Both wilting and unfavorable temperatures hasten the loss of carotene, but unfavorable temperatures are by far the more destructive of the two (Table I). Increased losses of carotene resulting from increased wilting are adequately expressed as a few percentage points over the lower wilting rate. But increased losses resulting from higher temperatures, such as may be encountered in the marketing channels, may better be indicated as a multiple of that lost at the lower temperature.

In a single test, kale was separated into leaves full grown; leaves half- to full-grown; and leaves less than half-grown. All lots were then placed at 32° F. with high humidity. Little or no visible wilting was evident within the 10-day test period. The amount of carotene was greater in the more mature leaves, but the rate of loss was not appreciably affected by the state of maturity.

From the data presented it may be concluded that kale held under conditions that prevent appreciable wilting will lose about one fourth of its carotene content if held at 32° F. for 4 weeks, at 50° F. for 5 days, or at 70° F. for 1 day. If appreciable wilting occurs, these losses may be expected to increase up to 30% at 32° F. and 30 to 40% at 50° and 70° F. Similar results may be expected with turnip greens and rape, and somewhat greater losses with collards. Prepackaging in plastic films effectively reduces the loss of moisture and preserves a fresh, crisp appearance, but low temperatures are also necessary to preserve the vitamin A values normally present in the product.

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A REVIEW OF CONTROL OF MILK COMPOSITION

The Importance of Rumen Metabolism in Relation to Milk Composition

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The substrates utilized by the mammary gland for synthetic and energy purposes in producing milk must be derived from the materials eaten by the cow. The feed constituents undergo extensive degradation and alteration by the bacteria and protozoa present in the rumen. The bovine derives the major portion of its nutrients from the digestion of these microorganisms as well as from the absorption of the products of microbial metabolism. A general discussion of the interrelated metabolism of the rumen microorganisms and bovine organism in regards to protein, carbohydrate, and lipide metabolism is presented. The major purpose of this discussion is to point out the dependence of bovine milk secretion on rumen activity, and to stress that the evaluation of any feeding regime must consider the reactions which occur in the rumen.

THE SUBSTRATES utilized by the mammary gland for synthetic and energy purposes in producing milk must be derived from materials eaten by the cow. The feed constituents enter the rumen where they undergo extensive degradation and alteration by the bacteria and protozoa present. The location of this fermentation vat at the beginning of the digestive tract enables ruminants to make extensive use of materials which would otherwise be of little value. The bovine derives the major portion of its nutrients from the digestion of these microorganisms, as well as from the absorption of the products of microbial metabolism. Because of this, the effects of a particular feed on the metabolism of the bovine must always be evaluated with regards to the influence it exerts on the rumen microorganisms. By selection of certain microorganisms, or by stimulating them to form adaptive enzymes, the products of rumen fermentation can be altered. A change in microbial end products available to the host animal can possibly have an effect on the metabolism of the cow and the composition of milk.

The study of rumen function is complicated by the dynamic nature of the system where production, interaction, and absorption of metabolites are continuously occurring. The frequent intake of food by the animal provides a regular supply of substrates for the microorganisms. At the same time, the soluble products of microbial activity appear to be readily absorbed through the rumen wall. Likewise, the volume of rumen contents is regularly influenced by two factors. Large volumes of saliva secreted by the host animal are continuously being added to the rumen contents, while at frequent intervals, a portion of the rumen material (small food particles and microorganisms) passes to the omasum and the lower digestive tract. The concentration of a metabolite in the rumen would then be determined by the interplay of all these factors. The study of the effect of a dietary component, mediated by the rumen, on the metabolism of the cow is hindered by the fact that the cow is in a sense eating all the time. Changes in the level of metabolites in the blood after a

meal, such as alimentary lipemia, cannot be adequately measured because digestion and absorption are rather uniform and continuous processes.

Knowledge of the action of the body tissues, especially the liver, on absorbed metabolites is also essential for an understanding of the factors influencing milk production. Some of the substances entering the blood from the gut undergo extensive modification before being presented to the mammary gland as precursors for milk constituents.

