Journal of Food Protection Vol. 43, No. 6, Pages 441-446 (June, 1980)

Yield and Curd Characteristics of Cottage Cheese Made by the Culture and Direct-Acid-Set Methods[1]

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(Received for publication August 31, 1979)

ABSTRACT

We compared yield and curd characteristics of cottage cheese made by the short-set culture and direct-acid-set methods using three skim milk protein concentrations, 3.1, 3.5 and 3.9 ± .1%. For each method of manufacture, approximately 380 kg of the same skim milk were set per experimental vat. Representative samples of whey, wash water and curd were analyzed and the total quantities of each were measured. Solids and protein recovered in whey, wash water and curd were related to yields for each method. The same curd samples also were used to measure curd size distribution, curd firmness and dressing retention. Analysis of variance showed highly significant differences in curd yield between the two methods when the three protein concentrations were considered. There was approximately 5% more yield when cottage cheese was made from skim milk containing 3.1 or 3.5% protein, using the direct-acid-set method. This yield advantage was less than 1% when the skim milk contained 3.9% protein. Curd firmness did not differ significantly between methods ($p < .01$). Curd from the 3.1% protein-skim milk, however, was firmer ($p < .01$) than that from either 3.5 or 3.9% protein-skim milk. Direct-acid-set curd was more uniform in size than that of the short-set culture curd. It retained dressing better only when made from 3.1% protein skim milk, and when 1.25 × the normal amount of dressing was used.

Mabbitt et al. in 1955 (*15*) reviewed early attempts to make cheese by substituting acidulants for bacterial starters. They also used lactic or hydrochloric acid or gluconic acid lactone to manufacture Cheddar or Cheshire-type cheese. Deane and Hammond in 1960 (*5*) used D-glucono-delta-lactone and mesolactides in manufacturing cottage cheese. These compounds hydrolyze slowly in solution to produce acids. When added to milk, they induce a characteristic coagulum while the milk remains quiescent. Hammond and Deane patented that process in 1961 (*13*). In 1963, Ernstrom patented a process for cottage cheese using hydrochloric acid in place of the more expensive gluconolactone (*8*). Then in 1971 Corbin (*2*) developed and patented a batch procedure using phosphoric acid as the initial and partial acidulating agent and D-glucono-delta-lactone for final milk acidification. This batch process was approved as another method of manufacture in the Standards of Identity for Cottage Cheese Dry Curd (*9*).

Vitex-American Laboratories introduced an in-line acidification system similar to Corbin's patented method (Vitex 750-850 system™)[1], based on a modification of the Hammond-Deane patent (*10,20*). This process, which involves continuously metering Vitex 750™ into the cold milk instead of adding the acidulant in batch, has been accepted commercially by some plants. Gerson (*11*) predicted that 8-10% of cottage cheese made in the U.S. would be made by the direct-set method by the end of 1977, and later estimated (*12*) that about 17% of the market of cottage cheese now manufactured in the U.S.is made by the direct-set method.

Replacing the starter culture method with a direct-set method eliminates the possible problems of bacteriophage, antibiotics and slow cultures, and at the same time reduces the manufacturing time by almost half. Such a process, however, must yield a quality product and be economical.

White and Ray (*22*) reported lower yields for cottage cheese made by the direct acidification method than by other methods when yields were expressed as curd per kilograms of solids, disregarding moisture content of the curd. Lower yield for the direct acidification method, however, reflected more total solids in the curd. Although the yields were lower, solids recovered were similar for the direct acidification and continuous fermentation methods and as high or higher than from other methods when curd solids were adjusted to 20%. High curd solids reported by White and Ray do not appear to be characteristic of the direct-acid-set method and may have reflected overcooking.

Recently Satterness et al. (*19*) compared the direct-set method and the culture method, using an experimental design similar to the one reported in this paper. It differed, however, in the following ways: we standardized the protein content in the skim milk, they did not; we used in-line acidification for initial acidification of cheese milk, whereas they used a batch system. In addition, we compared a number of cottage-cheese curd properties from the two methods.

Satterness et al. (*19*) compared the direct-set and culture methods with three types of milk: fresh, fortified and reconstituted skim milk. They found no significant ($p < .05$) difference in yields but the direct-set method yielded significantly less curd fines.

