommendations to lower intake of saturated fat, the Wisconsin Milk Marketing Board put together a panel consisting of 15 researchers both from academia and industry (O'Donnell, 1989). It was the intention of this panel to discuss the composition of the ideal fat or milk fat. The decision they reached stated that the ideal fat or milk fat would contain less than 10% polyunsaturated fatty acids, greater than or equal to 82% monounsaturated fatty acids, and up to 8% saturated fatty acids. This thesis can be considered to be one of the stepping stones in the direction of producing the ideal milk fat.

Health Benefits

Grundy (1975) stated the ingestion of unsaturated fatty acids can lower the concentrations of plasma lipids. By lowering the plasma lipids one can reduce the risk and formation of atherosclerosis. Atherosclerosis is the formation of plaque on the inner surfaces of the arteries and veins which is the major cause of CHD.

Grundy (1986) and Mensink and Katan (1990) observed that a diet higher in unsaturated fatty acids decreased TC by 18%, while the low fat diet only decreased TC by 7% when compared to the diet high in saturated fat. The unsaturated diet also decreased LDL by 27% relative to the high saturated fat diet while the high-density lipoproteins remained similar. Grundy (1986) suggests that it may be more important to consume more unsaturated fatty acids than it is to decrease fat intake when concerned with CHD. Mattson and Grundy (1985), Bonanome and Grundy (1988), and Grundy and Denke (1990) also observed similar trends when feeding diets high in stearic ($C_{18:0}$) and oleic ($C_{18:1}$) acids.

The misconception of dairy products being hypercholesterolemic is due to the oversimplification of the fatty acid composition of milk fat by health professionals. It seems that all saturated fatty acids have been lumped into one group and labeled as unhealthy. Milk has a unique fatty acid profile, although consisting mainly of saturated fat. Only two fatty acids in milk fat, myristic acid ($C_{14:0}$) and palmitic acid ($C_{16:0}$), are believed to increase TC (Jensen et al., 1991). Although lauric acid ($C_{12:0}$) may be linked to increased TC there is contradictory evidence (Jensen et al., 1991; Ney, 1991). The short-chain fatty acids ($C_{4:0}$ to $C_{10:0}$) act as carbohydrates, not affecting the TC. Since short-chain fatty acids are mostly saturated they are counted in nutritional labeling of foods as contributing to saturated fat content even though they do not affect health risks (O'Donnell, 1993). The long-chain fatty acids in milk fat, stearic ($C_{18:0}$), oleic ($C_{18:1}$), and

linoleic ($C_{18:2}$), are hypocholesterolemic, which have been reported to decrease TC (Jensen et al., 1991). One possible reason for the overestimation of CHD risks with consumption of dairy products is due to the higher concentrations of stearic acid ($C_{18:0}$) which is a saturated fatty acid but not proven to increase CHD risks (Hurley and Leibman, 1989). Hypercholesterolemic fatty acids make up only 17.5 to 20% of the milk fat and hypocholesterolemic fatty acids make up approximately 34% of the milk fat, therefore the fatty acid profile of milk has been oversimplified by labeling it as "unhealthy".

Cheese History

According to Kosikowski (1977) the art of cheese making started many centuries before the time of Christ, probably in the Mediterranean basin. The first people to refine the art of cheese making were the Romans. The Romans then taught these skills to the people they conquered. They taught the Swiss who subsequently invented Emmental and the English who later invented Cheddar.

Cheddar cheese was first developed in the village of Cheddar in England. The process was handed down through generations to be carried on. The first cheese factory in the United States was built by Jessie Williams in 1851 (National Cheese Institute, 1992). Joseph Harding was the first person to standardize a make procedure for Cheddar cheese and incorporate it into a commercial process in 1875. In 1991 the average American consumed over 9 pounds (19.8 kg) of

Cheddar cheese making it the most popular cheese in the United States (National Cheese Institute, 1992).

Cheddar Cheese Composition and Manufacturing

The Food and Drug Administration (1993c) describes Cheddar cheese as being made by the following procedure. "Any one or combination of milk, cream, or nonfat dry milk is heated or treated with hydrogen peroxide/catalase and subjected to lactic acid producing bacteria. A clotting enzyme is added of animal, plant, or microbial origin to set the milk into a semisolid mass. The mass is then cut, heated, and stirred to promote and regulate separation of whey and curd. The whey is drained and the curd is allowed to form a cohesive mass and cut into slabs. Slabs are piled and handled to promote the drainage of whey and formation of acidity. The slabs are then cut into pieces, salted, stirred, and allowed to drain further, and pressed into forms."

"Cheddar cheese is made by the previous procedure or by any procedure which produces a finished cheese with the same physical and chemical properties. If cheese is made from raw milk than cheese must be aged at least 60 days at a temperature of at least 1.67° C for 60 days." The legal definition of full fat Cheddar cheese states that it must contain a minimum of 50% fat in the dry matter, and a maximum of 39% moisture (Food and Drug Administration, 1993c). From this definition one can determine that a minimum of 30.5% fat is needed.

Reduced and Low-Fat Cheeses

Due to the increased awareness of health and weight by today's consumers, low-fat and reduced fat products are becoming increasingly more popular. Ney (1991) reported a decrease in fat relative to our total calories over the last 30 years. The increasingly mechanized world has led the human race as a whole to become more sedentary. It is important that this be balanced with an appropriate reduction in calories and fat for a healthy life style. While seeking "healthier" food products it is important to the consumer that flavor and texture properties not be sacrificed.

Another alternative to lowering the fat content of existing products is simply to manufacture a new type of reduced-fat cheese like Hargrove et al. (1966) accomplished. Other work to improve the quality of reduced fat Cheddar cheese has included ultrafiltration (McGregor and White, 1990), condensing (Anderson et al., 1993), and homogenization (Metzger and Mistry, 1993). Anderson et al. (1993) observed increased flavor qualities in cheese made from condensed milk despite the fact that there may have been more residual rennet than expected. McGregor and White (1990) observed improved characteristics in cheese made with acidified and diafiltered milk. This was due to the decreased concentrations of calcium and lactose which will enhance texture by creating a softer cheese because of reduced calcium and by a more controlled pH due to the decreased lactose concentrations.

The legal definition of "reduced fat", "reduced in fat", "fat reduced", "less fat", "lower fat", or "lower in fat" states that it must be at least 25% reduced in fat content from the reference amount of product (Food and Drug Administration, 1993a,b). This leads to the fact that it must contain less than 22.875% fat to be labeled as reduced fat Cheddar cheese. The standard for "low fat", "low in fat", "contains a small amount of fat", "low source of fat", or "little fat" states that the cheese should not contain more than 3 grams of fat per reference amount.

No standard has been set for the percent moisture of reduced fat Cheddar cheese. It is known that water must replace the missing fat or the protein matrix will be dense and hard. When Cheddar cheese contains 47% or more moisture the body is weak and readily breaks down. A target moisture of 45 to 46% is used for reduced fat Cheddar cheese, this maximizes economics and produces an acceptable body.

First and foremost fat is very essential in the flavor of Cheddar cheese. One of the most common defects in reduced fat Cheddar cheese is the lack of flavor (Jameson, 1990; McGregor and White, 1990; Hauser, 1992). Jameson (1990) found that short-chain fatty acids ($C_{4:0}$ to $C_{10:0}$) are crucial in the flavor development. Flavor compounds as well as bacteria tend to migrate to the fat-water interface and fat-protein interface suggesting that fat acts as a reservoir for flavor (Olson and Johnson, 1990).

Fat is essential to produce Cheddar cheese with acceptable rheology and flavor characteristics. Because of the reduced fat there is more protein per unit cross sectional area (Lawrence et al., 1987; Jameson, 1990; Prentice, 1992). With a denser protein matrix and fewer fat globules to entrap in the structural matrix it is important that something fill the spaces previously occupied by fat to avoid an unattractive product. By producing a reduced fat curd with more water one may overcome the hardness of the cheese; however there may still be excessive rubbery characteristics due to the decreased lubricity caused by the missing fat throughout the structural matrix (Jameson, 1990; Anderson and Mistry, 1994).

Cheese Texture

The physical functions of fat are much easier to elucidate. It acts as a lubricant as does any oil, allowing the cheese to take on the desirable creamy texture. The cheese structural matrix entraps the fat globules upon formation of the curd. The matrix is elastic when the casein is largely intact, but its elasticity is lost as proteolysis proceeds during cheese maturation (Jameson, 1990). Since the fat makes up 50% of the total solids of full fat Cheddar cheese it may be conclusive that a reduction of the fat would result in a denser protein matrix if the fat is not replaced with another substance. To counteract that denser protein matrix it may be necessary to increase the percent moisture within the cheese curd. Cheese firmness can be directly related to the relative amounts of fat,

protein, and moisture (Olson and Johnson, 1990). Elasticity and adhesiveness both increase as the fat:SNF ratio decreases.

The amount of unsaturated fatty acids directly affects the hardness of butter. Middaugh et al. (1988), Murphy and Connolly (1992), and Stegeman et al. (1992a) indicated that cows fed supplemental fat higher in unsaturated fatty acids yielded a milk fat that was higher in unsaturated fatty acid concentrations, and with this softer butter was manufactured. An unsaturated fatty acid with a cis double bond bends the molecule which will impair crystallization and keep the oil liquid (Mensink and Katan, 1990). Prentice (1992) observed seasonal variations in concentrations of unsaturated fatty acids in milk fat causing cheese to become noticeably harder or softer.

