COOLING CUSTARDS AND PUDDINGS WITH COLD-TUBE AGITATION[1]

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This investigation is concerned with the cooling of 4-gal batches of custards and puddings from an initial temperature of 140°F to a final temperature of 60°F, using a rotating cold tube agitator. Variables were: (a) level of egg, (b) level of cornstarch, (c) level of sugar, and (d) rate of cold-tube agitation. Total cooling time decreased as the rate of agitation increased. All but one of the forty-eight mixtures cooled within 3 hr when agitated at 18 rev/min; all but five cooled within 5½ hr. when agitated at 6 rev/min. As the level of egg in the mixture increased the total cooling time decreased. As the level of sugar increased the total cooling time also increased, but the increase in total time was not in proportion to the increase in the level of sugar. In each instance, agitation at 18 rev/min produced a greater increase in radius of spread. Cornstarch was the most significant factor influencing the change in density of the mixtures. There was a greater increase in density value in the mixtures made with the high level of cornstarch than in the mixtures made with the low level of cornstarch. As the level of egg in the mixtures increased, the differences in density value also increased.

The need for cooling large batches of food prior to their refrigeration has been emphasized *(3)*. Hammer *(1)* reported studies on the cooling of cornstarch puddings at room temperature, by agitation using a kitchen mixer. In this laboratory, starch-thickened food items were precooled using cold-tube agitation; the results indicated that efficient cooling of white sauces can be obtained by this method without objectionable changes in consistency *(2)*.

The present investigation is concerned with the cooling of large batches of custards and puddings using the rotating cold-tube agitator described in the earlier publication *(2)*. The aim was to gain information on the heat transfer from mixtures cooled in this manner, and to observe certain quality characteristics of the mixtures which might be affected by this method of cooling.

VARIABLES

Stirred custards and cream puddings were cooled using a rotating cold tube as agitator; refrigerated water flowed through the tube. During the cooling period temperatures were recorded in specified locations within the mixtures and in the surrounding air. Relative viscosity and density measurements were taken on the mixtures before and after cooling to determine possible changes in quality attributable to this method of cooling. The variables were:

1. The level of egg in the mixture (6, 9.5, 13, and 16.5 oz/gal milk).
2. The level of cornstarch in the mixture (3 and 6 oz/gal milk).
3. The level of sugar in the mixture (0, 8, and 16 oz/gal milk).
4. The rate of agitation of the cold tube (6 and 18 rev/min).

Forty-eight experiments were carried out. For each experiment the level of reconstituted egg, the level of cornstarch, the level of sugar, and the rate of agitation were varying factors.

EXPERIMENTAL PROCEDURE

Four-gal batches of the mixtures were prepared using the level of ingredients stated above. A 2-step method was used to combine the ingredients. The milk and one half of the sugar were heated to 88°C (190.4°F). The remaining half of the sugar and the cornstarch were sifted together and combined with the egg using no. 2 speed on the mixer[2]. The egg-cornstarch mixture was then added to the heated milk using approximately 50 brisk strokes. The mixture was cooked for 45 min, with occasional stirring until the raw starch flavor disappeared and the radius of spread measured approximately 25 to 35 mm for the 3-oz cornstarch mixtures, and 12 to 16 mm for the 6-oz cornstarch mixture. After cooking, 4 gal of the mixture were first cooled in a water bath[3] to 140°F and thoroughly blended before the agitator was inserted. The mixture was cooled under constant agitation to a final temperature of 60°F. Aliquots were removed from the mixture for specific tests before and after the cooling period.

The equipment and objective measurements of relative viscosity and density used in the present investigation were the same as described in the previous publication *(2)*.

RESULTS, ANALYSIS, AND DISCUSSION

The total times necessary for the custards and puddings to cool from an initial temperature of 140°F to a final temperature of 60°F, and the radius of

[1]This is part of a larger project titled "Heat Transfer in Foods Prepared and Cooled in Quantity."

[2]Hobart, Model A-200.

[3]The sauces were agitated at 15-min intervals while cooling in a flowing cold water bath (42°F); water flowed in at a rate of 0.6 ft^3 per min.

TABLE 1—THE TOTAL COOLING TIME, AND THE RADIUS OF SPREAD (RELATIVE VISCOSITY) AND DENSITY DETERMINED IN CUSTARDS AND PUDDINGS BEFORE AND AFTER COOLING WITH THE COLD-TUBE AGITATOR.