We compared yields and properties of cottage cheese made by the culture and the direct acidification methods at each of three protein concentrations in skim milk.

[1]*Contribution No. 78-410-J, Department of Animal Sciences and Industry and Statistics, Kansas Agricultural Experiment Station, Kansas State University, Manhattan 66506.*

MATERIALS AND METHODS

Experimental design

Raw skim milk with 3.1, 3.5, or 3.9 ± .1% protein was pasteurized, divided into two lots and manufactured into cottage cheese by the culture and direct-acid-set methods on the same day. Nine replicate pairs of each skim milk protein concentration were made into cottage cheese over 2 to 3 months and the two methods compared for yields and curd characteristics. The six treatment combinations were analyzed as a split-plot design with error (*a*) mean squares equal to replication within protein and error (*b*) mean squares estimated from residual variation.

Manufacturing methods

Milk for the 3.1% protein concentration was collected from the Kansas State University dairy herd. The 3.5 and 3.9 ± .1% protein milks were obtained by blending milks from the Kansas State University herd and a local Guernsey herd. Milk was separated and pasteurized (72.5 C/16 sec) in the Kansas State University dairy on the day received, held at 2 to 5 C, and made into cottage cheese the next day. The two cheese vats used were 378.5-liter (100 gal) and 757-liter (200 gal) capacity, and were alternated between the two methods throughout the study. Approximately 380 kg of skim milk was set in each vat.

Culture cottage cheese was made by the short-set method using 5% Hansen's Culture #56. Vitex Cottage Cheese Coagulator was added in the amount of 5.8 ml/100 kg of skim milk, and the curd was cut with 9.5-mm curd knives according to a positive AC test at pH about 4.7. Cooking procedures were essentially as described by Emmons and Tuckey (*7*). Final cooking temperatures varied from 47-57 C. Tap water was added to cool the curd to 27 C for the first wash and acidified (pH 4.5) chlorinated (10 ppm) ice water (4.5 C) was added to chill the curd to 7 C. In each instance whey or wash water was collected, measured and while thoroughly mixing, sampled. After the second wash the curd was drained until the drain rate reached 1 ml per min per 3.78 liters of skim milk set. After thoroughly mixing, samples of curd were collected for analysis and testing.

Direct-acid-set cottage cheese was made according to Vitex/American procedures (*20*). We added a prepared food-grade acid mixture, Vitex 750^{1M}, thru an in-line mixer directly to 2 to 5 C pasteurized skim milk to adjust the pH to 5.1 ± .15. The milk was heated to 32 C and based on the pH and weight of milk a measured amount of D-glucono-delta-lactone (Vitex 850^{TM}) and the Vitex coagulator (13 ml/100 kg skim milk) were added. The acidified milk was mixed thoroughly and maintained at 32 C for 1 h. After cutting the curd, approximately 89 ml of Vitex 750 per 378.5 liters of skim milk was added to adjust the pH of the whey to 4.4-4.5. Cooking, draining and sampling were the same as with the culture method.

Analytical procedures

Skim milk was measured by volume in the vats with a dip stick and curd was weighed on the creamery scales. Solids were determined gravimetrically (*5*); both total protein and casein were determined by AOAC methods (*1*). Curd size was measured by the method of Kosikowski (*14*), and curd fines by the method of Raab et al. (*18*). Curd firmness was determined by the method of deMan (*16*), using a Kramer Shear Press and expressed as shear value in kg/100 g of curd and dressing retention by a modification of the method of Emmons and Price (*6*). This modification involved first adjusting curd to 20% solids by draining a measured weight of whey from known amounts of curd that had previously been analyzed for total solids and dressing 100 g curd with 44, 55, 66 or 88 g of 14% fat-dressing containing sufficient salt to give 1% in the final product. The salted dressing and curd were mixed and stored in a closed carton at 5 C for 24 h. The mixture then was remixed and transferred to a circular 8-mesh screen placed horizontally in a 15-cm funnel to hold the cheese. Sheets of aluminum foil were used to cover the curd to minimize drying while dressing drained into tared 100 ml cylinders. After 30 min, the cylinders were reweighed and amounts of dressing retained calculated by difference and expressed as percentage of added dressing.