Lawrence et al. (1987) observed a correlation of cheese firmness and its ratio of moisture to intact α_{s1}-casein. The firmness changes over time as the casein is broken down into smaller peptides (Chen et al., 1979; Green et al., 1981; Creamer and Olson, 1982; Lawrence et al., 1987; Jameson, 1990). Lawrence et al. (1987) stated that the proteolysis of Cheddar cheese takes place in two phases. The first phase involves the young (squeaky) cheese to rapidly convert from rubbery to a smoother and more homogenous product by weakening the casein network when a single bond in about 20% of α_{s1}-casein is hydrolysed. The second phase involves the breakdown of the remaining α_{s1}-casein and other caseins further decreasing firmness of the cheese. Since most of the moisture in cheese is

bound by the casein, small changes in moisture can greatly effect the rate of proteolysis (Lawrence et al., 1987). Other variables that affect the texture profile of cheese are salt-to-moisture ratio, temperature, calcium content, and pH (Lawrence et al., 1987).

Lawrence et al. (1987) states that as the pH of the cheese decreases from 5.5 to 4.6 the sub-micelles of protein go from globular in shape to smaller globular forms to linear forms of protein. The "cheddary" characteristic is generally found between pH 5.0 and 5.2. A higher pH will yield a cheese that tends to be more springy and plastic, while a lower pH tends to be more mealy, short, or non-cohesive.

The most common method of analyzing cheese body and texture is the organoleptic method. The organoleptic taste panel is composed of one or more people who are experienced with evaluation of the product. This method compares the sample in question against samples that the grader has been exposed to in the past (Larmond, 1977).

Instrumental methods to observe cheese body and texture characteristics is by the use of a texturometer (Breene, 1975; Chen et al., 1979) or electron microscopy (Green et al., 1981). The main areas for error are sampling and temperature (for texturometer) of the sample which greatly affects cheese texture. Electron microscopy of cheese allows the individual to directly observe the protein matrix. When the cheese structure has a smooth appearance the cheese

texture is similarly smooth and creamy and when the structural matrix looks rough and fibrous with few holes for fat the corresponding cheese will demonstrate hard and dry characteristics (Anderson and Mistry, 1994). When using a texturometer the cheeses are cut into uniform samples which allows equal surface areas and equal compressibility. The samples must be at similar temperatures at time of test. The test involves the sample being compressed to a specific point at which time the plunger with a load cell attached will release. A second compression may be used in some cases to study cohesion and springiness.

Homogenization

Homogenization is a process in which milk is brought under high pressures and forced through a small orifice. Milk at the small opening is under immense turbulence. At the point the fat globule is forced through the small opening the sudden decrease in pressure causes the globule to undergo cavitation. Cavitation is caused by the sudden formation and disappearance of gas bubbles. At this point the fat globule collapses and shock waves go through the globule causing it to rupture and break into smaller globules. The extent of globule deformation is directly related to the pressures used (Walstra and Jenness, 1984). Walstra and Jenness (1984) also reported several other characteristics of homogenized milk, whiter color due to increased light scattering abilities, tendency to foam increases,

may become rancid quickly unless properly pasteurized, prone to autoxidation, and large casein micelles are broken into smaller fragments which generally reassociate within approximately 10 minutes.

Homogenization has been used for the manufacture of cheese to alter the properties of the end product. Peters (1955) studied the effects on Cheddar cheese made from milk homogenized at various pressures. With increasing homogenization pressures there was less fat loss in the whey, a decreased elasticity to the curd, and a loss of color intensity. Also, with increasing homogenization pressures the cheese would not oil off as much or as quickly. Pressures of 35 and 70 kg/cm^2 yielded a product of superior body and texture as well as maintaining some elasticity for proper cheddaring of the curd (Peters, 1956). Rao (1985) homogenized milk for Cheddar cheese manufacture and reported that higher pressure (140.8 kg/cm^2) made the curd brittle and harder to handle, with a greater loss of curd fines, than lower pressures of 35.2 and 70.4 kg/cm^2.

Homogenization of milk is said to decrease the elasticity of cheese by making it softer (partially due to increased water retention) (Olson and Johnson, 1990). Olson and Johnson (1990) also stated that excessive homogenization pressures produced a brittle inferior cheese. Metzger et al. (1993) reported improvements in body and texture characteristics for reduced fat Cheddar cheese made from skim milk standardized to 1.6% fat with homogenized cream.

Milk Fatty Acid Composition

Milk fat is made up of about 98% or more triacylglycerols, .5 to 1% phospholipids, and .2 to .5% sterols (Jensen et al., 1991). Fatty acids which make up the triacylglycerols have a profile that is unique to milk fat. Phospholipids and cholesterol are generally found in the fat globule membrane (Van Vliet and Dentener-Kikkert, 1982). Jensen et al. (1991) found differences in the fatty acid composition of fat globules in relation to size. They reported that the smaller fat globules contained fewer short-chain fatty acids ($C_{4:0}$ to $C_{10:0}$) and stearic acid ($C_{18:0}$), and more oleic acid ($C_{18:1}$). Higher concentrations of unsaturated fatty acids yielded a lower melting point in the end product, and therefore were softer at a given temperature (Macleod and Wood, 1972; Plowman et al., 1972; Harrap, 1973;). As concentrations of unsaturated fatty acids increase, the fat content in milk may be underestimated because filters in the mid-infrared spectrum are not adjusted correctly to read true fat content (Stegeman et al., 1991).

Almost all of the short-chain fatty acids ($C_{4:0}$ to $C_{10:0}$) and half of the medium-chain fatty acids ($C_{12:0}$ to $C_{17:0}$) are synthesized in the mammary gland epithelial cells. The rest of the medium-chain and most of the long-chain fatty acids ($C_{18:0}$ to $C_{18:2}$) have been shown to be derived from the blood plasma which is a result of dietary intake. Therefore one may conclude that increased intake of

dietary long-chain fatty acids would result in milk fat with higher concentrations of long-chain fatty acids.

Changing Milk Fatty Acid Composition

Feeding protected fat

One method to increase the unsaturated fatty acid content of milk fat is by feeding protected fats which are encapsulated in a protein and formaldehyde coating (Scott et al., 1971; Bitman et al., 1973; Mattos and Palmquist, 1974; Astrup et al., 1976; Wrenn et al., 1978). The formaldehyde coating allows the supplemental fat or oil to pass by the rumen without being hydrogenated by the resident microflora.

Some of the sources for protected fats include extruded soybeans or soybean oil (Mattos and Palmquist, 1974; Wrenn et al., 1978) and sunflower seeds (Scott et al., 1971) (Wong et al., 1973). Once past the rumen the protective coating dissolves and the fat is adsorbed by the small intestine, and ultimately transferred to the mammary gland via blood plasma.

Feeding unprotected fat

There are many sources of unprotected fat that can be incorporated into the diet and a portion of the fat will remain unhydrogenated by the rumen microflora. Some common forms of added dietary fat include sunflower seeds (Middaugh et al., 1988; Stegeman et al., 1992b), safflower oil (Parry et al., 1964; Stegeman et al., 1992b), extruded soybeans or soybean oil (Loosli et al., 1961; Larson and Schultz, 1970; Steele et al., 1971a,b; Banks et al., 1976; Banks et al., 1980; Okeke et al., 1983), or vegetable oil and tallow (Goering et al., 1977).

Palmquist and Jenkins (1980) stated that 3 to 5% added dietary fat may be used to increase milk production of cows. The added dietary fat carries the long-chain fatty acids through and suppresses the short-chain fatty acids synthesis (Palmquist and Jenkins, 1980). They also stated that a depression in milk fat and/or protein may occur due to the increased dietary fat; however the energy corrected values have been shown to be higher for those fed the added dietary fat.

Niacin

Niacin has been fed to cows as a top dressing on total mixed rations for several reasons. One is to stimulate epinephrine production to combat the effects of subclinical ketosis (Fronk et al., 1980; Riddell et al., 1980; Ruegsegger and Schultz, 1986; Horner et al., 1988; Erickson et al., 1990). Niacin suppresses the

mobilization of lipids by reducing plasma triglycerides and non esterified fatty acids (Horner et al., 1986; Martinez et al., 1991; Aseltine, 1992). Some studies indicated higher percentages of fat in energy corrected milk (Horner et al., 1986; Muller et al., 1986) and protein (Riddell et al., 1980; Erickson et al., 1992) from cows fed added niacin. Aseltine (1992) observed increased yield in high producing cows (8,000 to 9,000 kg/cow) fed supplemental niacin. Others (Driver et al., 1990; Lanham et al., 1992) found no effect with feeding supplemental niacin. Martinez et al. (1991) reported decreased concentrations of short- and medium-chain fatty acids ($C_{4:0}$ to $C_{14:0}$) with fat percentages staying the same which indicated increased concentrations of long-chain fatty acids.

MATERIALS AND METHODS

Experimental Treatments

Sixteen midlactational Holstein cows were randomly assigned to one of four diets in a 16 week factorial design. A control and three experimental diets were fed to evaluate the effects of added niacin and modified fatty acid diets on milk and reduced fat Cheddar cheese. Each replication consisted of a two week acclimation period, followed by two weeks of data collection. Total mixed diets on a dry matter basis were 25% corn silage, 25% alfalfa hay, and 50% respective concentrate mixture. The control (C) diet consisted mainly of rolled corn and soybean meal in the concentrate mixture (Table 1). Experimental diets consisted of the C diet with 12 grams per day of added niacin (Nutri-Flex Niacin Pack, Land O'Lakes, Inc., Fort Dodge, IA) as a top dressing (C+), supplemental dietary fat from extruded soybeans (ESB) substituted for part of the rolled corn and soybean meal, and the ESB diet with 12 grams per day of added niacin as a top dressing (ESB+).