Protein Metabolism

Protein metabolism provides a good example of the influence of the rumen on the nutrition of the host animal and, consequently, on the secretion of milk. In nonruminants, dietary proteins are broken down, by enzymes secreted by the animal, into peptides and amino acids which are then absorbed from the small intestine. The value of a dietary protein depends on the amino acid content, especially with regards to the 10 essential amino acids. The main value of the rumen to nitrogen metabolism of the bovine is that the microorganisms present can modify or supplement the amino acids of the diet, and can alter the amount of nitrogen available to the host animal. Much of the protein which enters the rumen is converted into organic acids and ammonia. New protein of bacterial origin is synthesized, and when these microbes pass to the lower digestive tract, the protein becomes available to the host animal. Bacterial proteins have a good, but not outstanding biological value. However, since the ruminant most likely has the same requirements for the essential amino acids as other mammals, the microorganisms ensure a source of these metabolites, in the event the diet is deficient. If an adequate carbohydrate source is present in the rumen, bacteria can use urea coming from the diet, saliva, or the blood through the rumen wall (*8*), for the synthesis of amino acids.

The essential amino acids of casein and β-lactoglobulin in milk must come from the free amino acids of the plasma or plasma protein (*5*). Likewise, many of the nonessential amino acids used in the synthesis of milk proteins are taken from the blood. In some instances, these blood metabolites were originally synthesized by the rumen microorganisms.

Branched chain acids arise from the breakdown of dietary protein in the rumen (*1, 41*). The deamination of valine, leucine, and isoleucine by the rumen microorganisms leads to the formation of isobutyric, isovaleric, and 2-methylbutyric acids, respectively (*1, 2*). The direct absorption of these acids from the rumen into the blood has been demonstrated (*3*). These metabolites could serve as primary precursors of branched chain acids in milk fat.

Table I. Distribution of Recovered C^{14} Following 1-Hour Perfusions of Goat Livers in Which Carboxyl-Labeled Volatile Fatty Acids Were Added to Blood[a]

Substance Isolated	Distribution of Label from Added Metabolite, %			
	Formate	Acetate	Propionate	Butyrate
Blood				
Valeric acid	0.0	0.0	0.0	0.0
Butyric acid	0.0	0.0	0.0	0.0
Propionic acid	0.0	0.0	1.6	0.6
Acetic acid	2.1	75.2	3.6	10.3
Formic acid	12.5	4.1	8.3	2.0
Lactic acid	5.1	7.4	25.1	49.9
Glucose	1.3	2.4	3.1	1.1
Acetone bodies				
Derived acetone	0.0	0.0	0.0	0.0
Derived carboxyl CO_2	0.6	1.5	0.6	1.1
Liver				
Glycogen	57.8	2.4	46.5	31.5
Neutral fat	0.4	1.9	0.7	0.5
Phospholipides	5.6	0.4	1.1	0.2
Nucleotide fraction	15.1	6.0	10.0	4.0
Added C^{14} recovered, %	61.9	71.6	50.1	90.0

[a] Data of McCarthy *et al.* (*27*).

Carbohydrate Metabolism

Essentially, none of the digestible dietary carbohydrate escapes the action of the rumen microorganisms. Because of this, much attention has been focused on the volatile fatty acids (VFA), which are the major end products of microbial fermentation in the rumen. These acids, consisting principally of acetic, propionic, and butyric acids, are primary metabolites serving to meet the energy and synthetic requirements of the host animal. The total concentration of the VFA in the rumen, and the quantity of individual acids are dependent to a large degree on the diet. Changes in the proportions of the various acids may have a profound influence on the ruminant animal. Rumen perfusion was used to study VFA metabolism (*28*). In this technique, blood is circulated through the vascular system of the isolated living rumen by means of a heart lung apparatus. Since the rumen is isolated, it is possible to measure total production of VFA in the rumen, and total absorption into the blood during specified periods of time. The addition of radioactive tracers to the rumen contents makes it possible to follow the course of various metabolites and to determine in what form rumen substances enter the blood.

Conclusions from numerous perfusion studies, pertinent to the present discussion and later confirmed by Brown *et al.* (*6*), are summarized as follows:

Large quantities of organic acids are normally produced in the rumen. On a common diet of hay and grain, the relative rates of production of VFA are—acetic>propionic>butyric>valeric.

The VFA produced in the rumen are absorbed into the blood of the animal; the relative quantities of the acids absorbed are, in general, a reflection of their production in the rumen.

Under most circumstances, rumen acids do not serve as precursors for ketone body formation during absorption.