RESULTS AND DISCUSSION

Curd yields

The direct-acid-set method of making cottage cheese produced higher average yields ($p < .001$) than the culture method when expressed as kg of curd per 100 kg of skim milk, per kg of protein, per kg of casein, or per kg of total solids (see Table 1).

Increasing the protein concentration in the skim milk increased yields ($p < .001$) when based on 100 kg of skim milk and means of the two methods were combined. When comparing yields as kg of curd per kg of protein or kg of total solids, yield means from the 3.5 and 3.9% protein skim milk did not differ; however, the yield from 3.1% protein skim milk was lower ($p < .01$), (Table 1).

TABLE 1. *Analysis of variance and mean for curd and solids recovery.*

		Mean square							
		Curd recovered per				Solids recovered in			
Source of variation	df	100 kg of skim milk	kg of protein	kg of casein	kg of solids	Whey	1st wash	2nd wash	Curd
Protein	2	86.36***	.268**	.014	.3736***	231.6***	.728	1.816	151.701***
Rep/prot.	24	.68	.045	.070	.0061	17.5	12.674	2.282	2.569
Method	1	2.58***	.210***	.465***	.0315***	312.2***	159.412***	18.680***	11.612***
Method × protein	2	.52	.037	.110*	.0064*	39.5	14.332	.611	2.442
Residual	24	.16	.015	.021	.0014	13.4	6.117	1.394	.807
		Means (%)							
Method									
Culture		16.41	4.68	Because interaction is		45.17	9.35	4.73	35.34
Direct-set		16.84	4.81	significant, see Table 4 for		49.98	12.79	5.91	36.27
		(.225)[1]	(.070)	the protein, protein ×		(2.05)	(1.39)	(.663)	(.505)
Protein (%)				method means					
3.1		14.36	4.60			51.68	11.03[a]	5.62[a]	32.70
3.5		16.78	4.81[a(2)]			46.01	11.28[a]	4.99[a]	36.27
3.9		18.73	4.82[a]			45.03[a]	10.89[a]	5.35[a]	38.45
		(.575)	(.146)			(2.88)	(2.45)	(1.05)	(1.10)

*Significant at 5%
**Significant at 1%
***Significant at 0.1%
[1]$LSD_{.05}$ are bracketed.
[2]Means not significantly different at the 5% level are joined by a common letter.

Yields did not differ at the three protein concentrations when based on kg curd/kg casein; this merely reflects the correlation between casein and yield of cottage cheese. Individual average yields for both methods and each concentration of protein are presented in Table 4.

Figure 1 illustrates the effect of method and skim milk-protein concentration on yield. The nearly parallel lines of the two methods between 3.1 and 3.5% protein represent a similar rate of increase in curd yield for the two methods from increased protein concentration in the skim milk. The direct-set method produced approximately a 5% greater yield than the culture method for normal mixed herd milk (3.1 or 3.5% protein). We cannot explain the convergence of the lines (Fig. 1) representing a loss in advantage of yield in the high-protein (3.9%) milk. From a practical point of view, however, this is of little consequence with today's milk supply.

In comparing yields by the two methods and at protein concentrations of 3.1 and 3.5%, differences were more distinct (Table 2) than when all three protein concentrations were considered. The direct-set method produced higher yields ($p < .001$) than the culture method for all four methods of expressing yields. Those from 3.5% protein-skim milk were higher ($p < .001$) than from 3.1% protein except when expressed as kg curd/kg casein. The method × protein interaction that occurred with the three protein concentrations (Table 1) disappeared when only the two protein concentrations (Table 2) were considered.

Satterness et al. (*19*), in comparing cottage cheese yields obtained using the culture and direct-set methods and fresh skim milk containing an average 3.04% protein, reported no difference ($p < .05$) due to method. In our study, the yield differences ($p < .001$) between these two methods from skim milk containing 3.1 ± .1% protein reflected less variability than did data of Satterness et al. among replicates.

Factors contributing to uniformity among our replicates were protein standardization and in-line acidification of the skim milk. Because protein concentrations in skim milk contribute to cottage cheese yields, we standardized milk into three groups: 3.1, 3.5, and 3.9 ± .1% protein. In-line acidification, in which the initial acidulating agent is metered into the milk at a constant rate, is an improvement over the batch addition of acid and probably reduces variability. Certainly the relatively large volume of milk we set, 380 kg, tended to reduce variations due to small errors in measurements. These factors contributed to precision and the small variability among replicates.