Milk Collection and Preparation

Milk from individual cows was sampled during a twenty-four hour period for each of the last two weeks of each period. Milk from cows on C and ESB+ diets was collected for 48 hours during the third week of each period into 38-L

stainless steel milk cans for manufacture into reduced fat Cheddar cheese. The milk was strained with the use of a filter funnel (KenAg milk filter, Veratec, Inc., Animal Care Group, Walpole, MA) and cooled within two hours after collection. Milks in equal amounts from each cow were composited by treatment at the time of processing. Standardization of milk fat to 1.67% for manufacture of 1/3 reduced fat Cheddar cheese was done by separating the milk by treatment using a DeLaval model 318 centrifugal separator (DeLaval Separator Co., Chicago, IL). By treatment the milks were transferred to a vat (DCI Inc., St. Cloud, MN) and pasteurized at 63° C for 30 minutes. The first half of each milk treatment was pumped through a two-stage homogenizer (Manton-Gaulin Manufacturing Co., Inc., Everett, MA) under no pressure and a plate cooler and the second half was partially homogenized at 35 kg/cm^2 pressure on the first stage and 0 kg/cm^2 on the second stage and also through the plate cooler where both portions of milks were transferred to 38-L stainless steel milk cans. The homogenization pressure was selected from previous trials of Peters (1956) and Rao (1985). Milk treatments for reduced fat Cheddar cheese consisted of a control not homogenized (CNH), control part homogenized (CPH), milk higher in unsaturated fatty acids not homogenized (UNH), and milk higher in unsaturated fatty acids part homogenized (UPH). Milks were kept separate and held at 2° C until cheese manufacture within 48 hours.

Cheese Manufacture

Double-O Kusel model MX 250-L cheese vats (Kusel Equipment Co., Watertown, WI) were used to manufacture the reduced fat Cheddar cheeses (Anderson et al., 1993). Milk from the four treatments were made into cheese over a two day period with two vats each day. The treatments were rotated for each replication to reduce experimental error. Milk (110 kg) was added to the cheese vat and heated to 31 to 32° C. Frozen concentrated protease negative starter, LF 301 (acid producer) (Rhone-Poulenc, Marschall Products, Madison, WI) was added at a rate of .28 g/kg of milk, and LF 304 (flavor producer) (Rhone-Poulenc, Marschall Products, Madison, WI) was added at a rate of .14 g/kg of milk. Annato cheese color was added at a rate of .06 ml/kg of milk then was diluted 5:1 with cold water prior to adding to the vat. A 45 minute ripening period was utilized. Single strength calf rennet extract (Rhone-Poulenc, Marschall Products, Madison, WI) was added at a rate of .28 ml/kg of milk then was diluted 20:1 with cold water prior to adding to the vat. When the coagulum had set to the desired consistency (approximately 30 minutes after rennet addition) the curd was cut with 1 cm stainless steel knives. Both vertical and horizontal knives were drawn through the curd. Curd was allowed to heal at 32° C for 30 minutes. Curd was stirred and heated to 34.5° C over 20 minutes and held for an additional 30 minutes while stirring (50 minutes total elapsed time). Half of the whey was drained and replaced with 26.7° C water and allowed to

wash for five minutes. Whey and wash water were drained and curd was ditched to allow matting. Matted curds were cut into 25 to 40 cm slabs and turned every 20 minutes maintaining a curd temperature of approximately 30° C. After one hour the slabs were stacked two high. After the whey reached a pH of 5.4 the curd was milled (Damrow Brothers Inc., Fond Du Lac, WI). Jameson (1990) stated a deficiency of inelastic fat globules allows the syneresis process to proceed further during cheese manufacture; therefore in this study a higher pH at the endpoint of cheddaring was used to retain more moisture. Milled curd was then salted at a rate of 2.27 g of salt/kg of milk used. Curd and salt were stirred for five minutes after final salting. Curds were packed in 11-kg rectangular hoops, pressed, and drained overnight. Cheese blocks were then placed in vacuum-shrink bags (Cryovac Division, W.R. Grace and Co., Duncan, SC) and vacuum sealed by a Multivac (Koch, Kansas City, MO). Sixteen reduced fat Cheddar cheeses were manufactured (4 CNH, 4 CPH, 4 UNH, and 4 UPH). Cheeses were ripened at 6° C for 6 months.

Compositional Analyses

Milk was stored at 4° C until total solids and milk fat percentages could be determined by the Mojonnier methods (Atherton and Newlander, 1977). All samples of milk, cheese, and whey were analyzed in duplicate. Protein percentages for the milk, cheese, and whey were determined using the Kjeldahl

nitrogen procedure (AOAC, 1990). Percent fat of cheese and whey, and total solids of whey were determined by the Mojonnier methods (Atherton and Newlander, 1977). Cheese acid soluble nitrogen was determined using a combination extraction-filtration with a Kjeldahl procedure (Kosikowski, 1977).

Milk fat globules were sized and counted for each of the 4 diets of the 4 replicates using an Olympus BH-2 microscope (Olympus Optical Co., Ltd., Tokyo, Japan) according to Foster et al. (1990). Each milk was prepared in duplicate and 2 random fields were counted for each sample. Fat globules were assigned into size categories of <1, 1 to 2, 2 to 3, 3 to 5, and >5 μm and were reported as percentages of the total number. A scale in the eyepiece of the microscope, graduated from 1 to 100 μm was rotated one full circle to count the fat globules in that field. Freezing point of milk in degrees Horvet (°H) was determined with a Fiske MS^{TM} cryoscope (Fiske Associates, Norwood, MA) (AOAC, 1990). pH of the milk, cheese, and whey was measured using an ion analyzer (Orion Research Inc., Cambridge, MA). Milk and whey titratable acidity were measured using .10 N NaOH and phenolphthalein (Atherton and Newlander, 1977) and percent ash for milk, cheese, and whey was determined according to AOAC procedures (1990). Milk and cheese fatty acids were quantified using a Mojonnier ether extraction method to isolate milk fat (Atherton and Newlander, 1977) and butyl esters were determined (Casper et al., 1988).

Cheeses were analyzed for composition at least seven days after date of manufacture. Percent moisture was determined using a moisture balance (Crosser and Mistry, 1991). Sodium chloride content was calculated from sodium content determined with a selective ion electrode (Orion Research, Inc., Cambridge, MA) (Kindstedt et al., 1983).

Rheology and Sensory Evaluation

An experienced seven member judging panel evaluated the cheeses for flavor, body, and texture scores. Each cheese was assigned a three digit random code and evaluated at 1, 3, and 6 months. Scores for the flavor, body, and texture ranged from 1 = none, 5 = definite, and 9 = extreme. Each sample was also given a score for overall acceptability with 1 = poor and 9 = excellent. Panelists had the opportunity to write comments or criticisms on all score sheets.

Rheological measurements were made on each cheese at 1 and 6 months using an Instron model 1100 (Instron Corp., Canton, MA) (Breene, 1975). Cheeses were cut into cylinders 1 cm diameter by 2 cm length pieces for measurements. Due to uneven curd junctures 5 replicates were run for each sample and the average was used for data measurements. Cheese samples were held at 7.2° C until time of analysis. A 2 compression test was run with a compression of 75% (1.5 cm). A crosshead speed of 50 mm per minute and a chart speed of 200 mm per minute were used with a 0 to 500 kg load cell.

The 6 measurements obtained were fracturability, hardness, springiness, cohesiveness, gumminess, and chewiness (Breene, 1975). Values were determined by a plotted graph and measurements were taken in the following manner (Figure 1). The point at which the sample first yields is the fracturability value. The next peak is at the end point of the first compression which is the hardness value. The length of the second compression multiplied times the crosshead speed divided by the chart speed is considered the springiness value. Areas for first and second compressions were determined with the aid of a planimeter. Cohesiveness is measured by dividing the area of the second bite by the area of the first bite. Gumminess is calculated by using the value for cohesiveness and multiplying by the hardness; chewiness is the gumminess multiplied by the springiness .

Statistical Analysis

Data were analyzed using general linear models procedure (SAS, Institute, Cary, NC). Milks from diets were set up as a 4 X 4 Latin Square design and were analyzed as individual treatments. Cheese data were set up as a 2 X 2 X 4 factorial and similar to the milks, the cheeses were analyzed as 4 individual treatments. Differences were considered to be significant at $P < .1$.

RESULTS AND DISCUSSION

Milk Composition

The pH, titratable acidity, and freezing point values of milk from each diet are given in Table 2. All values were similar ($P > .1$) and within expected ranges for milks from all diets.

Milk fat globules from cows fed the ESB+ diet exhibited decreased ($P < .10$) percentages of fat globules in the 1 to 2 μ range (Table 3). Milk fat globule size from the ESB diet was similar ($P > .1$) to ESB+. Higher percentages of small fat globules in milk may improve cheese body and texture (Metzger and Mistry, 1993).

