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OBSERVATIONS ON THE BACTERICIDAL EFFICIENCY OF SINGLE-UNIT VACREATORS.

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SUMMARY.

Bactericidal efficiency appears to reach a critical level at a pasteurizing temperature of about 200° F. A considerable loss in efficiency occurs for each degree below about 200°.

The bacteriological quality of the raw cream has an appreciable influence on the survival of thermoduric bacteria.

Misuse of the equilibrium valve, rate of cream flow, and intensity of cream treatment have no apparent influence on the bacteriological quality of the treated cream.

A method for the laboratory pasteurization of ripened cream is suggested.

INTRODUCTION.

In most Queensland butter factories a vacreator is used to pasteurize and deodorize the soured cream supplied for manufacture into butter. The Department's Butter Improvement Service (Muller and Nichols, 1950) commonly showed high plate counts in butters from some of the factories equipped with single unit vacreators, and very high bacteria counts were frequent in freshly pasteurized cream examined during surveys of these factories. While there was no reason to suspect that the types of bacteria surviving pasteurization in this manner were harmful to cream or butter quality, difficulties in the fair assessment of Butter Improvement Service and factory survey results made it desirable to find the cause of this high survival of bacteria. For this reason, experiments were conducted to investigate the factors in the operation of a single unit vacreator which would be liable to influence its bactericidal efficiency.

These factors include:—

(1) misuse of the equilibrium valve;

(2) the pasteurizing temperature;

(3) the bacteriological quality of the raw cream;

(4) the rate of cream flow; and

(5) the intensity of cream treatment.

PROCEDURE.

The single unit vacreators employed in the experimental work were of standard design, consisting of the following parts:—

(1) A pasteurizing chamber in which cream is mixed with steam to reach a pasteurizing temperature corresponding to the boiling point of water at the partial vacuum existing in the chamber.

(2) A deodorizing chamber in which the hot cream is subjected to a higher vacuum and in consequence boils vigorously. The vacuum difference between the two chambers is controlled by the equilibrium valve.

(3) An ejector-condenser which creates the vacuum by means of a jet of water and condenses the vapour evolved during boiling of the cream in the deodorizing chamber.

The method adopted was to treat a vat of cream, graded choice by platform examination, under conditions as standard as could be obtained, except for alterations in one variable. Single plate counts were done on duplicate samples of pasteurized cream taken at intervals, and all plates of laboratory pasteurized cream were made by single plates on triplicate samples, pasteurized in triplicate. Plate counting methods similar to those described by Muller and Nichols (1950) were used.

The accuracy of the plate counting methods may be summarized as follows. In 65 sets of counts on duplicate or triplicate samples, the mean variation from the mean of the counts was $\pm 11{\cdot}1$ per cent. One pair showed a variation of ± 73 per cent. from their mean count, six were between 20 and 28 per cent. and the remainder were within ± 0 to 19 per cent. of their mean. It is considered that this degree of inaccuracy did not materially affect the significance of the findings.

RESULTS.

The Influence of the Equilibrium Valve.

During the operation of a vacreator the pasteurizing temperature should be largely controlled by raising or lowering the partial vacuum in the pasteurizing chamber by means of adjustments in the tension of the equilibrium valve. Observations in factories had frequently shown that operators did not appreciate this point and were inclined to leave the valve slack or even remove it to hasten the cream flow. On the assumption that the equilibrium valve would slightly delay passage of individual cream particles, it was considered possible that a variation sufficient to increase the bacterial survival may occur in the time factor of the temperature-time relationship to bacterial destruction.

An experiment was designed to treat one half of a vat of cream without the equilibrium valve and the remaining half with the valve operating and as

near as practicable to the same conditions of vacuum, temperature and rate of cream flow. The experiment was performed on two successive days with results as in Table 1.

Table 1.