The principle of absorption in direct relation to production is extremely important, since it indicates that analysis of rumen fluid for VFA content gives a direct measure of the proportion of the various acids becoming available to the animal. VFA are also absorbed from the omasum; the recent work of Johnston, Kesler, and McCarthy (*20*) demonstrated that the VFA absorbed are directly related to the proportion of various acids in the rumen.

The question remained whether the VFA composition of rumen fluid is sufficiently uniform throughout the day to permit a valid estimation of the relative production of the various acids from the analysis of a single sample. This question was answered affirmatively by Ensor (*9*). Analyses of rumen fluid, at short intervals over a period 10 hours after feeding, from a number of animals on different diets, showed that for each diet, the particular proportion of VFA being produced remained rather uniform over the entire period. Thus, the analysis of rumen fluid is a valid measure of the proportion of the individual VFA being produced and becoming available to the host animal.

The VFA entering the blood are immediately transported to the liver by way of the portal vein. Since the liver is capable of acting on all digestive products, it influences the nature and quantity of the metabolites presented to the mammary gland for milk synthesis. Liver perfusion was the technique selected for studying liver metabolism

Table II. Influence of Diet on the Proportion of Rumen VFA and Fat Per Cent in Milk[a]

Diet Lb./Day	Exptl. Period, Days	Milk Fat, %	Molar % of Total Rumen VFA			
			C_2	C_3	C_4	C_5
20 pounds alfalfa hay 20 pounds dairy mix	30	3.4	63.9	22.0	12.2	1.9
32 pounds alfalfa meal pellets	21	3.3	63.1	24.7	9.0	3.2
30 pounds alfalfa meal pellets + 4 pounds steamed corn	19	1.4	50.3	32.5	10.4	6.8

[a] Data of Shaw (*36*).

of VFA (*27*). Complete mixtures of VFA, in which one acid was labeled with C^{14}, were added to the perfusing blood. Quantitative results showed that propionic, butyric, and valeric acids were removed completely from blood by the liver. The level of acetic acid in the blood did not decrease, while formic acid concentration increased several fold. Blood ketone bodies showed approximately a 100% increase in all perfusions. Table I presents the distribution of recovered C^{14} in blood and liver tissue compounds at the end of four perfusions (*27*). The label from formic, propionic, and butyric acid recovered in carbohydrate (glycogen, blood glucose, and lactic acid) account for 64, 75, and 83%, respectively, of the total C^{14} recovered. Only 12% of the recovered C^{14} from acetic acid was found in these compounds. The fact that only a trace of label was recovered in the blood ketone bodies indicates that VFA are not directly converted to ketones, but rather, this normal blood metabolite arises from hepatic lipide metabolism as in the monogastric animal.

The metabolic fate of rumen butyric acid is not completely understood at present. Under most circumstances, butyric acid is glycogenic and enters carbohydrate metabolism (*21*, *27*). However, when present in large quantities, butyric acid tends to be ketogenic and contributes to the formation of β-hydroxybutyrate (*31*). It can be postulated that β-hydroxybutyrate is an intermediate in the conversion of butyric acid to carbohydrate. When large quantities of butyric acid are present, this intermediate (derived from butyrate) accumulates.

Three blood metabolites—glucose, acetate, and β-hydroxybutyrate—serve as precursors for almost 50% of the total organic solids in milk. Glucose is utilized by the mammary gland for the synthesis of lactose (*21*), and for the production of the glycerol of milk fat (*25*). Acetate and β-hydroxybutyrate provide the necessary metabolites for the synthesis of a portion of the fatty acids in milk fat. β-Hydroxybutyrate entering the gland apparently follows one of two schemes (*23*). A portion of the β-hydroxybutyrate is reduced directly to butyrate, while the remainder is apparently cleaved to yield methyl and carboxyl two carbon fragments. The carboxyl two carbon fragment is preferentially used for fat synthesis and most likely follows the same pathway as acetate in synthesizing longer chain fatty acids.