Fatty acids that are referred to as hypercholesterolemic, myristic ($C_{14:0}$) and palmitic ($C_{16:0}$) (Hegsted et al., 1965), exhibited decreased ($P < .05$) concentrations in the ESB and ESB+ milks (Table 4). Fatty acids referred to as hypocholesterolemic, stearic ($C_{18:0}$) (Bonanome and Grundy, 1988), oleic ($C_{18:1}$) (Grundy, 1986), and linoleic ($C_{18:2}$) (Mattson and Grundy, 1985), increased ($P < .05$) in concentration in the ESB and ESB+ milks. Percentages of total short-chain ($C_{4:0}$ to $C_{10:0}$) and medium-chain ($C_{12:0}$ to $C_{17:1}$) fatty acids in milk fat were depressed ($P < .05$) in the ESB and ESB+ milks. Long-chain ($C_{18:0}$ to $C_{18:2}$) fatty acid concentrations increased ($P < .05$) in the ESB and ESB+ milks. Milk from the C+ diet was similar ($P > .1$) in fatty acid composition to the C diet; thus

addition of niacin had no effect. However, when supplemental fat was fed (ESB+), niacin did increase ($P < .10$) the percentage of unsaturated fatty acids compared to the other diets. The difference is from an increase in the linoleic acid ($C_{18:2}$) concentration which was 3.70, 3.51, 5.89, and 6.58% for C, C+, ESB, and ESB+ diets, respectively. Linoleic acid ($C_{18:2}$) concentrations were higher ($P < .05$) in ESB+ than ESB. Unsaturated fatty acid concentrations were 29.42, 29.03, 35.38, and 36.44% for C, C+, ESB, and ESB+ diets, respectively. The ESB and ESB+ exhibited increased ($P < .05$) percentages of unsaturated fatty acids. In a previous study (Lightfield et al., 1993), short- and medium-chain fatty acids also deceased while long-chain fatty acids increased when extruded soybeans were fed.

Cheese milk protein percentages were reduced ($P < .05$) for the UNH and UPH treatments (Table 5). Added dietary fat may reduce both protein and fat in the milk although the reasons for which are not fully explained (Palmquist and Jenkins, 1980; Stegeman et al., 1992a). To account for the reduced protein in the UNH and UPH cheese milk treatments and maintain the one third reduction in fat:protein ratio of the cheese these treatments were standardized with less fat ($P < .05$). Cheese milk ash, total solids, titratable acidity, and pH were also determined and were similar ($P > .1$) for all treatments. The ash content in the cheese milks was about .1% lower than expected (Atherton and Newlander, 1977) for reasons which are unexplainable.

Cheese and Whey Composition

Similar to the cheese milks the whey from UNH and UPH had lower ($P < .05$) protein percentages (Table 6). Fat, ash, and total solids percentages were similar ($P > .1$) for all wheys.

Cheeses exhibited no differences ($P > .1$) between treatments for total solids, fat, total protein, or NaCl (Table 7). There were differences ($P < .05$) in the ash content of the cheeses with CNH and UPH possibly due to the fluctuating NaCl content of the cheeses.

There were no differences ($P > .1$) between treatments for soluble nitrogen (Table 7). As expected, soluble nitrogen increased ($P < .05$) for all treatments as the cheeses ripened. Small peptides and amino acids are cleaved from the protein structure by enzymes during the ripening process. This yields a softer body and higher levels of soluble nitrogen. The pH of the cheeses were similar ($P > .1$) with the exception of the UNH cheese at 1 week when compared to itself over time, and the CNH cheese at 6 months when compared to other cheese treatments (Table 7). These differences in pH are of little consequence.

Cheese fatty acid composition and trends tended to be similar with the fatty acid composition of the milks (Tables 4 and 8). Decreased concentrations of short- ($C_{4:0}$ to $C_{10:0}$) and medium-chain ($C_{12:0}$ to $C_{17:0}$) fatty acids ($P < .05$) as well as increased concentrations of long-chain fatty acids ($C_{18:0}$ to $C_{18:2}$) ($P < .05$) were present in the UNH and UPH cheeses (Table 8). Part homogenization of the

cheese milk had no effect ($P > .1$) on the fatty acid profile of cheese treatments. The UNH and UPH cheeses exhibited higher ($P < .05$) concentrations of unsaturated fatty acids. Unsaturated fatty acid concentrations were 29.06, 30.65, 36.08, and 35.29% for CNH, CPH, UNH, and UPH cheeses, respectively. Previous research (Middaugh et al., 1988; Stegeman et al., 1992a; Lightfield et al., 1993) indicated increased concentrations of unsaturated fatty acids in milk and milk products from cows fed diets higher in unsaturated fat.

Sensory Evaluation

Cheeses were evaluated by an experienced taste panel consisting of seven members. A score of 1 would mean no defect, a score of 5 is a definite defect, and a score of 9 would be an extreme defect. Acidity scores were similar ($P > .10$) between treatments and did increase ($P < .05$) over time (Table 9). Bitterness scores were similar ($P > .10$) between treatments and did increase ($P < .05$) over time, but never nearing a definite bitterness score. As expected, flat or lacks flavor had a definite score for all cheeses at 1 month and decreased ($P < .05$) over time as the flavor increased with no differences ($P > .10$) between treatments.

Body and texture scores were evaluated with the same scoring system and at the same times as flavor scores (Table 10). Cheeses had definite scores for curdiness at 1 month which decreased ($P < .05$) over time since this is a common

expected defect in young cheese. There was no difference ($P > .10$) between treatments for curdiness. Mealiness scores were similar ($P > .10$) between treatments and only differed ($P < .10$) in the UNH cheese at 3 months when it decreased. Shortness scores were similar ($P > .10$) between treatments and over time with the exception of UNH being less ($P < .10$) than CPH at 6 months and CNH being less ($P < .10$) at 3 months than at 6 months. Weakness scores were similar ($P > .10$) between treatments and only CNH and UNH both being weaker ($P < .05$) at 3 months when compared at 1 and 6 months of age.

Overall acceptability scores of the cheeses were similar ($P > .10$) over time (Table 9). There were no differences ($P > .1$) between treatments at 1 month of age. Overall acceptability scores ranged from 6.66 to 7.13 which would be considered to be a good score. At 3 months the UNH had a higher ($P < .10$) overall acceptability score compared to the CPH and UPH treatments and at 6 months CPH had a lower ($P < .10$) score compared to the CNH or UNH cheeses. All cheeses had acceptable overall acceptability scores during the aging process.

Texture Profile Analysis

Cheeses were analyzed for rheological characteristics at 1 and 6 months of age (Table 11). All treatments differed ($P < .05$) in the 6 rheological measurements between 1 and 6 months of age. The hardness variable indicated

that the UNH and UPH cheeses were softer ($P < .05$) than the CNH and CPH cheeses at 1 month. At 6 months the CNH cheese was the hardest ($P < .05$) with CPH and UPH being similar ($P > .10$) and UNH being softer ($P < .05$) than CPH and only slightly softer ($P < .10$) than UPH. These differences in hardness may be due to higher amounts of unsaturated fatty acids, particularly oleic acid ($C_{18:1}$) which has a low melting point, in the UNH and UPH cheeses. Melting point of fats is affected by degree of unsaturation, chain length of the fatty acid, and position of the fatty acid on the triglyceride (DeMan, 1980). These trends in hardness are similar to fracturability results where the UNH and UPH cheeses have a lower ($P < .05$) fracture point compared to the CNH and CPH cheeses. The springiness or rubberiness of the cheeses was also decreased ($P < .05$) in the UNH and UPH cheeses at 1 month. The CNH cheese had consistently higher numbers in all rheological measurements compared to the CPH, UNH, and UPH cheeses.

Cohesiveness, gumminess, and chewiness measurements are all derived from previous data through equations defined in the materials and methods section. Cohesiveness is defined by Prentice (1992) as the ability of a needle to move through the curd mass with the adhesive forces and mass giving resistance. At 1 month the cohesiveness measurement of the UNH cheese was lower ($P < .05$) than the other cheeses with CPH and UPH being similar ($P > .1$) and the CNH cheese having a highest ($P < .05$) value at 1 and 6 months. Gumminess

was lower ($P < .05$) in the UNH and UPH cheeses at one month. At 6 months the UNH cheese had a lower ($P < .05$) gumminess measurement than CNH and UPH and was lower ($P < .10$) than CPH with CNH having the highest ($P < .05$) value. The UNH and UPH cheeses had lower ($P < .05$) chewiness values than CNH and CPH at one month. At 6 months the CPH, UNH, and UPH cheeses were similar ($P > .1$) with CNH having a higher ($P < .05$) chewiness value.

Conclusions

Cows fed unsaturated dietary fat from extruded soybeans produced milk fat containing higher concentrations of unsaturated fatty acids. Milk fat from cows fed extruded soybeans had lower concentrations of short- and medium-chain fatty acids and increased concentrations of long-chain fatty acids. Protein content from the milk of cows fed extruded soybeans was depressed. Niacin only had a slight effect on milk composition when feeding extruded soybeans by increasing the concentrations of unsaturated fat in milk; especially linoleic acid ($C_{18:2}$).

Acceptable reduced fat Cheddar cheese was manufactured from milk higher in unsaturated fatty acids and maintained acceptable body, texture, and flavor characteristics. Part homogenization of cheese milk had little effect on cheese properties. Cheeses made from milk with higher concentrations of unsaturated fatty acids demonstrated improved rheological characteristics. While differences were found with the texturometer they may have been too small for

the sensory panel to detect when evaluating body and texture. More research is needed to increase the amount of unsaturated fatty acids in milk fat.