Sample No.	Pasteurizing Temp. (°F.)	Equivalent Vacuum (in.)	Deodorizer Vacuum (in.)	Mean Plate Count per ml.
		TRIAL A.		
		EQUILIBRIUM VALVE OUT.		
1 ..	184	13	13	3,000,000
2 ..	200	6½	13	120,000
3 ..	202	5½	12½	120,000
4 ..	202	5½	13	290,000
		EQUILIBRIUM VALVE IN.		
5 ..	203	5	15	130,000
6 ..	201	6	15	220,000
7 ..	200	6½	15	420,000
8 ..	200	6½	15	650,000
		TRIAL B.		
		EQUILIBRIUM VALVE OUT.		
9 ..	196	8½	15	1,950,000
10 ..	196	8½	15	2,250,000
11 ..	196	8½	15	1,800,000
		EQUILIBRIUM VALVE IN.		
12 ..	202	5½	15	660,000
13 ..	201	6	15	680,000
14 ..	201	6	15	700,000

Practical difficulties in the operation of the vacreator prevented the attainment of the same conditions of temperature and vacuum with the valve in and out; the variability was greater in trial A than in trial B. However, examination of the results suggested that the variations in count in each trial could be ascribed to the changes in pasteurizing temperature. Again, the difference between the counts obtained in trials A and B at similar temperatures possibly could be related to the difference in bacteriological quality of the raw cream on the two days. The results showed no evidence that the postulated variation in the time factor of the temperature-time relationship to bacterial destruction operated.

The Influence of the Pasteurizing Temperature.

To investigate the significance of changes in the pasteurizing temperature within the range normally used (viz., 195-202 deg. F.), an experiment was designed in which a vat of cream was treated at gradually increasing temperatures while an endeavour was made to keep the vacuum and rate of cream flow the same. This was carried out on three successive days at one factory and on two successive days at another factory to eliminate possible variations between vacreator units. The results are set out in Table 2.

Table 2.

Sample No.	Pasteurizing Temperature (°F.)	Deodorizing Vacuum (in.)	Mean Plate Count per ml.	Mean Plate Count of Lab. Past. Cream.	Percentage of Lab. Past. Count.
		FACTORY A.			
		TRIAL 1.			
1	194	15	2,000,000	16,500,000	12·1
2	196	14½	1,760,000	..	10·7
3	198	14½	1,130,000	..	6·9
4	200	13½	830,000	..	5·0
5	202	14	810,000	..	4·9
6	205	14	600,000	..	3·6
		TRIAL 2.			
1	193·5	16	1,250,000	7,200,000	17·6
2	196	15	850,000	..	11·8
3	198	14½	470,000	..	6·5
4	200	14	410,000	..	5·7
5	202	15	320,000	..	4·5
6	204	15	320,000	..	4·5
		TRIAL 3.			
1	194	14½	500,000	3,900,000	12·8
2	197	15	370,000	..	9·5
3	198	14	270,000..	..	6·9
4	200	14	170,000	..	4·4
5	202	14	130,000	..	3·3
6	204	14	90,000	..	2·3
		FACTORY B.			
		TRIAL 4.			
1	194	15	635,000	670,000	94·8
2	196	15	530,000	..	85·5
3	198	15	380,000	..	56·7
4	200	15	375,000	..	56·0
5	202	15	150,000	..	22·4
6	203·5	15	135,000	..	20·2
		TRIAL 5.			
1	194	15	2,100,000	1,810,000	116
2	196	15	1,605,000	..	88·7
3	198	15	820,000	..	45·4
4	200	15	460,000	..	25·4
5	202	15	160,000	..	8·9
6	203·5	15	150,000	..	8·3

These results show that variations in pasteurizing temperature of even two degrees may have an appreciable influence on the bacterial survival.