Amount[a] of			Agitation rate	Total cooling time	Radius of Spread[b] (relative viscosity)		Density[c]	
Egg	Cornstarch	Sugar			Before cooling	After cooling	Before cooling	After cooling
(oz)	(oz)	(oz)	(rev/min)	(min)	(mm)	(mm)		
6	3	0	6	290	33.6	34.1	1.177	1.174
			18	130	31.1	36.1	1.166	1.172
		8	6	180	38.3	38.4	1.225	1.194
			18	120	38.9	42.1	1.207	1.191
		16	6	330	31.8	34.8	1.219	1.217
			18	130	30.4	35.6	1.222	1.218
	6	0	6	410	16.0	18.8	1.152	1.181
			18	130	17.4	18.9	1.165	1.173
		8	6	235	12.6	16.9	1.168	1.190
			18	180	14.1	19.4	1.198	1.200
		16	6	390	17.0	17.1	1.195	1.215
			18	160	19.0	25.3	1.189	1.207
9.5	3	0	6	270	27.8	28.8	1.161	1.176
			18	110	28.9	33.4	1.173	1.177
		8	6	300	25.8	29.4	1.199	1.193
			18	105	25.6	27.9	1.199	1.195
		16	6	340	26.6	28.5	1.192	1.209
			18	130	28.5	33.9	1.215	1.216
	6	0	6	270	16.6	17.8	1.161	1.163
			18	210	16.0	20.5	1.162	1.166
		8	6	305	12.0	16.8	1.178	1.193
			18	160	12.5	19.4	1.179	1.202
		16	6	370	18.8	20.6	1.196	1.199
			18	170	18.1	22.3	1.194	1.205
13	3	0	6	320	25.3	26.8	1.153	1.165
			18	110	24.5	29.0	1.159	1.166
		8	6	240	24.6	25.5	1.172	1.197
			18	105	25.3	30.4	1.202	1.206
		16	6	340	26.0	29.3	1.199	1.211
			18	170	25.9	28.5	1.193	1.191
	6	0	6	300	14.9	17.1	1.151	1.163
			18	115	14.8	18.5	1.149	1.168
		8	6	215	11.8	16.1	1.181	1.200
			18	125	15.8	19.5	1.180	1.182
		16	6	210	18.4	20.6	1.181	1.192
			18	180	14.8	21.5	1.179	1.207
16.5	3	0	6	250	18.6	19.5	1.167	1.181
			18	135	20.6	25.4	1.161	1.170
		8	6	260	22.1	22.3	1.181	1.187
			18	100	20.4	24.4	1.185	1.187
		16	6	270	18.6	27.0	1.210	1.216
			18	150	22.6	27.0	1.211	1.212
	6	0	6	310	14.5	17.4	1.161	1.163
			18	125	12.3	19.4	1.170	1.171
		8	6	265	10.5	14.3	1.169	1.202
			18	95	13.6	17.4	1.181	1.198
		16	6	300	9.3	15.9	1.186	1.223
			18	120	11.0	15.3	1.201	1.211

[a]Ounces per gal. of milk.
[b]Figures were carried to 3 decimal places for statistical analysis.
[c]Figures were carried to 5 decimal places for statistical analysis.

TABLE 2—MEAN SQUARES AND F VALUES FOR THE SOURCES OF VARIATION.

Source of variation	Degrees of freedom	Total cooling time: Mean square	Total cooling time: F value	Change in Radius of spread relative (viscosity): Mean square	Change in Radius of spread relative (viscosity): F value	Change in density: Mean square	Change in density: F value
E[a]	3						
E_L	1	6161.1	7.99*	7.0881	2.02	3045.938	7.24*
E_Q	1	216.8	<1	.6522	<1	285.188	<1
E_C	1	1643.3	2.13	1.1711	<1	440.104	1.05
C[b]	1	4563.0	5.92	7.0879	2.02	12903.521	30.67**
S[c]	2						
S_L	1	2363.3	3.07	10.0072	2.86	148.781	<1
S_Q	1	16511.3	21.42**	.0339	<1	326.344	<1
R[d]	1	286443.0	371.62**	46.3249	13.22*	2173.521	5.17
EC							
E_LC	1	5860.8	7.60*	.2670	<1	1876.004	4.46
E_QC	1	1727.9	2.24	.0377	<1	3553.521	8.45*
E_CC	1	2926.0	3.80	.0100	<1	297.038	<1
ER	3						
E_LR	1	390.1	<1	3.9540	1.13	964.004	2.29
E_QR	1	341.3	<1	.2633	<1	150.521	<1
E_CR	1	660.0	<1	.1300	<1	28.704	<1
ES	6						
E_LS_L	1	213.9	<1	.6194	<1	514.806	1.22
E_QS_L	1	569.5	<1	1.9776	<1	38.281	<1
E_CS_L	1	406.4	<1	.0044	<1	200.256	<1
E_LS_Q	1	1119.4	1.45	7.3124	2.09	2985.019	7.10*
E_QS_Q	1	645.8	<1	6.9580	1.99	348.844	<1
E_CS_Q	1	2345.3	3.04	.2514	<1	348.502	<1
CS	2						
CS_L	1	1444.5	1.87	.8272	<1	2432.531	5.78
CS_Q	1	27.1	<1	11.0399	3.15	2450.260	5.82
CR	1	140.1	<1	.6086	<1	28.521	<1
SR	2						
S_LR	1	7.0	<1	3.9235	1.12	81.281	<1
S_QR	1	4662.1	6.05*	.8261	<1	25.010	<1
ECS	6						
E_LCS_L	1	113.9	<1	.9310	<1	1282.556	3.05
E_QCS_L	1	94.5	<1	2.3680	<1	520.031	1.24
E_CCS_L	1	262.7	<1	2.2884	<1	41.006	<1
E_LCS_Q	1	0.6	<1	4.6031	1.31	174.002	<1
E_QCS_Q	1	102.1	<1	.2704	<1	276.760	<1
E_CCS_Q	1	722.8	<1	1.0797	<1	5247.019	12.47*
ECR	3						
E_LCR	1	13.1	<1	.0176	<1	781.204	1.86
E_QCR	1	9020.2	11.70*	1.0784	<1	7178.521	17.06**
E_CCR	1	91.2	<1	.5386	<1	42.504	<1
ESR	6						
E_LS_LR	1	787.7	1.02	21.2030	6.05*	644.006	1.53
E_QS_LR	1	0.8	<1	1.8264	<1	116.281	<1
E_CS_LR	1	8482.7	11.01*	2.7602	<1	85.556	<1
E_LS_QR	1	7704.0	9.99*	3.4265	<1	840.052	2.00
E_QS_QR	1	2390.0	3.10	2.5204	<1	388.010	<1
E_CS_QR	1	3472.3	4.50	.8263	<1	2021.302	4.80
CSR	2						
CS_LR	1	488.3	<1	8.4615	2.41	331.531	<1
CS_QR	1	333.7	<1	3.3171	<1	1433.760	3.41
ECSR	6	770.8		3.50475		420.701	