Reduced fat cheeses made from milk higher in unsaturated fatty acids will benefit consumers searching for products to fulfill the current dietary recommendations of reduced fat and reduced saturated fatty acids. The demand for such labeled cheeses requires that minimal sacrifices for flavor, body, and texture be made. Since consumer perception is marketing reality, the health conscious consumer will find products similar to these cheeses reduced in fat and/or higher in unsaturated fatty acids to be of higher value.

REFERENCES

Anderson, D. L., V. V. Mistry, R. L. Brandsma, and K. A. Baldwin. 1993. Reduced fat Cheddar cheese from condensed milk. 1. manufacture, composition, and ripening. J. Dairy Sci. 76:2832.

Anderson, D. L., and V. V. Mistry. 1994. Reduced fat Cheddar cheese from condensed milk. 2. microstructure. J. Dairy Sci. 77:7.

Anonymous. 1984. The lipid research clinics coronary primary prevention trial results: I. reduction in the incidence of coronary heart disease. J. Am. Med. Assn. 251:351.

Aseltine, M. 1992. Niacin supplementation, protein degradibility are conference topics. Feedstuffs 64(48):36.

Association of Official Analytical Chemists. 1990. Official Methods of Analysis. 15th ed. AOAC, Arlington, VA.

Astrup, H. N., L. Vik-Mo, A. Ekern, and F. Bakke. 1976. Feeding protected and unprotected oils to cows. J. Dairy Sci. 59:426.

Atherton, V. H., and J. A. Newlander. 1977. Chemistry and Testing of Dairy Products. 4th ed. AVI Publ. Co., Inc., Westport, CT.

Banks, W., J. L. Clapperton, and M. E. Ferrie. 1976. Effect of feeding fat to dairy cows receiving a fat-deficient basal diet. J. Dairy Res. 43:219.

Banks, W., J. L. Clapperton, and M. E. Kelly. 1980. Effect of oil enriched diets on the milk yield and composition, and on the composition and physical properties of the milk fat, of dairy cows receiving a basal ration of grass silage. J. Dairy Res. 47:277.

Bitman, J., L. P. Dryden, H. K. Goering, T. R. Wrenn, R. A. Yoncoskie, and L. F. Edmondson. 1973. Efficiency of transfer of polyunsaturated fats into milk. J. Am. Oil Chem. Soc. 50:93.

Block, G., C. M. Dresser, A. M. Hartman, and M. D. Carroll. 1985. Nutrient sources in the American diet: quantitative data from the NHANES II survey. Am. J. Epidem. 122:27.

Bonanome, A., and S. M. Grundy. 1988. Effect of dietary stearic acid on plasma cholesterol and lipoprotein levels. N. Engl. J. Med. 318:1244.

Breene, W.M. 1975. Application of texture profile analysis to instrumental food texture evaluation. J. Texture Stud. 6:53.

Casper, D. P., D. J. Schingoethe, R. P. Middaugh, and R. J. Baer. 1988. Lactational responses of dairy cows to diets containing regular and high oleic sunflower seeds. J. Dairy Sci. 71:1267.

Chen, A. H., J. W. Larkin, C. J. Clark, and W. E. Irwin. 1979. Textural analysis of cheese. J. Dairy Sci. 62:901.

Creamer, L. K., and N. F. Olson. 1982. Rheological evaluation of maturing Cheddar cheese. J. Food Sci. 47:631.

Crosser, A. E., and V. V. Mistry. 1991. Use of a moisture balance to determine moisture in cheese. J. Dairy Sci. 74:(Suppl. 1):126.(Abstr.)

DeMan, J. M. 1980. Principles of Food Chemistry. AVI Publ. Co., Westport, CT.

Driver, L. S., R. C. Grummer, and L. H. Schultz. 1990. Effects of feeding heat-treated soybeans and niacin to high producing cows in early lactation. J. Dairy Sci. 73:463.

Eppard, P. J., D. E. Bauman, J. Bitman, D. L. Wood, R. M. Akers, and W. A. House. 1985. Effect of dose of bovine growth hormone on milk composition: alpha-lactalbumin, fatty acids, and mineral elements. J. Dairy Sci. 68:3047.

Erickson, P. S., A. M. Trusk, and M. R. Murphy. 1990. Effects of niacin source on epinephrine stimulation of plasma nonesterified fatty acid and glucose concentrations, on diet digestibility and on rumen protozoal numbers in lactating dairy cows. J. Nutr. 120:1648.

Erickson, P. S., M. R. Murphy, and J. H. Clark. 1992. Supplementation of dairy cow diets with calcium salts of long-chain fatty acids and nicotinic acid in early lactation. J. Dairy Sci. 75:1078.

Food and Drug Administration. 1993a. Code of Federal Regulations. Title 21-Food and drug, Sect. 101.13 Nutrient content claims-general principles.

Food and Drug Administration. 1993b. Code of Federal Regulations. Title 21-Food and drug, Sect. 101.62 Nutrient content claims for fat, fatty acid, and cholesterol content in foods.

Food and Drug Administration. 1993c. Code of Federal Regulations. Title 21-Food and drug, Sect. 133.113 Cheddar cheese.

Foster, S. J., R. J. Baer, and V. V. Mistry. 1990. Cheddar cheese manufactured from condensed milk. J. Dairy Sci. 73:1980.

Fronk, T. J., L. H. Schultz, and A. R. Hardie. 1980. Effect of dry period overconditioning on subsequent metabolic disorders and performance of dairy cows. J. Dairy Sci. 63:1080.

Goering, H. K., T. R. Wrenn, L. F. Edmondson, J. R. Weyant, D. L. Wood, and J. Bitman. 1977. Feeding polyunsaturated vegetable oils to lactating cows. J. Dairy Sci. 60:739.

Green, M. L., A. Turvey, and D. G. Hobbs. 1981. Development of structure and texture in cheddar cheese. J. Dairy Res. 48:343.

Grummer, R. R. 1991. Effect of feed on the composition of milk fat. J. Dairy Sci. 74:3244.

Grundy, S. M. 1975. Effects of polyunsaturated fats on lipid metabolism in patients with hypertriglyceridemia. J. Clin. Invest. 55:269.

Grundy, S. M. 1986. Comparison of monounsaturated fatty acids and carbohydrates for lowering plasma cholesterol. New Engl. J. Med. 314:745.

Grundy, S. M., and M. A. Denke. 1990. Dietary influences on serum lipids and lipoproteins. J. Lipid Res. 31:1149.

Hargrove, R. E., F. E. McDonough, and R. P. Tittsler. 1966. New type of ripened low-fat cheese. J. Dairy Sci. 49:796.

Harrap, B. S. 1973. Recent developments in the production of dairy products with increased levels of polyunsaturation. Aust. J. Dairy Technol. 28:101.

Hauser, N. 1992. Putting the squeeze on cheese: some reduced fat cheeses taste grate-but others lack even a shred of flavor. Am. Health 11(8):76.

Hegsted, D. M., R. B. McGandy, M. L. Myers, and F. J. Stare. 1965. Quantitative effects of dietary fat on serum human cholesterol. Am. J. Clin. Nutr. 17:281.

Horner, J. L., L. M. Windle, C. E. Coppock, J. M. Labore, J. K. Lanham, and D. H. Nave. 1988. Effects of whole cottonseed, niacin, and nicotinamide on in vitro rumen fermentation and on lactating holstein cows. J. Dairy Sci. 71:3334.

Horner, J. L., C. E. Coppock, G. T. Schelling, J. M. Labore, and D. H. Nave. 1986. Influence of niacin and whole cottonseed on intake, milk yield and composition, and systemic responses of dairy cows. J. Dairy Sci. 69:3087.

Hurley, J., and B. Leibman. 1989. Heart smarts. Nut. Action Health Letter 16:5.

Jameson, G.W. 1990. Cheese with less fat. Aust. J. Dairy Technol. 45:93.

Jensen, R. G., A. M. Ferris, and C. J. Lammi-Keefe. 1991. Symposium: milk fat-composition, function, and potential for change. J. Dairy Sci. 74:3228.

Kindstedt, P. S., and F. V. Kosikowski. 1983. Measurement of sodium chloride in cheese by a simple sodium ion electrode method. J. Dairy Sci. 67:879.

Kosikowski, F. V. 1977. Cheese and Fermented Milk Foods. 2nd ed. F. V. Kosikowski and Associates, Brooktondale, NY.

Lanham, J. K., C. E. Coppock, K. N. Brooks, D. L. Wilks, and J. L. Horner. 1992. Effects of whole cottonseed or niacin or both on casein synthesis by lactating Holstein cows. J. Dairy Sci. 75:184.

Larmond, E. 1977. Laboratory Methods for Sensory Evaluation of Food. Agric. Can. Publ. No. 1637.

Larson, S. A., and L. H. Schultz. 1970. Effects of soybeans compared to soybean oil and meal in the ration of dairy cows. J Dairy Sci. 53:1233.

Lawrence, R. C., L. K. Creamer, and J. Gilles. 1987. Textural development during cheese ripening. J. Dairy Sci. 70:1748.

Lightfield, K. D., R. J. Baer, D. J. Schingoethe, K. M. Kasperson, and M. J. Brouk. 1993. Composition and flavor of milk and Cheddar cheese higher in unsaturated fatty acids. J. Dairy Sci. 76:1221.

