Role of Fat in Flavor of Cheddar Cheese[1]

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Abstract

The flavor of Cheddar cheese made from various kinds of fats homogenized into skim milk was compared with cheese made from natural milk emulsion. Milk fat homogenized into skim milk gave better flavors than other fats but was inferior to the natural milk emulsion. Commercial fats with composition and physical properties similar to milk fat seemed to give off-flavors during cheese ripening and performed less well than an inert mineral oil. Deodorized milk fat was not significantly different from milk fat in flavor production. Adding dimethyl sulfide and milk-fat-globule membrane material did not significantly improve cheese flavor. The addition of gum acacia as an emulsifying agent made the flavor more Cheddar-like, indicating that the water-fat interface is important in development of Cheddar flavor.

Introduction

In spite of many studies (3, 11, 13, 17), the role of fat in the flavor of Cheddar cheese has not been fully elucidated. Cheese made like Cheddar from skim milk has an abnormal texture and flavor (8, 12, 14). Lawrence (9) reported that Cheddar cheese made from skim milk and triundecanoin or triheptanoin gave typical Cheddar flavors. Kristoffersen et al. (7) reported that a soy-cottonseed oil blend and hydrogenated soybean oil, but not sunflower oil, could be substituted for milk fat in Cheddar cheese and give acceptably flavored products, but milk fat gave a superior flavor. Law et al. (8) reported that cheese made from skim milk and milk fat was indistinguishable from whole milk Cheddar cheese if the milk fat was homogenized into the skim milk at low pressures so that lipolysis did not occur.

Short-chain fatty acids, which may arise from lipolysis of milk fat, play a significant role in the flavor of Cheddar cheese (6, 14, 15). Such acids would not be produced from most animal and vegetable fats. Milk fat is also unique in containing precursors of methyl ketones and lactones, which are important to flavors of some dairy products (1, 4, 10, 16, 19).

Because of the price structure of dairy products and possible demand for low-fat cheeses or cheeses containing fats richer in polyunsaturated fatty acid, there is considerable interest in cheeses made with altered fat composition. Our experiments were to elucidate the role of milk fat in the characteristic flavor of Cheddar cheese.

Methods

Cheese was made in 200 kg vats at the Dairy Products Laboratory, Food Technology Department, Iowa State University, by using 102 Kg of milk per vat according to the procedure of Wilson and Reinbold (20).

Milk and skim milk were pasteurized at 62.8 C for 30 min. To introduce fat into the skim milk, the skim milk was heated to 43.5 C and fed, along with the desired fat, into a single-stage homogenizer operated at 35 Kg/cm^2 pressure. The homogenized milk was collected in 38 liter cans and cooled immediately in a brine tank. The milk was converted into cheese the following day.

Milk fat was prepared by melting sweet, unsalted butter in a 40 C bath with an equal volume of distilled water. The milk fat was isolated by centrifugation in a Westfalia LWA 205 separator. The milk fat was washed three times with an equal volume of water to remove milk solids.

Deodorized milk fat was prepared by steam distillation at 190 C and 1 to 10 μ Torr for 5 h. The distillate was collected in liquid-nitrogen-cooled traps. Appropriate aliquots of the distillate were homogenized with skim milk and deodorized milk fat to test the effect on the flavor of Cheddar cheese.

Kaola and Kaomel were obtained from the Durkee Famous Foods Company, Chicago, Illinois. The fatty acid composition reported for

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TABLE 1. Fatty acid composition of Kaola and Kaomel.

	Wt %	
Fatty acid	Kaola	Kaomel
6:0	.2	...
8:0	3.1	...
10:0	2.5	...
12:0	18.3	.5
14:0	6.9	.5
16:0	11.2	1.5
18:0	8.4	9.8
18:1	44.0	87.3
18:2	5.4	.2

these fats by the manufacturer is given in Table 1.

The amounts of tributyrin and tricaproin needed to make the fatty-acid composition of Kaola more like that of a typical milk fat were transesterified with Kaola by stirring with .05% sodium methoxide at 60 C under reduced pressure for 1 to 2 h. The resulting oil was washed with sodium carbonate solution and water and passed through a Rotafilm molecular still (A. F. Smith and Co., Rochester, New York) at 25 C and 5-10 μ Torr to remove off-flavors.

A bland mineral oil, No. 13-3988, was obtained from the Mineral Oil Refining Company, Dickinson, Texas.

Buttermilk solids from the State Brand Creamery, Mason City, Iowa, were added to the cheese milk at 1.16% by weight.