The relative amount of acetate available to the udder may be regulated directly by acetic acid production in the rumen. In general, the quantity of glucose available is directly influenced by the amount of propionic and butyric acid produced in the rumen, since these acids are converted to glycogen by the liver. The amount of β-hydroxybutyrate produced by the liver is controlled indirectly by the amount of fat oxidation occurring in the liver. This is primarily influenced by the amount of glucose produced. Less fat is oxidized when ample amounts of carbohydrate are present, and thus ketones, the products of oxidation, will decrease. This means less β-hydroxybutyrate will be available when propionate predominates in the rumen. With this background information, it is possible to present a reasonable explanation for the drop in per cent fat in milk, when a cow is fed a low roughage, high concentrate ration (*4*), or a so-called exotic diet (*36*). Shaw (*36*) and Ensor (*9*) found that feeding a cow pelleted alfalfa meal, plus as little as 4 pounds of steam-heated corn, decreased the fat content of milk by as much as 50%, while total production and solids-not-fat actually increased slightly. On these diets, the relative proportion of acetic acid in the rumen decreased, while the proportion of propionic acid increased (Table II). Studies have shown a highly significant positive correlation between fat test and level of acetate in the rumen, while there was a highly significant negative correlation between fat test and the rumen level of propionate (*36*, *37*). These diets, in addition to decreasing the per cent fat in milk, also changed the composition of the fat. There was a decrease in short-chain acids and an increase in unsaturated acids, as measured by iodine number.

An explanation for this effect was made by Shaw (*35*). He proposed that the decrease in fat content of milk which is effected by feeding exotic diets is due to a relative and/or absolute deficiency of the two substances most needed for the synthesis of the lower fatty acids of milk fat, namely acetic acid and β-hydroxybutyrate. He considers the decrease in β-hydroxybutyrate as due to the increased production of propionate in the rumen. This provides more glucose which results in a decrease in the oxidation of fats, and thus a decrease in formation of β-hydroxybutyrate. He states: "A shortage in two substances most needed for the synthesis of the lower fatty acids of milk fat readily explains the decrease in the fat content of milk since it appears to be rather well proved that the formation of these fatty acids within the udder controls the formation of milk fat."

McClymont and Kondos (*29*) believe that the increased propionate production increases the glucose level, which in turn suppresses the liberation of non-esterified fatty acids (NEFA) by adipose tissue. This drop in plasma level of NEFA depresses hepatic glyceride synthesis and the release of these glycerides into the plasma. The plasma glyceride level rapidly declines because of a rapid uptake by the mammary gland. The low level of glycerides in the plasma eventually decreases the uptake of glycerides by the mammary gland and thereby reduces the rate of milk fat synthesis. Since short chain acids are not present in any quantity in plasma glycerides, the proposal of McClymont and Kondos does not completely explain the compositional change in the milk fat.

Rations which increase butyric acid, rather than propionic acid levels, at the expense of acetate, do not have a very marked effect on reduction of milk fat yield. This was demonstrated by Shaw (*37*) in a trial in which alfalfa pellets and glucose were fed. On this ration, acetic acid decreased and butyric acid increased, while propionic acid remained the same. The reason for the lack of a decrease in per cent fat is most likely that the increased butyrate went into the formation of ketones. Thus, adequate substrate was still available for fat synthesis in the udder. Demonstration of this would support the theory of Shaw for the decline in milk fat synthesis on exotic diets.

Lipides

Dietary lipides of the ruminant consist primarily of C_{18} unsaturated acids. Most of the lipides in grain and a high proportion of those in grasses are in glyceride form. Grasses also contain a

Table III. Major Component Fatty Acids of Depot Lipides in Bovine Raised on Fat-Free and Normal Diets

Fatty Acid	Fat-Free Diet,[a] Wt. %	Normal Diet,[b] Wt. %
14:0	2.2	6.1
16:0	27.3	31.0
16:1	3.7	3.2
17:0	2.9	..
18:0	29.2	23.0
18:1	35.0	34.0
18:2	0.5	1.5
18:3	0.3	

[a] Data of Reiser and Reddy (*33*).
[b] Data of McCarthy *et al.* (*26*).

Table IV. Major Component Fatty Acids in Various Segments of the Goat Digestive Tract, Given in Weight Per Cent

	Location in the Digestive Tract				
				Small Intestine	
Fatty Acid	Rumen	Omasum	Abomasum	1st half	2nd half
14:0	4.0	2.8	3.6	0.6	0.6
16:0	23.6	24.5	21.8	20.8	17.7
18:0	40.4	52.6	42.7	31.5	46.3
18:1	22.6	16.6	26.4	19.1	17.5
18:2	8.0	2.7	4.7	24.2	14.8
18:3	1.3	0.8	0.7	3.8	3.1