Loosli, J. K., R. G. Warner, and H. F. Hintz. 1961. Value of corn distillers dried grains, soybean oil meal, heated soybeans, and soybean oil meal plus starch for milk production. J. Dairy Sci. 44:1910.

Macleod, G. K., and A. S. Wood. 1972. Influence of amount and degree of saturation of dietary fat on yield and quality of milk. J. Dairy Sci. 55:439.

Martinez, N., E. J. DePeters, and D. L. Bath. 1991. Supplemental niacin and fat effects on milk composition of lactating Holstein cows. J. Dairy Sci. 74:202.

Mattos, W., and D. L. Palmquist. 1974. Increased polyunsaturated fatty acid yields in milk of cows fed protected fat. J. Dairy Sci. 57:1050.

Mattson, F. H., and S. M. Grundy. 1985. Comparison of effects of dietary saturated, monounsaturated, and polyunsaturated fatty acids on plasma lipids and lipid proteins in man. J. Lipid Res. 26:194.

McGregor, J. U., and C. H. White. 1990. Optimizing ultrafiltration parameters for the development of low-fat Cheddar Cheese. J. Dairy Sci. 73:314.

Mensink, R. P., and M. B. Katan. 1990. Effect of dietary trans fatty acids on high-density and low-density lipoprotein cholesterol levels in healthy subjects. New Engl. J. Med. 323:439.

Metzger, L. E., and V. V. Mistry. 1993. Effect of homogenization on quality of reduced-fat Cheddar cheese. J. Dairy Sci. 76(Suppl. 1):100.(Abstr.)

Metzger, L. E. 1994. Application of cream homogenization in the manufacture of reduced fat Cheddar cheese. M. S. Thesis, South Dakota State Univ., Brookings.

Middaugh, R. P., R. J. Baer, D. P. Casper, D. J. Schingoethe, and S. W. Seas. 1988. Characteristics of milk and butter from cows fed sunflower seeds. J. Dairy Sci. 71:3179.

Milk Industry Foundation. 1993. Milk Facts. Washington, DC.

Muller, L. D., A. J. Heinrichs, J. B. Cooper, and Y. H. Atkin. 1986. Supplemental niacin for lactating dairy cows during summer feeding. J. Dairy Sci. 69:1416.

Murphy, J. J., and J. F. Connolly. 1992. Manipulating the diet of the cow to produce a softer milk fat high in monounsaturated fatty acids. Irish J. Agric. Food Res. 31:92(Abstr.)

National Cheese Institute. 1992. Cheese Facts. Washington, DC.

Ney, D. M. 1991. Symposium: the role of the nutritional and health benefits in the marketing of dairy products. J. Dairy Sci. 74:4002.

O'Donnell, J. 1989. Milk fat technologies and markets: a summary of the Wisconsin milk marketing board 1988 milk fat round table. J. Dairy Sci. 72:3109.

O'Donnell, J. 1993. FDA raises saturated fat content in milk fat by 20%. Cheese Market News 13(1):4.

Okeke, G. C., J. G. Buchanan-Smith, and D. G. Grieve. 1983. Effect of sodium bicarbonate on rate of passage and degradation of soybean meal in postpartum dairy cows. J. Dairy Sci. 66:1023.

Olson, N. F., and M. E. Johnson. 1990. Light cheese products: characteristics and economics. Food Technol. 44(10):93.

Palmquist, D.L., and T.C. Jenkins. 1980. Fat in lactation rations: review. J. Dairy Sci. 63:1.

Park, Y. K., and E. A. Yetley. 1990. Trend use and current intakes of tropical oils in the United States. Am. J. Clin. Nutr. 51:738.

Parry, R. M. Jr., J. Sampugna, and R. G. Jensen. 1964. Effect of feeding safflower oil on the fatty acid composition of milk. J. Dairy Sci. 47:37.

Peters, I. I. 1955. Cheddar cheese made from pasteurised milk homogenised at various pressures. J. Dairy Sci. 38:589.

Peters, I. I. 1956. Cheddar cheese made from pasteurised milk homogenised at various pressures. J. Dairy Sci. 39:1083.

Plowman, R. D., J. Bitman, C. H. Gordon, L. P. Dryden, H. K. Goering, T. R. Wrenn, L. F. Edmondson, R. A. Yoncoskie, and F. W. Douglas. 1972. Milk fat with increased polyunsaturated fatty acids. J. Dairy Sci. 55:204.

Prentice, J. H. 1992. Dairy rheology: a concise guide. VCH Publ., Inc., New York, NY.

Rao, A. 1985. Effects of partial homogenization of milk on yield and quality of Cheddar cheese. M. S. Thesis, South Dakota State Univ., Brookings.

Riddell, D. O., E. E. Bartley, and A. D. Dayton. 1980. Effect of nicotinic acid on rumen fermentation in vitro and in vivo. J. Dairy Sci. 63:1429.

Ruegsegger, G. J., and L. H. Schultz. 1986. Use of a combination of propylene glycol and niacin for subclinical ketosis. J. Dairy Sci. 69:1411.

SAS User's guide: Statistics, version 6.0 Edition. 1990. SAS Inst., Inc., Cary, NC.

Scott, T. W., L. J. Cook, and S. C. Mills. 1971. Protection of dietary polyunsaturated fatty acids against microbial hydrogenation in ruminants. J. Am. Oil Chem. Soc. 48:358.

Steele, W., R. C. Noble, and J. H. Moore. 1971a. The effects of 2 methods of incorporating soybean oil into the diet on milk yield and composition in the cow. J. Dairy Res. 38:43.

Steele, W., R. C. Noble, and J. H. Moore. 1971b. The effects of dietary soybean oil on milk fat composition in the cow. J. Dairy Res. 38:49.

Stegeman, G. A., R. J. Baer, D. J. Schingoethe, and D. P. Casper. 1991. Influence on milk fat higher in unsaturated fatty acids on the accuracy of milk fat analyses by the mid-infrared spectroscopic method. J. Food Prot. 54:890.

Stegeman, G. A., R. J. Baer, D. J. Schingoethe, and D. P. Casper. 1992a. Composition and flavor of milk and butter from cows fed unsaturated dietary fat and receiving bovine somatotropin. J. Dairy Sci. 75:962.

Stegeman, G. A., D. P. Casper, D. J. Schingoethe, and R. J. Baer. 1992b. Lactational responses of dairy cows fed unsaturated dietary fat and receiving bovine somatotropin. J. Dairy Sci. 75:1936.

Van Vliet, T., and A. Dentener-Kikkert. 1982. Influence of the composition of the milk fat globule membrane on the rheological properties of acid milk gels. Neth. Milk Dairy J. 36:261.

Walstra, P., and R. Jenness. 1984. Dairy Chemistry and Physics. John Wiley and Sons, Inc., New York, NY.

Wong, N. P., H. E. Walter, J. H. Vestal, D. E. Lacroix, and J. A. Alford. 1973. Cheddar cheese with increased polyunsaturated fatty acids. J. Dairy Sci. 56:1271.

Wrenn, T. R., J. Bitman, R. A. Waterman, J. R. Weyant, D. L. Wood, L. L. Strozinski, and N. W. Hooven. 1978. Feeding protected and unprotected tallow to lactating cows. J. Dairy Sci. 61:49.

FIGURE 1.

Instron generated graph depicting texture characteristics.

FIGURE 1.

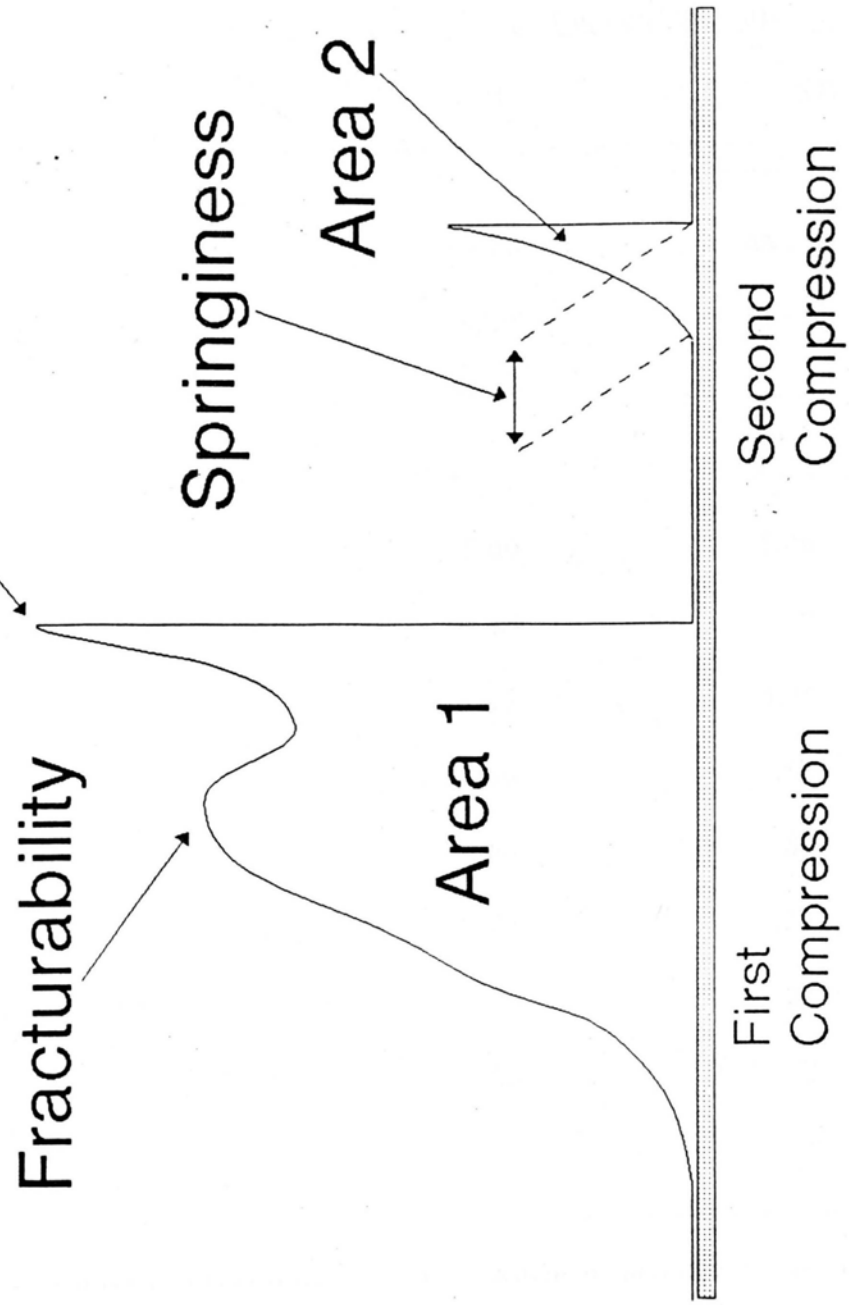
Hardness
Springiness
Area 2
Second
Compression
Fracturability
Area 1
First
Compression