Milk-fat-globule membrane material was prepared as follows: Cream was washed once with distilled water and churned. The butter was melted, and the butter serum recovered. Both buttermilk and butter serum were freeze-dried and added to the cheese skim milk during the homogenization step in an amount equivalent to the membrane material in an equal volume of whole milk.

Gum acacia, U.S.P. powder equal to 1.5% of the weight of cheese milk fat was dissolved by heating in a small portion of the milk. The gum acacia solution was added to the cheese milk. Dimethyl sulfide was added to the fat phase at 40 ppm before homogenization.

The cheese was judged for Cheddar flavor at 3, 4, 5, 6, 9, and 12 mo by a panel drawn from a group of 24 judges. At least 13 of the judges were at each tasting. The cheese was brought to room temperature (about 25 C) and judged in booths lighted so the color of the cheese could not influence judgments. The judges were asked to rate the Cheddar-like flavor of the cheese on a scale marked in equal divisions of No, Slight, Moderate, and Pronounced. The judges were told that "pronounced" meant the flavor was "almost identical" to "typical" Cheddar flavor.

The various kinds of cheese were made in 10 experimental groups. Within each group the skim milk for the experiments was common. In most of the 10 experimental groups, milk fat re-emulsified into the skim milk was a control with which other treatments could be compared. The kinds of cheese in each group were: (1) Milk fat, Kaola, Kaomel; (2) Milk fat, Kaola, Kaomel; (3) Milk fat, milk fat plus buttermilk solids, deodorized milk fat, deodorized milk fat plus deodorizer distillate; (4) Milk fat, Kaola, Kaola esterified with tributyrin and tricaproin; (5) Milk fat, mineral oil, mineral oil plus dimethyl sulfide; (6) Milk fat, deodorized milk fat, deodorized milk fat plus dimethyl sulfide, deodorized milk fat plus deodorizer distillate; (7) Milk fat, milk fat plus gum acacia; (8) Milk fat, milk fat plus gum acacia, natural milk emulsion; (9) Kaola, Kaola plus gum acacia, natural milk emulsion; and (10) Milk fat plus fat-globule membrane, milk fat plus heated fat-g'obule membrane, mineral oil plus fat-globule membrane, mineral oil plus heated fat-globule membrane.

Chemical analyses showed that, except for two cheeses with fat-on-the-dry basis (FDB) of 48 and 49%, all experimental cheese contained more than 50% FDB. Cheese moistures were 36% or lower, varying less than 3% within experiments. Salt percentage ranged from 1.5 to 2.1%, but there was little significant variation within experimental groups.

Flavor scores for all experimental groups except experiment 10 were pooled and analyzed by an analysis of variance and multiple comparison of adjusted means according to Snedecor and Cochran (18): $Y_{ijkl} = u + (\text{experiment})_i + (\text{ripening period})_j + (\text{type})_k + (\text{judge})_l + (\text{experiment} \times \text{ripening period})_{ij} + (\text{type} \times \text{ripening period})_{jk} + (\text{error})_{ijkl}$; $i = 9, j = 6, k = 13, l = 24$.

Experiment 10 had no treatment in common with the other groups, so it was analyzed separately by: $Y_{ijkl} = u + (\text{ripening period})_i + (\text{type})_j + (\text{judge})_k + (\text{ripening period} \times \text{type})_{ij} + (\text{error})_{ijk}$; $i = 6, j = 4, k = 16$.

Results

Table 2 shows an analysis of variance of flavor scores in experiments 1 through 9. Experiment number, ripening period, type of fat, judge, experiment × ripening period interaction, and ripening period × type of fat interaction were all significant.

TABLE 2. An analysis of variance of flavor scores for experiments 1 through 9.

Source	df[a]	Mean squares	F[b]
Experiment	8	123.21	20.40[c]
Ripening period	5	35.84	5.93[d]
Type of fat	12	388.56	64.33[c]
Judge	23	67.32	11.15[c]
Exp. × ripening period	40	16.35	2.71[c]
Ripening period × type	60	9.19	1.52[d]
Error	1,517	6.04	

[a] Degrees of freedom.
[b] Variance ratio.
[c] Significant at $P < .01$.
[d] Significant at $P < .05$.

Table 3 shows a comparison of the mean flavor responses for the types of fat in experiments 1 through 9. The significance of differences in the means was determined with the t-test.

Table 4 shows an analysis of variance for experiment 10 where raw and heated milk-fat-globule membrane was used with milk fat and mineral oil. Only ripening period and judges were significant sources of variation.