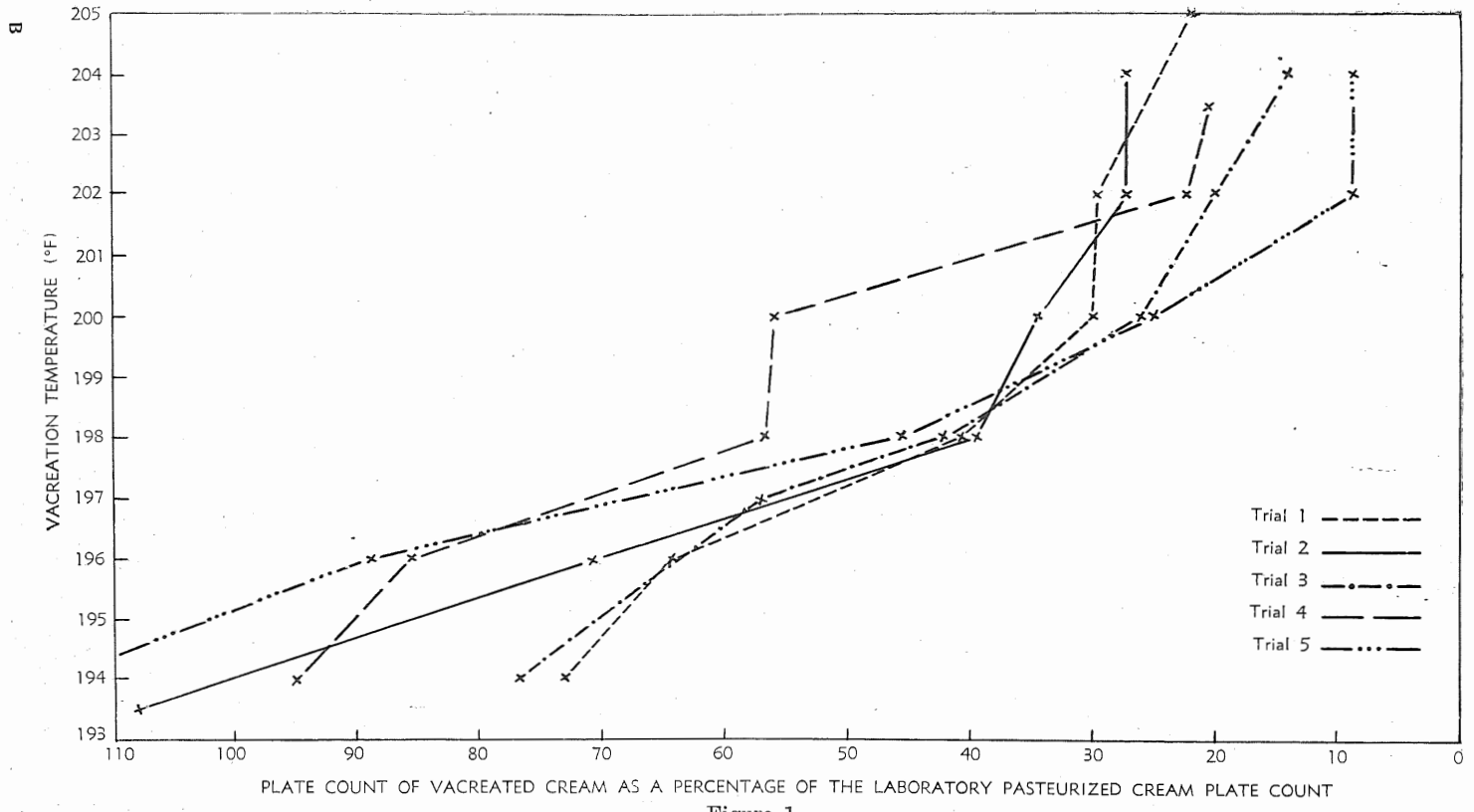

Figure 1.

Vacreation Temperature and Bactericidal Efficiency.

The Influence of the Bacteriological Quality of the Cream.

The preliminary experiments on the use of the equilibrium valve had shown the possibility of considerable variation in plate counts due to the bacteriological quality of the raw cream. To compensate for this effect, triplicate samples of the cream were laboratory pasteurized and the factory pasteurized cream counts were expressed as a percentage of the counts obtained on laboratory pasteurized cream. In the first three experiments (Trials 1-3) laboratory pasteurization was performed on undiluted raw cream for 35 minutes at 62.5-63.0 deg. C. The plate counts obtained at this temperature were much higher than those obtained on cream treated with the vacreator. For this reason trials were conducted to determine a more suitable method and temperature. This resulted in the adoption of the following technique, which was used for all later trials. Cream samples were taken in triplicate and 1 ml. transferred to 9 ml. of sterile tap water with 0·1 per cent. of agar added to improve the emulsification. Five millilitres of this diluted cream were transferred aseptically to a sterile tube and pasteurized in a water bath at 70.5-71.0 deg. C. for 35 minutes. Table 2 shows the results obtained in this manner for trials 1-5, and Figure 1 shows the results graphically. For the sake of clarity, in compiling Figure 1 the percentages obtained for trials 1-3 have been multiplied by an arbitrary figure six so as to compensate for the much higher laboratory pasteurized counts and consequently lower percentages obtained when 62.5-63 deg. C. was used.