TABLE 1. Ingredient composition of concentrate mixes containing soybean meal (C) and extruded soybeans (ESB).

Ingredient	Concentrate mix	
	C	ESB
	----------(%)----------	
Corn, rolled	55.60	48.25
Barley, rolled	9.40	8.50
Soybean meal, 44% CP	26.70	------
Extruded soybeans	------	34.00
Molasses, liquid	5.00	5.00
Dicalcium phosphate	1.25	1.10
Limestone	.25	1.35
Trace mineral salt	.50	.50
Sodium bicarbonate	.80	.80
Magnesium oxide	.25	.25
Vitamin A, D, & E premix[1]	.20	.20
Vitamin E premix[2]	.05	.05

[1]Contains 4,400,000 international units (IU) of vitamin A, 880,000 IU of vitamin D, and 440 IU of vitamin E/kg.

[2]Contains 44,000 IU of vitamin E/kg.

TABLE 2. Physical properties of milk from cows fed control (C), control with added niacin (C+), supplemental fat from extruded soybeans (ESB), and supplemental fat from extruded soybeans with added niacin (ESB+) diets.

	Diet				
Item	C	C+	ESB	ESB+	SE
pH	6.81[a]	6.81	6.86	6.83	.02
Titratable acidity, %	.17[a]	.17	.17	.16	.003
Freeezing point, C°	-.529[a]	-.530	-.530	-.529	.85

[a]Means in the same row do not differ ($P > .1$).

TABLE 3. Milk fat globule size and number expressed as a percent from cows fed control (C), control with added niacin (C+), supplemental fat from extruded soybeans (ESB), and supplemental fat from extruded soybeans with added niacin (ESB+) diets.

	Diet				
Size (μ)	C	C+	ESB	ESB+	SE
	%				
<1	32.44[a]	30.06	34.08	37.03	3.01
1-2	48.10[a]	48.28[a]	46.46[ab]	43.38[b]	1.95
2-3	18.09[a]	19.20	16.84	17.40	1.82
3-5	1.38[a]	2.44	2.45	2.16	.50
>5	0[a]	.02[a]	.16[b]	.03[a]	.05

[a,b]Means in the same row with unlike superscript differ ($P < .1$).

TABLE 4. Fatty acid composition of milk fat from cows fed control (C), control with added niacin (C+), supplemental fat from extruded soybeans (ESB), and supplemental fat from extruded soybeans with added niacin (ESB+) diets.

	Diet				
Fatty acid[1]	C	C+	ESB	ESB+	SE
	g/100 g fat				
4:0	6.29[a]	6.35	6.58	6.59	.20
6:0	4.36[a]	4.42[a]	3.81[b]	3.82[b]	.13
8:0	2.66[a]	2.68[a]	2.10[b]	1.99[b]	.07
10:0	5.41[a]	5.43[a]	3.77[b]	3.63[b]	.13
10:1	.30[a]	.36[a]	.61[b]	.40[ab]	.11
12:0	5.77[a]	5.82[a]	3.65[b]	3.56[b]	.13
14:0	11.57[a]	11.46[a]	9.32[b]	9.33[b]	.19
14:1	2.59[a]	2.61[a]	1.45[b]	1.53[b]	.12
15:0	1.83[a]	1.87[a]	.96[b]	.94[b]	.10
15:1	.34[a]	.35[a]	.24[b]	.26[b]	.02
16:0	17.90[a]	18.00[a]	15.27[b]	14.81[b]	.36
16:1	4.08[a]	4.00[a]	2.62[b]	2.66[b]	.14
17:0	.93[a]	.98[a]	.60[b]	.58[b]	.04
17:1	.35[a]	.35[a]	.23[b]	.23[b]	.03
18:0	9.94[a]	10.01[a]	13.60[b]	13.47[b]	.42
18:1	18.06[a]	17.84[a]	24.34[b]	24.79[b]	.36
18:2	3.70[a]	3.51[a]	5.89[b]	6.58[c]	.29
SC[2]	24.79[a]	25.07[a]	20.53[b]	20.00[b]	.52
MC[2]	39.58[a]	39.62[a]	30.69[b]	30.34[b]	.47
LC[2]	31.70[a]	31.37[a]	43.83[b]	44.83[b]	.64
Unsaturated	29.42[a]	29.03[a]	35.38[b]*	36.44[c]*	.55
Saturated	66.65[a]	67.03[a]	59.67[b]	58.74[b]	.69
Other	3.93[a]	3.94[a]	4.96[b]	4.82[b]	.24

[1]Expressed as number of carbons:number of double bonds.
[2]SC = short-chain (4:0 to 12:0); MC = medium-chain (14:0 to 17:1); LC = long-chain (18:0 to 18:2).
[a,b,c]Means in the same row with unlike superscript differ ($P < .05$).
*If superscript is followed by asterisk, ($P < .1$) only for asterisk in the same row.

TABLE 5. Composition and physical properties of reduced fat Cheddar cheese milk after standardization, homogenization, and pasteurization from control not homogenized (CNH), control part homogenized (CPH), supplemental dietary fat from extruded soybeans with added niacin not homogenized (UNH), and supplemental dietary fat from extruded soybeans with added niacin part homogenized (UPH) treatments.

	Treatment				
Item	CNH	CPH	UNH	UPH	SE
Protein, %	3.17[a]	3.20[a]	2.90[b]	2.89[b]	.03
Fat, %	1.66[ab]	1.73[a]	1.58[b]	1.58[b]	.03
Ash, %	.60[a]	.58	.58	.57	.01
Total solids, %	10.22[a]	10.32	10.04	10.05	.10
Titratable acidity, %	.17[a]	.16	.17	.17	.01
pH	6.60[a]	6.65	6.62	6.59	.01

[a,b]Means in the same row with unlike superscript differ ($P < .05$).

TABLE 6. Composition of reduced fat Cheddar cheese whey from control not homogenized (CNH), control part homogenized (CPH), supplemental dietary fat from extruded soybeans with added niacin not homogenized (UNH), and supplemental dietary fat from extruded soybeans with added niacin part homogenized (UPH) treatments.

	Treatment				
Item	CNH	CPH	UNH	UPH	SE
Protein, %	.90[a]	.89[a]	.82[b]	.81[b]	.02
Fat, %	.19[a]	.19	.17	.16	.02
Ash, %	.42[a]	.42	.42	.43	.01
Total solids, %	6.47[a]	6.56	6.49	6.52	.04

[ab]Means in the same row with unlike superscript differ ($P < .05$).

TABLE 7. Composition of reduced fat Cheddar cheese made from control not homogeized (CNH), control part homogenized (CPH), supplemental dietary fat from extruded soybeans with added niacin not homogenized (UNH), and supplemental dietary fat from extruded soybeans with added niacin part homogenized (UPH) treatments.

	Treatment				
Item	CNH	CPH	UNH	UPH	SE
Total solids, %	54.45[a]	54.25	54.91	54.36	.58
Fat, %	19.70[a]	19.25	19.73	19.60	.29
Total protein, %	30.31[a]	29.67	30.08	29.83	.46
Ash, %	2.92[a]	2.97[ab]	3.04[ab]	3.10[b]	.05
NaCl, %	1.09[a]	1.10	1.16	1.12	.06
Fat, % on dry basis	36.15[a]	35.48	35.91	36.06	.46
	Soluble nitrogen, %				
1 week	1.50[a,A]	1.50[A]	1.58[A]	1.56[A]	.06
1 month	2.16[a,B]	2.16[B]	2.32[B]	2.24[B]	.09
3 month	2.97[a,C]	2.92[C]	3.11[C]	3.10[C]	.08
6 month	3.69[a,D]	3.70[D]	3.88[D]	3.84[D]	.11
	pH				
1 week	5.11[a,A]	5.11[A]	5.06[A]	5.09[A]	.04
1 month	5.16[a]	5.15	5.15[B]	5.10	.04
3 month	5.27[a]	5.26	5.23[B]	5.29	.04
6 month	5.37[a]	5.27[b]	5.27[b,B]	5.28[b]	.03

[a,b]Means in the same row with unlike superscript differ ($P < .05$).
[A,B,C,D]Means in the same column with unlike superscript differ ($P < .05$).