Fig. 1 and 2 show flavor response vs. storage time curves for some of the types of fat. These flavor responses have been corrected for experiment and judges and are comparable with each other.

Discussion

All types of fat in these experiments yielded cheese with reasonably pleasant flavors, and in agreement with Kristoffersen et al. (7) we believe they might be acceptable to consumers. But, as the results show, all kinds of fat gave cheese with flavors significantly lower in Cheddar-like flavor than conventional Cheddar cheese made with natural milk emulsion. This contrasts with the findings of Law et al. (8), who reported that their panel could not distinguish cheese made with natural emulsion from that made by emulsifying milk fat into skim milk as long as lipolysis was avoided. The differences in our findings and those of Law et al. may be from differences in the cheese-make procedure or flavor evaluation.

Kaola and Kaomel gave significantly lower flavor scores than milk fat, with Kaomel

TABLE 3. Difference in mean Cheddar-like flavor scores for cheese made with various types of fats.

Type[a]	1	2	3	4	5	6	7	8	9	10	11	12
1	...											
2	2.4[b]	...										
3	6.1[b]	3.7[b]	...									
4	2.4[b]	.0	− 3.7[b,c]	...								
5	1.5[b]	− .9	− 4.6[b]	− .9	...							
6	1.6[b]	− .9	− 4.5[b]	− .8	.1	...						
7	1.3[b]	−1.2[d]	− 4.8[b]	−1.1[d]	− .2	− .3	...					
8	.5	−1.9[b]	− 5.6[b]	−1.9[b]	−1.0	−1.1[d]	− .8[d]	...				
9	2.1[b]	− .3	− 4.0[b]	− .3	.6	.5	.8[d]	1.6[b]	...			
10	.4	−2.1[b]	− 5.7[b]	−2.0[b]	−1.1	−1.2[d]	− .9	− .1	−1.7[b]	...		
11	−4.0[b]	−6.4[b]	−10.1[b]	−6.4[b]	−5.4[b]	−5.5[b]	−5.2[b]	−4.5[b]	−6.1[b]	−4.3[b]	...	
12	−1.7[b]	−4.1[b]	− 7.8[b]	−4.1[b]	−3.2[b]	−3.2[b]	−3.0[b]	−2.2[b]	−3.8[b]	−2.1[b]	2.3[b]	...
13	1.1[b]	−1.3[b]	− 5.0[b]	−1.3[b]	− .4	− .5	− .2	.6[d]	−1.0[b]	.7[d]	5.1[b]	2.8[b]

[a] 1, milk fat; 2, Kaola; 3, Kaomel; 4, Kaola + tributyrin and tricaproin; 5, mineral oil; 6, mineral oil + dimethyl sulfide; 7, milk fat + buttermilk solids; 8, deodorized milk fat; 9, deodorized milk fat + distillate; 10, deodorized milk fat + dimethyl sulfide; 11, whole milk cheese; 12, milk fat + gum acacia; and 13, Kaola + gum acacia.
[b] Significant at $P < .01$.
[c] Minus means the fat type in the vertical column scored lower than that in the horizontal row. No sign means the fat type in the column scored higher than that in the row.
[d] Significant at $P < .05$.

TABLE 4. An analysis of variance of the experiment 10 flavor scores (Milk fat and mineral oil with heated and unheated fat-globule membrane material.)

Source	df[a]	Mean squares	F[b]
Ripening period	5	26.26	4.87[c]
Type	3	7.85	1.46
Judge	15	21.19	3.93[d]
Ripening period × type	15	7.67	1.42
Error	181	5.39	

[a] Degrees of freedom.
[b] Variance ratio.
[c] Significant at $P < .05$.
[d] Significant at $P < .01$.

being significantly lower than Kaola. Kaola has a fatty-acid composition more like milk fat than does Kaomel, but esterification of tributyrin or tricaproin into Kaola to make it more like milk fat did not improve it. Mineral oil, which is bland and which furnishes no fatty acids at all, performed better than Kaola but not as well as milk fat.