high proportion of galactosyl glyceryl esters of linolenic acid (*45*). As with other feed constituents, first consideration must be given to the fate of these metabolites in the rumen. Garton, Hobson, and Lough (*13*) found that the rumen bacteria rapidly hydrolyze glyceride material on contact, and that 80 to 90% of the lipides in the rumen and other stomachs of the bovine consisted of free, long-chain fatty acids. Thus, any dietary glyceride structure could have little or no effect on the metabolism of the animal. Extensive hydrogenation of unsaturated fatty acids within the rumen has been demonstrated (*14, 33, 43*). Microorganisms not only convert fatty acids to a highly saturated form, but also are instrumental in the formation of many positional and spatial isomers in the remaining unsaturated acids (*14*). *trans*-11-Octadecenoic acid, commonly known as vaccenic acid and particularly characteristic in summer milk fat, is such an isomer. Rumen hydrogenation of unsaturated dietary lipides has been assumed to be the primary reason for the saturated nature of all ruminant fats. However, other factors may be involved as was pointed out by the recent study of Reiser *et al.* (*32*), in which a calf was raised on a completely fat-free diet. The animal did not do well, but its depot fat had the same characteristic saturated composition as normal beef tallow, as reported in Table III. The synthesis of long-chain fatty acids from nonlipide precursors in the rumen was not investigated in this study. Rumen microorganisms may synthesize lipides which are later utilized by the host animal.

The major fatty acid components of the lipides in various segments of the digestive tract of a goat are presented in Table IV. The analyses of the composition in the rumen, omasum, and abomasum show the characteristic preponderance of saturated acids. However, lipides in the first half of the small intestine show a rather dramatic shift in composition. The most logical conclusion to be drawn from this analysis is that linoleic acid is secreted into the lumen of the intestine. The secretion of lipides into the intestine of rats has been observed by Burr, McPherson, and Tidwell (*7*). The reason for this secretion is not known, but does warrant additional study. A possible explanation is that the unsaturated fat is necessary to aid in the absorption of the saturated fatty acids passing down the digestive tract from the rumen. Frazer (*11*) reports that higher melting, saturated fatty acids are poorly absorbed from the intestine of man unless they are provided with an adequate liquid oil vehicle.

Absorption of lipides, as in the monogastric animal, is assumed to occur from the small intestine of the ruminant. Preliminary studies from this laboratory indicate that this may not be the only site of absorption, but rather free acids may also be absorbed directly from the rumen.

In one study, a goat was drenched with the potassium salts of a mixture of C^{14} labeled long-chain fatty acids. Blood samples were taken hourly, and milk samples at several hour intervals. After 8 hours, the animal was sacrificed and the contents of the digestive tract assayed for radioactivity. At slaughter, only 12% of the added activity was left in the digestive tract, the largest quantity still being in the rumen. Blood samples showed considerable activity at 1 hour and remained at a high level over a 7-hour period. Milk samples displayed a trace of activity at 1 hour and increasing activity with time. At slaughter, the liver, mammary tissue, and adipose fat all contained C^{14}. The average rate of passage of feed material through the digestive tract of the bovine has been estimated at 54 hours (*42*). Therefore, to explain the results, one must assume that the labeled fatty acids passed very rapidly into the intestine, or what seems more logical, they were absorbed directly from the rumen. To follow this lead, the rumina from two goats were perfused. In one experiment, K-palmitate-1-C^{14} was added, while in the other tripalmitin-1-C^{14} was added to the contents. After 1 hour, in both experiments, preliminary analyses demonstrated the presence of C^{14} labeled non-

Table V. Weight Percentages of Lipide Fractions from the Serum of Two Lactating Holstein Cows[a]

Lipide Fraction	Cow 1, %	Cow 2, %
Cholesterol esters	54	54
Triglycerides	3	3
Nonesterified fatty acids	2	2
Cholesterol	7	6
Phospholipides	34	35
Total	100	100

[a] Data of Evans *et al.* (*10*).

esterified fatty acids in the perfusing blood.