TABLE 8. Fatty acid composition of reduced fat Cheddar cheese from control not homogenized (CNH), control part homogenized (CPH), supplemental dietary fat from extruded soybeans with added niacin not homogenized (UNH), and supplemental dietary fat from extruded soybeans with added niacin part homogenized (UPH) treatments.

	Treatment				
Fatty acid[1]	CNH	CPH	UNH	UPH	SE
	g/100 g fat				
4:0	6.87[a]	5.84	6.83	7.15	.51
6:0	4.82[a]	4.15[a]	3.98[b]	4.24[a]	.26
8:0	2.89[a]	2.53[b]	2.06[c]	2.16[c]	.11
10:0	5.58[a]	5.33[a]	3.71[b]	3.80[b]	.20
10:1	.82[a]	.69	.79	.89	.17
12:0	5.74[a]	5.75[a]	3.51[b]	3.52[b]	.19
14:0	11.07[a]	11.32[a]	9.12[b]	9.22[b]	.32
14:1	2.65[a]	2.84[a]	1.37[b]	1.32[b]	.29
15:0	1.86[a]	1.93[a]	.81[b]	.84[b]	.22
15:1	.32[a]	.33	.26	.27	.03
16:0	17.25[a]*	17.28[a]*	14.37[b]	14.76[b]*	.90
16:1	4.00[a]	4.17[a]	2.64[b]	2.59[b]	.31
17:0	1.01[a]	1.03[a]	.62[b]	.61[b]	.09
17:1	.38[a]	.36[a]	.26[b]	.24[b]	.03
18:0	9.35[a]	9.83[a]	13.47[b]	13.36[b]	.38
18:1	17.48[a]	18.48[a]	24.51[b]	24.08[b]	.51
18:2	3.42[a]	3.79[a]	6.25[b]	5.91[b]	.55
SC[2]	26.73[a]	24.30[ab]*	20.89[c]*	21.77[bc]	1.08
MC[2]	38.54[a]	39.25[a]	29.45[b]	29.85[b]	.67
LC[2]	30.24[a]	32.09[a]	44.23[b]	43.35[b]	1.24
Unsaturated	29.06[a]	30.65[a]	36.08[b]	35.29[b]	1.22
Saturated	66.46[a]	64.99[a]	58.49[b]	59.68[b]	1.52
Other	4.48[ab]	4.36[a]*	5.44[b]*	5.03[ab]	.38

[1]Expressed as number of carbons:number of double bonds.
[2]SC = short-chain (4:0 to 12:0); MC = medium-chain (14:0 to 17:1); LC = long-chain (18:0 to 18:2).
[a,b,c]Means in the same row with unlike superscript differ ($P < .05$).
*If superscript is followed by asterisk, ($P < .1$) only for asterisk in the same row.

TABLE 9. Flavor scores and overall acceptability of reduced fat Cheddar cheese from control not homogenized (CNH), control part homogenized (CPH), supplemental dietary fat from extruded soybeans with added niacin not homogenized (UNH), and supplemental dietary fat from extruded soybeans with added niacin part homogenized (UPH) treatments.

Month	Treatment				SE
	CNH	CPH	UNH	UPH	
	Acidity[1]				
1	$3.13^{a,A}$	3.09^{A*}	3.25^{A}	3.00^{A}	.95
3	$3.72^{a,AB}$	3.75^{AB}	4.34^{B}	4.03^{B}	
6	$4.34^{a,B}$	3.91^{B*}	4.38^{B}	4.38^{B}	
	Bitterness[1]				
1	$1.41^{a,A}$	1.53^{A}	1.59^{A}	1.47^{A}	.69
3	$2.50^{a,B}$	2.59^{B}	2.50^{B}	2.72^{B}	
6	$2.56^{a,B}$	2.94^{B}	2.81^{B}	2.91^{B}	
	Flat or lacks flavor[1]				
1	$5.53^{a,A}$	5.56^{A}	5.44^{A}	5.44^{A}	.93
3	$3.41^{a,B}$	3.81^{B}	3.47^{B}	3.59^{B}	
6	$3.31^{a,B}$	3.81^{B}	3.28^{B}	3.63^{B}	
	Overall acceptability[2]				
1	$6.69^{a,A}$	6.69^{A}	6.91^{A}	7.02^{A}	.57
3	6.97^{ab}	6.66^{a*}	7.13^{b*}	6.66^{a*}	
6	7.05^{a*}	6.58^{b*}	7.13^{a*}	6.69^{ab}	

[1]1 = None, 5 = definite, and 9 = extreme.
[2]1 = Poor and 9 = excellent.
^{a,b}Means in the same row with unlike superscript differ ($P < .05$).
^{A,B}Means in the same column with unlike superscript differ ($P < .05$).
*If superscript is followed by asterisk, ($P < .1$) only for asterisk in the same row or column.

TABLE 10. Body and texture scores[1] of reduced fat Cheddar cheese from control not homogenized (CNH), control part homogenized (CPH), supplemental dietary fat from extruded soybeans with added niacin not homogenized (UNH), and supplemental dietary fat from extruded soybeans with added niacin part homogenized (UPH) treatments.

Month	Treatment				SE
	CNH	CPH	UNH	UPH	
	Curdy				
1	$4.97^{a,A}$	4.50^{A}	4.91^{A}	4.47^{A}	1.01
3	$3.59^{a,B}$	3.78^{AB}	3.69^{B}	3.75^{AB}	
6	$3.47^{a,B}$	3.47^{B}	3.34^{B}	3.38^{B}	
	Mealy				
1	$2.75^{a,A}$	2.59^{A}	3.00^{A*}	2.63^{A}	.85
3	2.34^{a}	2.72	2.28^{B*}	2.31	
6	2.31^{a}	2.38	2.53^{AB}	2.72	
	Short				
1	$2.53^{a,AB}$	2.84^{A}	2.47^{A}	2.34^{A}	.84
3	$2.13^{a,A*}$	2.56	2.06	2.16	
6	$2.88^{ab,B*}$	3.09^{a*}	2.34^{b*}	2.75^{ab}	
	Weak				
1	$2.03^{a,A}$	1.91^{A}	2.00^{A}	2.00^{A}	.92
3	$3.13^{a,B}$	2.59	3.06^{B}	2.72	
6	$1.94^{a,A}$	2.22	2.03^{A}	1.92	

[1]1 = None, 5 = definite, and 9 = extreme.

^{a,b}Means in the same row with unlike superscript differ ($P < .05$).

^{A,B}Means in the same column with unlike superscript differ ($P < .05$).

*If superscript is followed by asterisk, ($P < .1$) only for asterisk in the same row or column.

TABLE 11. Rheology measurements of reduced fat Cheddar cheese from control not homogenized (CNH), control part homogenized (CPH), supplemental dietary fat from extruded soybeans with added niacin not homogenized (UNH), and supplemental dietary fat from extruded soybeans with added niacin part homogenized (UPH) treatments.

Month	Treatment				SE
	CNH	CPH	UNH	UPH	
	Hardness[1]				
1	$8.12^{a,A}$	$7.68^{a,A}$	$6.30^{b,A}$	$6.62^{b,A}$	.24
6	$7.22^{a,B}$	$6.29^{b,B}$	$5.42^{c*,B}$	$5.93^{bd*,B}$	
	Fracturability[1]				
1	$7.48^{a,A}$	$6.87^{b,A}$	$5.40^{c,A}$	$5.52^{c,A}$	.21
6	$4.91^{a*,B}$	$4.43^{b*,B}$	$3.55^{c,B}$	$3.63^{c,B}$	
	Springiness[2]				
1	$7.06^{ab,A}$	$7.23^{a,A}$	$6.65^{c,A}$	$6.77^{bc,A}$	.17
6	$5.02^{a*,B}$	$4.67^{b*,B}$	$4.47^{b,B}$	$4.69^{b*,B}$	
	Cohesiveness				
1	$.23^{a*,A}$	$.24^{ab,A}$	$.21^{c,A}$	$.22^{b*c,A}$	.01
6	$.17^{a,B}$	$.15^{b*,B}$	$.14^{b*,B}$	$.16^{a*,B}$	
	Gumminess[1]				
1	$.19^{a,A}$	$.19^{a,A}$	$.13^{b,A}$	$.14^{b,A}$	.01
6	$.12^{a,B}$	$.09^{b*,B}$	$.08^{c*,B}$	$.10^{b,B}$	
	Chewiness[3]				
1	$1.38^{a,A}$	$1.41^{a,A}$	$.89^{b,A}$	$.99^{b,A}$	.06
6	$.63^{a,B}$	$.45^{b,B}$	$.34^{b,B}$	$.46^{b,B}$	

[1]Values measured in kg.
[2]Values measured in mm.
[3]Values measured in kg mm.
[abcd]Means in the same row with unlike superscript differ ($P < .05$).
[AB]Means in the same column with unlike superscript differ ($P < .05$).
*If superscript is followed by asterisk, ($P < .1$) only for asterisk in the same row.