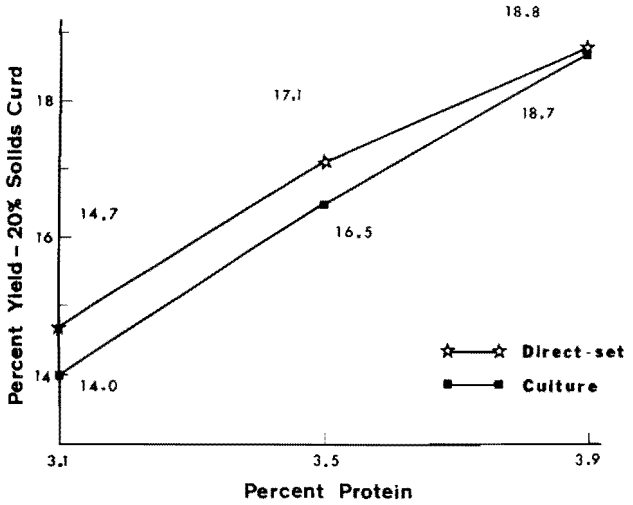

Figure 1. *Average yields of cottage cheese by culture and direct-acid methods from skim milks containing three protein concentrations.*

TABLE 2. *Analysis of variance of yields between two methods of making cottage cheese at each of two protein concentrations.*

Source variation	d.f.	Mean squares of curd recovered per 100 kg of skim milk	kg of protein	kg of casein	kg of solids
		Mean square kg			
Protein	1	52.80***	.386***	.027	.273***
Rep/prot.	16	.330	.018	.043	.002
Methods	1	3.61***	.283***	.672***	.044***
Methods × Protein	1	.00	.000	.012	.000
Residual	16	.100	.014	.017	.001
		Means[1]			
Methods					
Culture		15.25	4.62	6.19	1.69
Direct-set		15.89	4.79	6.46	1.76
		(.225)[2]	(.084)	(096)	(.021)
Protein					
3.1%		14.36	4.60	6.30[a]	1.64
3.5%		16.78	4.81	6.35[a]	1.81
		(.405)	(.091)	(.146)	(.033)

***Significant at 0.1%

[1]Means not significantly different at the % level are joined by a common letter.

[2]$LSD_{.05}$ are bracketed.

The yield means by the two methods in both of these studies were remarkably similar. Our yields expressed as kg of curd/100 kg of skim milk were 14.04 and 14.68 for culture and direct-set, respectively, and theirs (*19*) were 15.25 and 15.94. Our difference between methods was .64, and theirs (*19*) was .69--both in favor of the direct-set method.

The high fat content in skim milk used by Satterness et al. (*19*) resulted in an excess fat recovered in the curd. This contributed to 1 to 2% higher yields for both methods from fresh or fortified skim milk. Fat in the cheese curd was 1.68 to 2.46%; whereas, the fat content of uncreamed curd would be less than 0.4% (*21*) from efficiently skimmed cheese milk.

Total solids recovery

A total solids and protein accountability study was designed to help explain difference in yields. The acids added, Vitex 750TM, Vitex 850, and GDL contributed to the solids in the whey and wash waters but probably only to a small degree in the curd. Table 1 presents these solids recovery data without including GDL as part of the total milk solids used. Partial accountability was made for the Vitex 750TM because the volume measurement used in the vat included the liquid acid added. The

added acidulants are reflected in our results for solids recovered in direct-set whey and wash waters (Table 1). Milk solids both with and without GDL were used to calculate total solids distributed in whey, wash waters and curd, as shown in Table 4a. When GDL was considered as part of the milk solids entering the vat, total solids in the whey, wash waters and curd were lower.

Table 1 shows that more milk solids were recovered in the curd by the direct-acid method than by the culture method ($p < .001$). This probably reflected less protein lost in the whey by the direct-acid-set method (Table 3). Differences in solids recovered in the curd were greater from 3.1 and 3.5% protein skim milk than from 3.9% (see curd less GDL, Table 4a).