The relatively good performance of mineral oil agrees with the findings of Lawrence (9) and suggests that one role of fat in the development of Cheddar flavor is to act as a reservoir for fat-soluble flavor compounds and perhaps to furnish a water-lipid interface. Kaola and Kaomel probably give poorer flavors than mineral oil because these fats give

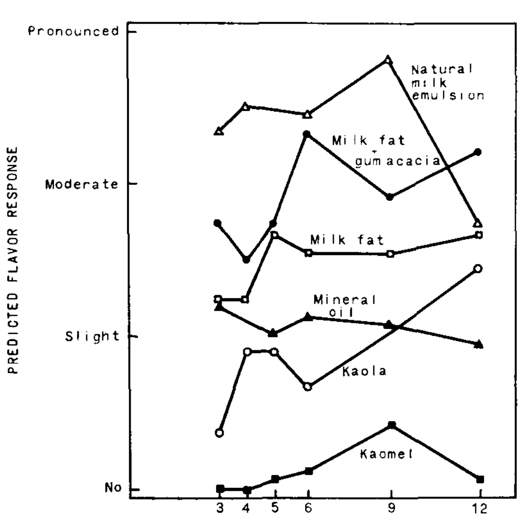

FIG. 1. Cheddar flavor response vs ripening period. Pronounced is identical to typical Cheddar flavor. The flavor response has been corrected for the effect of experimental group and judges.

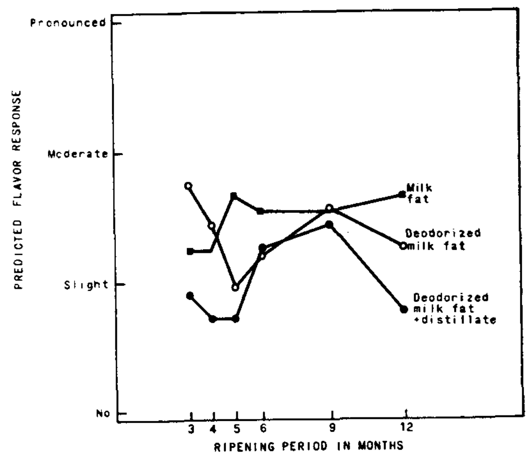

FIG. 2. Cheddar flavor response vs ripening period. Pronounced is identical to typical Cheddar flavor. The flavor response has been corrected for the effect of experimental group and judges.

rise to flavors not normal to Cheddar cheese during ripening. The original fat and fresh curd are bland.

It is not clear from these experiments whether short-chain fatty acids of milk fat play a significant role in the development of Cheddar flavor. Milk fat might perform better than mineral oil because it contains short-chain fatty acids. Perhaps Kaola, which also contains short-chain fatty acids, would approach milk fat in performance and surpass mineral oil if it did not contain some off-flavor precursor.

Milk fat also contains precursors of lactones and methyl ketones that may play a role in the flavor of Cheddar cheese. These flavor compounds can be released and removed from milk fat by steam distillation (4, 5). Deodorized milk fat gave flavor scores lower than those of undeodorized milk fat, but the differences were not statistically significant. When the deodorizer distillate, which should contain the methyl ketones and lactones of the milk fat, was added back to the cheese, the Cheddar-like flavor was significantly decreased. The distillate seemed to impart an abnormal flavor to the cheese. These results do not demonstrate a significant role for compounds released from milk fat by steam distillation in the flavor of Cheddar cheese but rather indicate that too complete a release of the flavors from their precursors, or the development of some off-flavor during steam distillation, causes an abnormal flavor in Cheddar cheese.

The cheese made with milk fat did not

have a pronounced Cheddar-like flavor. Some judges felt that one of the missing characteristics was a sulfur flavor. Milk normally contains a small amount of dimethyl sulfide (2). An amount of dimethyl sulfide considerably in excess of that in milk was added to deodorized milk fat and mineral oil but results of adding dimethyl sulfide were not significant.

We postulated the reason that cheese made from natural milk emulsion was better than that made with milk fat was because the milk-fat-globule membrane material, which was removed in the preparation of the milk fat, had important enzymes or other factors that played a role in the development of Cheddar flavor. Cheese was made from milk fat with buttermilk solids added and with heated and unheated milk-fat-globule membrane material emulsified with milk fat and mineral oil. The buttermilk solids decreased the amounts of Cheddar-like flavor apparently because they imparted a stale flavor to the cheese. The analysis of variance of experiment 10 showed that the effect of type of lipid and membrane material was not significant. This means that the effect of heating the membrane material or of using milk fat vs. mineral oil could not be distinguished in this experiment. Experiment 10 contained no treatment common to the other experiments so direct comparisons were not possible, but flavors were in the same range as those for cheese made with milk fat.