**Significant at the 1% level.
*Significant at the 5% level.

Egg[a]
Cornstarch[b]

Sugar[c]
Rate of Agitation[d]

spread and density measurements taken on the mixtures before and after cooling by agitation, are presented in Table 1. An analysis of variance was carried out on the total cooling times and also on the radius of spread and density values, each value representing the difference in measurements taken on the mixtures before and after cooling (Table 2).

Total Cooling Time

In all the custards and puddings prepared, the total cooling time decreased as the rate of agitation increased. The mixtures agitated at 18 rev/min cooled in less than one half the time necessary to cool the mixtures agitated at 6 rev/min in all but eight instances, four of which were mixtures made with the 8-oz level of sugar. All but one of the 48 mixtures cooled within 3 hr when agitated at 18 rev/min. All but five of the mixtures cooled within 5 1/2 hr when agitated at 6 rev/min (Table 1).

In the analysis of variance, rate of agitation (R) was the most significant factor influencing the total cooling time. The effect of sugar (S), although significant, was not linear; that is, as the level of sugar increased the total cooling time also increased, but the increase in total time was not in proportion to the increase in the level of sugar. The egg (E) affected cooling time significantly; as the level of egg in the mixture increased the cooling time decreased linearly. There were several 2- and 3-factor interactions, as shown in Table 2.

This method of cooling pudding resulted in shorter cooling times than the method reported by Hammer *(1)* who cooled 100 portions (less than 2 gal.) of a cornstarch pudding at room temperature by beating in a kitchen mixer. Her data showed that 1 3/4 hr were required to cool these puddings from 142°F to 77°F. In the present study, the same length of time was sufficient to cool batches of pudding twice as large by cold tube agitation. To make this comparison, the cooling times of batches made with a formula similar to that used by Hammer, were used (9.5 oz. egg, 16 oz. sugar, and 6 oz. cornstarch).

Quality Characteristics

Relative viscosity. Since the relative viscosity was measured as radius of spread in millimeters, an increase in radius of spread denotes a decrease in relative viscosity and a thinner consistency.

The radius of spread was influenced by rate of agitation. In each instance, a greater increase in radius of spread was noted in the mixtures agitated at 18 rev/min than in the mixtures agitated at 6 rev/min; the increase being one and one-half times as great in the mixtures agitated at the faster rate (Table 1). In the analysis of variance, rate of agitation (R) was the only main effect affecting relative viscosity (Table 2).

Density. The density was determined by the weight of the mixture compared to the weight of an equal volume (50 ml) of water, the density of water being 1.0 at 39.2°F (4°C).

In every case the density of the mixtures was greater than that of water, before and after cooling by agitation. Cornstarch (C) was the most significant factor influencing the change in density. There was a greater increase in density value observed in the mixtures made using a 6-oz level of cornstarch than in the mixtures made using a 3-oz level of cornstarch. Level of egg (E) was also a significant factor; as the level of egg in the mixtures increased the differences in density value attributable to cooling by agitation increased.

Observations. Observations on consistency and texture were made on the majority of the mixtures by six members of the Department of Institution Management staff; not included were batches made with the 8 oz level of sugar and the 16.5 oz level of egg. In general, the mixtures were judged to be smoother and glossier after agitation; this observation is in accord with the results reported by Hammer *(1)*. Although there was a change in radius of spread attributable to agitation, this change in the consistency of the custards and puddings was acceptable for service.

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