Increasing the protein in the skim milk (3.1, 3.5, and 3.9%) decreased solids lost in the whey and increased solids recovered in the curd when means for the two methods were combined ($p < .001$). Total solids lost in the first and second wash did not differ ($p < .01$) at each protein concentration.

Protein recovery

Results of protein accountability are presented in Table 3. Protein recoveries distributed among wash water and curd by the two methods and for the three protein concentrations did not differ significantly ($p < .01$). More protein, however, was lost in the whey by the culture than the direct-set method ($p < .05$). Increasing protein in the skim milk (3.1 and 3.5%) reduced protein lost in the whey ($p < .01$) when means for the two methods were combined. Protein lost in the whey, however, did not differ when the protein level was increased to 3.9%.

Curd size distribution

Curd size distribution for each protein concentration and for the two methods is shown in Table 4b, and results of the statistical analysis for the large and small curd particles (eg. those retained on 12.7 mm (½ inch) and 1.4 mm (1/18 inch) sieves, combined) are presented in Table 3. Particle sizes are important because they indicate problems with cheese manufacture. Small curd particles, those deposited on a 1.4-mm sieve, are called "grit." A high grit value is undesirable in cottage cheese because it indicates curd shattering and poor yields (3). Particles retained on a 12.7-mm sieve indicate matting, more common to the culture than the direct-set method. A combination of curd particle sizes distributed on 12.7-mm and 1.4-mm (1/2 + 1/18 inch) sieves was chosen because matting may be associated with shattering (resulting from excessive agitation necessary to break lumpy curd). Table 3 shows more large and small curds from the culture (8.09) than from the direct-acid method (5.85) ($p < .05$). Because skim milk for both methods was identical, and the personnel involved in making the cheese were the same, the method must account for difference in the curd particle size. Lower mean values for the combined particle sizes for the 12.7-mm and 1.4-mm sieves for the direct-acid method ($p < .01$) indicate more uniform curd size. Increasing the percent protein in the skim milk (3.1, 3.5, 3.9%) did not affect the combined curd particle size distribution significantly when the means for the two methods were combined.

Curd fines, firmness and dressing retention

We also measured but found no significant differences between methods for curd fines, curd firmness and dressing retained (Tables 3 and 4b). Only curd made by the direct-set method from 3.1% protein-skim milk retained more dressing ($p < .05$) when 1.25 times the

TABLE 3. *Analysis of variance comparing recovery of protein and properties of curd by the two methods and at the three protein concentrations.*

Source of variation	d.f.	Mean squares: Protein (%) recovered in Whey	1st wash	2nd wash	Curd	Curd properties: Size[1] (%)	Fines[2] (%)	Firmness[3]
Protein	2	26.7**	.067	.859	15.950	12.72	.197	1.9×10^{4}**
Rep/prot.	24	2.7	1.422	.333	6.601	7.160	.111	1.7×10^{3}
Method	1	10.1*	2.003	.254	3.894	68.07**	.002	2.8×10^{2}
Methods × Protein	2	5.6	.987	.189	2.321	5.698	.130	1.2×10^{3}*
Residual	24	1.8	.635	.281	3.943	8.532	.057	2.9×10^{2}
		Means[4]						
Methods								
Culture		15.90	3.30[a]	1.92[a]	77.99[a]	8.09	.62[a]	94.4[a]
Direct-set		15.04	3.68[a]	1.78[a]	78.53[a]	5.85	.63[a]	99.7[a]
		(.832)[5]	(.447)	(.298)	(1.115)	(1.64)	(.134)	(9.57)
Protein (%)								
3.1		16.85	3.55[a]	2.02[a]	77.52[a]	6.70[a]	.51[a]	135.2
3.5		15.01[a]	3.43[a]	1.60[a]	77.94[a]	6.30[a]	.70[a]	76.6[a]
3.9		14.55[a]	3.49[a]	1.92[a]	79.32[a]	7.92[a]	.67[a]	79.3[a]
		(1.129)	(.820)	(.397)	(1.769)	(1.843)	(.228)	(89.6)

*Significant at 5%
**Significant at 1%.
[1]Curd retained by 12.7 mm + 1.4 mm sieves.
[2]Whey and 1st + 2nd wash fines. Percent yield lost as curd fines.
[3]Curd firmness = shear value, kg per 100 g curd.
[4]Means not significantly different at the 1% level are joined by a common letter.
[5]$LSD_{.05}$ are bracketed.