Another possible explanation for the difference in natural milk emulsion and milk fat cheese is that the interface between the lipid and aqueous phase in the cheese was important in flavor development. We cannot be sure that the membrane material homogenized into the cheese milk ended up unaltered in the interface. Gum acacia, an agent for preparing oil in water emulsions, was added to the cheese milk before homogenization. This agent significantly improved the flavor of the cheese. Gum acacia also significantly improved the flavor of cheese made with Kaola but did not bring it up to milk fat without gum acacia. We cannot be sure that the gum acacia was concentrated in the fat-water interface, but these results suggest that the interface between the fat and water phases is important in the development of Cheddar cheese flavor. The reason for this is obscure.

Besides the large effect caused by the type of fat, Table 2 shows statistically significant flavor effects that can be attributed to judges and ripening period, as might be expected. The significant effect caused by experimental group is probably caused by seasonal changes in the milk and the greater uniformity in composition of the cheese within experimental groups. These sources of variation also probably account for the small but significant experiment × ripening period interaction. The significant ripening period × type of fat interaction is attributable to the decrease in flavor score at 12 mo in certain types of cheese in Fig. 1 and 2.

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References

(1) Day, E. A., R. Bassette, and M. Keeney. 1960. Identification of volatile carbonyl compounds from Cheddar cheese. J. Dairy Sci. 43:463.
(2) Dunham, J. R., G. Ward, R. Bassette, and M. C. Reddy. 1968. Occurrence of methyl sulfide in milk from cows fed fresh, dried, or stored alfalfa. J. Dairy Sci. 51:44.
(3) Forss, D. A., and S. Patton. 1966. Flavor of Cheddar cheese. J. Dairy Sci. 49:89.
(4) Kinsella, J. E., S. Patton, and P. S. Dimick. 1967. The flavor potential of milk fat. A review of its chemical nature and biochemical origin. J. Am. Oil Chem. Soc. 44:449.
(5) Kontson, A., A. Tamsma, F. E. Kurtz, and M. J. Pallansch. 1970. Method for separating volatiles from steam-deodorized milk fat into lactones, free fatty acids and nonacidic compounds. J. Dairy Sci. 53:410.
(6) Kristoffersen, T., and I. A. Gould. 1958. Characteristic Cheddar cheese flavor in relation to hydrogen sulfide and free fatty acids. J. Dairy Sci. 41:717. (Abstr.)
(7) Kristoffersen, T., W. J. Harper, and T. E. Roth. 1971. Fat modified cheese. Page 36 *in* Dairy and Ice Cream Field (Nov.), 57.
(8) Law, B. A., M. E. Sharpe, H. R. Chapman, and B. Reiter. 1973. Relationship of milk fat globule membrane material to flavor development in Cheddar cheese. J. Dairy Sci. 56:716.
(9) Lawrence, R. C. 1967. The possible role of milk fat in the formation of Cheddar cheese flavor. N. Z. J. Dairy Technol. 2:55.
(10) Liebich, H. M., D. R. Douglas, E. Bayer, and A. Zlatkis. 1970. The volatile components of Cheddar cheese. J. Chromatogr. Sci. 8:355.
(11) Mabbitt, L. A. 1961. The flavor of Cheddar cheese. J. Dairy Res. 28:303.
(12) Mabbitt, L. A., and M. Zielinska. 1956. Flavor production in Cheddar cheese. 14th Int. Dairy Congr. Rome. 2:323.
(13) Marth, E. H. 1963. Microbiological and chemical aspects of Cheddar cheese ripening. A review. J. Dairy Sci. 46:869.

(14) Ohren, J. A., and S. L. Tuckey. 1965. Relation of fat hydrolysis to flavor development in Cheddar cheese. J. Dairy Sci. 48:765. (Abstr.)
(15) Ohren, J. A., and S. L. Tuckey. 1969. Relation of flavor development in Cheddar cheese to chemical changes in the fat of the cheese. J. Dairy Sci. 52:598.
(16) O'Keefe, P. W., L. M. Libbey, and R. C. Lindsay. 1969. Lactones in Cheddar cheese. J. Dairy Sci. 52:888. (Abstr.)
(17) Reiter, B., T. F. Fryer, M. E. Sharpe, and R. C. Lawrence. 1966. Studies in cheese flavor. J. Appl. Bacteriol. 29:231.
(18) Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. 6th ed. Iowa State University Press, Ames.
(19) Walker, J. R. L. 1961. Some volatile compounds in New Zealand Cheddar cheese and their possible significance in flavor formation: IV. The addition of flavor compounds to cheese curd to simulate Cheddar flavor. J. Dairy Res. 28:1.
(20) Wilson, H. L., and G. W. Reinbold. 1965. American cheese varieties. Pfizer Cheese Monographs. Vol. II. Chas. Pfizer and Co., Inc., New York.