The lipides in blood are carried as lipoprotein complexes. The origin of these lipoproteins and the mechanism of transfer of fatty acids from the gut is not known. The per cent of each lipide class in serum is presented in Table V (*10*). Cholesterol esters comprise the major fraction in ruminant blood. The earlier work of Garton and Duncan (*12*) showed cholesterol esters as comprising 79.8% of the total plasma lipides. However, they reported phospholipides as only 3.8% of the total lipides. Triglycerides and nonesterified fatty acids combined account for only 5% of the total lipide. The fatty acid composition of the various classes is presented in Table VI (*10*). The major component fatty acids of the cholesterol esters are overwhelmingly linoleic and linolenic acids. Similar results were originally reported by Lough and Garton (*24*). Nowhere else in the ruminant is such a concentration of these acids encountered. Since cholesterol esters are the major fraction in blood, these acids become the predominant ones in total blood lipides. In contrast, the triglycerides are very saturated and resemble rumen lipides. The nonesterified fatty acids are similar to triglycerides, but do contain a larger proportion of oleic and linoleic acids, while the phospholipides contain about the same per cent oleic acid as the triglycerides, but are much higher in linoleic acid.

Which component(s) of blood lipides contributes to the synthesis of milk fat in the mammary gland has not been clearly demonstrated. It is generally

Table VI. Fatty Acid Composition of Lipide Fractions from Whole Serum of the Bovine, Given in Weight Per Cent[a]

	Serum Lipid Fraction			
Fatty Acid	Cholesterol esters	Triglycerides	Nonesterified fatty acid	Phospholipides
10:0	0.3	0.5	0.5	0.1
12:0	0.3	0.8	0.6	0.2
14:0	2.5	2.4	1.6	1.0
14:1	1.0	1.0	0.2	0.2
16:0	7.0	27.0	24.0	22.0
16:1	2.6	3.0	4.5	2.4
18:0	1.9	51.0	37.0	40.0
18:1	3.0	14.0	28.0	14.0
18:2	72.0	..	4.0	20.0
18:3	9.0	..	..	..

[a] Data of Evans *et al.* (*10*).

Table VII. Difference of Fatty Acid Methyl Ester Analyses of Samples of Winter (March) and Summer (June) Milk Fat[a]

Methyl Ester[b]	Weight %		Difference, %
	Winter	Summer	
4:0	3.5	3.6	+0.1
6:0	1.4	1.3	−0.1
8:0	1.1	0.9	−0.2
10:0	2.7	2.4	−0.3
12:0	3.9	2.7	−1.2
14:0	12.7	9.8	−2.9
16:0	34.4	25.4	−9.0
16:1	1.3	0.9	−0.4
18:0	11.6	15.8	+4.2
18:1 cis	19.9	24.3	+4.4
18:1 trans	2.5	6.4	+3.9
18:2 + 3	1.5	1.9	+0.4

[a] Data from Patton *et al.* (*30*).
[b] Minor components not reported.

Table VIII. Weight and Per Cent Distribution of Major Fatty Acids Present in a Winter and a Summer Ration Adequate to Meet the Needs of a Typical Cow

	Summer Ration		Winter Ration	
Fatty Acid	Grams	%	Grams	%
16:0	33.9	10.1	28.6	8.2
18:0	6.3	1.9	7.8	2.1
18:1	82.0	24.5	43.2	11.9
18:2	79.0	23.6	123.0	34.0
18:3	132.7	39.0	158.8	43.0
Total	333.9		362.4	

believed that the udder absorbs large quantities of triglycerides from the plasma (*16, 17, 40*). The contribution of other lipide fractions, like phospholipides and cholesterol esters, to milk fat, or the role they play in lipide transport, have yet to be established. However, the report of Riis, Luick, and Kleiber (*34*) indicates that approximately 50% of the butterfat carbon arose from one or another of the plasma lipide classes.

Recent work in this laboratory (*26*) on the structure and composition of blood triglycerides and milk fat in the same animal indicates that, if blood triglycerides contribute to milk fat, there must be a rearrangement of fatty acids on the glycerol which changes the pattern of fatty acid positioning. In the blood triglycerides and depot fats of the ruminant, oleic acid tends to be concentrated on the C-2 or middle position of glycerol, while in milk fat, palmitic acid is concentrated in this position with oleic acid being concentrated on the terminal carbons.

Information on lipide metabolism in the ruminant is inconclusive. With the advent of silicic acid chromatography and gas chromatography, we have obtained good measures of the lipide classes and fatty acids present in the feed, digestive tract, blood, depot fats, and milk fat. However, the integrated relationship of these various components is not yet understood. What is the source of blood lipides? What factors control and influence their composition? What fractions and to what extent do these lipides contribute to milk fat synthesis? What role is played by the liver and adipose tissue in lipide metabolism? These are but a few of the questions which need answers.