TABLE 4a. *Comparison of means of nine replications for the following combinations of treatments.*

	3.1% Protein		3.5% Protein		3.9% Protein	
	Culture	Direct-set	Culture	Direct-set	Culture	Direct-set
YIELD						
1. Kg curd/100kg skim milk	14.04	14.68	16.48	17.10	18.71	18.76
2. Kg curd/kg protein	4.52	4.69	4.72	4.90	4.81	4.83
3. Kg curd/kg casein	6.14	6.45	6.24	6.47	6.31	6.32
4. Kg curd/kg	1.60	1.67	1.78	1.84	1.92	1.92
TOTAL SOLIDS DISTRIBUTION				(% Recovery)		
1. Whey Less $-GDL_1$	49.92	53.43	44.65	47.37	40.93	49.13
1. Whey $+GDL_2$		49.50		44.57		44.78
2. 1st wash Less $-GDL_1$	8.80	13.26	9.05	13.52	10.20	11.58
2. 1st wash $+GDL_2$		12.27		12.03		10.64
3. 2nd wash Less $-GDL_1$	4.84	6.40	4.42	5.56	4.94	5.76
3. 2nd wash $+GDL_2$		5.93		5.15		5.26
4. Curd Less $-GDL_1$	31.94	33.45	35.69	36.85	38.39	38.50
4. Curd $+GDL_2$		30.98		34.22		34.44

	[a]$LSD_{.05}$	[b]$LSD_{.05}$
Kg curd/100g skim milk	.389	.631
Kg curd/Kg protein	.119	.169
Kg curd/Kg casein	.141	.208
Kg curd/Kg solids	.036	.060

[a]LSD's for comparing methods (culture vs direct-set) *within* protein %.
[b]LSD's for comparing protein % *within* each method.

TABLE 4b. *Comparison of means of nine replications for the following combinations of treatments.*

	3.1% Protein		3.5% Protein		3.9% Protein	
	Culture	Direct-set	Culture	Direct-set	Culture	Direct-set
PROTEIN DISTRIBUTION				(% Recovery)		
1. Whey	17.84	15.86	15.43	14.59	14.43	14.67
2. 1st wash	3.22	3.88	3.10	3.76	3.57	3.41
3. 2nd wash	2.11	1.92	1.56	1.64	2.08	1.77
4. Curd	77.11	77.92	77.40	78.48	79.46	79.18
CURD SIZE DISTRIBUTION				(%)		
1. 1.4 mm (1/18")	5.26	4.03	3.13	2.62	3.72	3.12
2. 2.83 mm (1/9")	67.50	67.91	55.23	56.90	52.21	60.58
3. 6.35 mm (1/4")	25.04	26.14	37.61	37.65	37.44	33.50
4. 12.7 mm (1/2")	2.18	1.91	4.02	2.83	5.96	3.03
1&4. 12.7 mm (1/4")	7.44	5.95	7.16	5.45	9.69	6.15
				(%)		
LOSSESS AS CURD FINES	.529	.485	.602	.807	.732	.605
CURD FIRMNESS[1]	140.4	130.0	74.2	78.9	68.5	90.1
DRESSING RETENTION				(%)		
Normal[2]	84.4	92.0	—	—	—	—
1.25 × Normal	73.2	90.5	—	—	—	—
1.5 × Normal	—	—	86.7	89.2	81.8	75.8
2 × Normal	—	—	68.8	65.6	64.7	61.1

[1]Curd Firmness = shear value, kg/100g curd.
[2]Normal = 44 grams dressing/100 grams curd.

	[a]$LSD_{.05}$	[b]$LSD_{.05}$
Whey	1.305	1.459
1st wash	.775	.987
2nd wash	.516	.539
Curd	1.932	2.234
Fines	.232	.282
Firmness	16.6	30.7

[a]LSD's for comparing methods culture vs Direct-set *within* Protein %.
[b]LSD's for comparing protein % *within* method.

normal amount (44 g of 14% fat dressing/100 g of curd) was used.

ACKNOWLEDGMENTS

This research was supported in part by Diamond Shamrock, Food Division, (Vitex/American) St. Louis, MO.

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