Although present knowledge is limited, one can look at a few of the factors apparently influencing lipide metabolism and thus the composition of milk. Cod liver oil feeding has been known for sometime to cause a decrease in the fat test and a reduction in the short chain acids present in milk. Hilditch (*19*) proposed that the unsaturated fatty acids of the C_{20} and C_{22} series were responsible for exerting a poisoning effect on the mammary enzyme systems. Shaw and Ensor (*38*) explained this phenomena when they demonstrated that the feeding of cod liver oil or linoleic acid altered the rumen microorganism population which caused a shift in VFA production. Less acetic acid and more propionic acid were produced; thus the effect is essentially the same as described earlier for the exotic diet.

The exotic diet itself may affect lipide metabolism by altering rumen hydrogenation of dietary fatty acids. The analysis of milk fat from a cow receiving this diet showed 8.6% linoleic and 2.3% linolenic acids. Such relatively high levels of these acids are usually not found in any tissues of the ruminant. The question arises as to their source. A higher proportion of these acids may be escaping rumen hydrogenation. This would be supported by the fact that the depot fat of steers fed these rations had a higher iodine number than those on normal diets (*39*).

The difference between fatty acid composition of winter milk fat and that produced when animals are fed on pasture is presented in Table VII (*30*). There is an increase in C_{18} fatty acids, both saturated and unsaturated, and a corresponding decrease in palmitic and shorter chain acids. The reason for this compositional change has been explained by an increase in dietary unsaturated acids. However, calculations on the quantity and nature of the fatty acids in a winter and summer feeding regime, which would adequately meet the needs of a typical cow, show that it is possible for the winter ration to contain actually more unsaturated C_{18} acids (Table VIII). The explanation may be that the succulent, less-fibrous forage alters rumen fermentation sufficiently to decrease hydrogenation. However, the increased concentration of *trans*-9-octadecenoic or elaidic acid in milk fat is indicative of an increased hydrogenation of dietary unsaturated acids in the rumen.

The quantitative contribution to lipide metabolism of the bovine by the synthesis of lipides from nonlipide precursors by rumen microorganisms has not been investigated. Apparently, they are the source of some of the odd carbon number acids which appear in milk fat. The report of Gerson *et al.* (*15*) indicates that the odd carbon fatty acids can also be synthesized in the mammary gland from propionate and acetate. Studies on lipide metabolism of the rumen microorganisms would certainly seem to be warranted.

The mammary gland will use many substances, if they are presented in a suitable manner. Tove (*44*) showed that intravenous infusion of cottonseed oil could raise the linoleic acid content of milk fat to 14%. Likewise, intramammary infusion of *n*-pentadecanoic acid in this laboratory demonstrated a marked secretion of this acid in the triglycerides of milk fat.

Conclusion

It was not the object of the foregoing discussion to provide a critical review of rumen physiology or bovine metabolism. Rather, information was selected which, in the judgment of the author, reflects the trends in the field. Unpublished data and speculation were included. The major purpose was to point out the dependence of bovine milk secretion on rumen activity, and to stress that the evaluation of any feeding regime must consider the reactions which occur in the rumen. Future progress in this area depends on gaining more fundamental information on the metabolism of the rumen microorganisms, the metabolism of the animal organism, and the interrelation of the two.

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SEED POLYSACCHARIDES

New Sources of Seed Mucilages

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An extensive search for potential industrial raw materials from plants not now under cultivation is under way by the U. S. Department of Agriculture (*12*). This paper reports the first phase of a survey of seeds for their content of water-soluble polysaccharides. Aside from guar and seaweed products, no industrial mucilages of consequence are produced from domestic plants. Guar gum, from the seed of a leguminous annual, has become widely accepted within the last decade; but only a minor fraction of the total consumption comes from domestic sources. Since many mucilages such as gum arabic or gum tragacanth, are imported, hand-picked plant exudates, the supply is often erratic. In this paper the terms mucilage and gum are used interchangeably.

Anderson (*1*) reported a survey of legume mucilage sources in 1949, but there has been no general search among plant seeds. The distribution of known mucilages is discussed in a recent monograph (*9*). Nearly all the seeds of the 175 species in 26 plant families examined in this study were from herbaceous annuals, mostly wild plants not cultivated in the United States or elsewhere.

Materials and Methods

Seed samples were from the same sources used by Earle *et al.* (*5*) in their search for new industrial oils. Samples

[1] Deceased.