From the close proximity of all the curves relating pasteurizing temperature to the percentages obtained as above, it will be seen that the variability in the bacteriological quality of the raw cream accounts for the discrepancies observed in the plate counts of different batches of cream pasteurized at the same temperature. Figure 1 also shows the marked effect of small changes in pasteurizing temperature on bacterial survival. The general slope of the curves from 194 deg. F. to about 200 deg. F. shows that a considerable improvement in the bacteriological quality of the resulting cream is obtainable for each degree F. rise in pasteurizing temperature. Above about 200 deg. F., however, the slope changes and there is comparatively little improvement in the plate count for each degree rise in temperature. These results appear to show that 200 deg. F. can be taken as a critical temperature for good bacteriological results when using a single-unit vacreator to pasteurize cream containing a high count of heat-resistant bacteria.

The Effect of Rate of Cream Flow and the Intensity Factor.

A further experiment was designed to determine the influence on the bactericidal efficiency of the vacreator of the rate at which cream was treated and of the intensity of deodorization in the vacuum chamber. This intensity is expressed by the "Intensity Factor" (Smith, 1947), which is the amount

of heat (B.T.U.) expended on deodorization per pound of cream treated. The experiment, which was repeated on three successive days, consisted of treating a vat of cream in four stages, namely:—

(1) 195 deg. F. and low rate of cream flow;

(2) 200 deg. F. and low rate of cream flow;

(3) 200 deg. F. and high rate of cream flow; and

(4) 195 deg. F. and high rate of cream flow.

Table 3.

Sample Number.	Past. Temp. (°F.)	Vacuum (in.)	Rise in Temp. of Condenser Water (°F.)	Condenser Water Pressure (lb./sq. in.)	Intensity Factor.	Rate of Cream Flow (galls./hr.)	Mean Plate Count per ml.	Percentage of Lab. Past. Count.
			TRIAL 1.					
1 ..	Laboratory Pasteurized Cream			..	..	..	1,130,000	..
2 ..	195	16½	21	92	61	720	2,020,000	179
3 ..	200	16½	33	92	96	720	490,000	43
4 ..	200	16½	32	92	70	950	600,000	53
5 ..	195	16½	24	92	53	950	1,760,000	156
			TRIAL 2.					
1 ..	Laboratory Pasteurized Cream			..	..	..	1,100,000	..
2 ..	195	15	49	92	205	500	1,410,000	128
3 ..	200	15	56	92	234	500	830,000	75
4 ..	200	15	54	92	141	800	650,000	59
5 ..	195	15	50	92	131	800	1,510,000	138
			TRIAL 3.					
1 ..	Laboratory Pasteurized Cream			..	..	..	1,620,000	..
2 ..	195	15	47	92	164	600	1,600,000	99
3 ..	200	15	49	92	171	600	360,000	22
4 ..	200	15	41	92	101	850	480,000	30
5 ..	195	15	45	92	111	850	1,490,000	92

Again laboratory pasteurization of the raw cream and expression of the plate counts of the vacreated cream as a percentage of the laboratory pasteurized counts was used as a device to eliminate the influence of the bacteriological quality of the cream. The results are shown in Table 3 and Figure 2.

The results show that the rate of cream flow used has no apparent influence on bacterial survival during pasteurization. This is shown in Fig. 2, where the slight variation of the lines from the vertical is apparently at random and can be accounted for by the inaccuracy of the plate count.

The Intensity Factor is given by the expression:—

$$\frac{\text{Gallons of water per hour} \times \text{Temperature rise}}{\text{Gallons of cream per hour}}$$

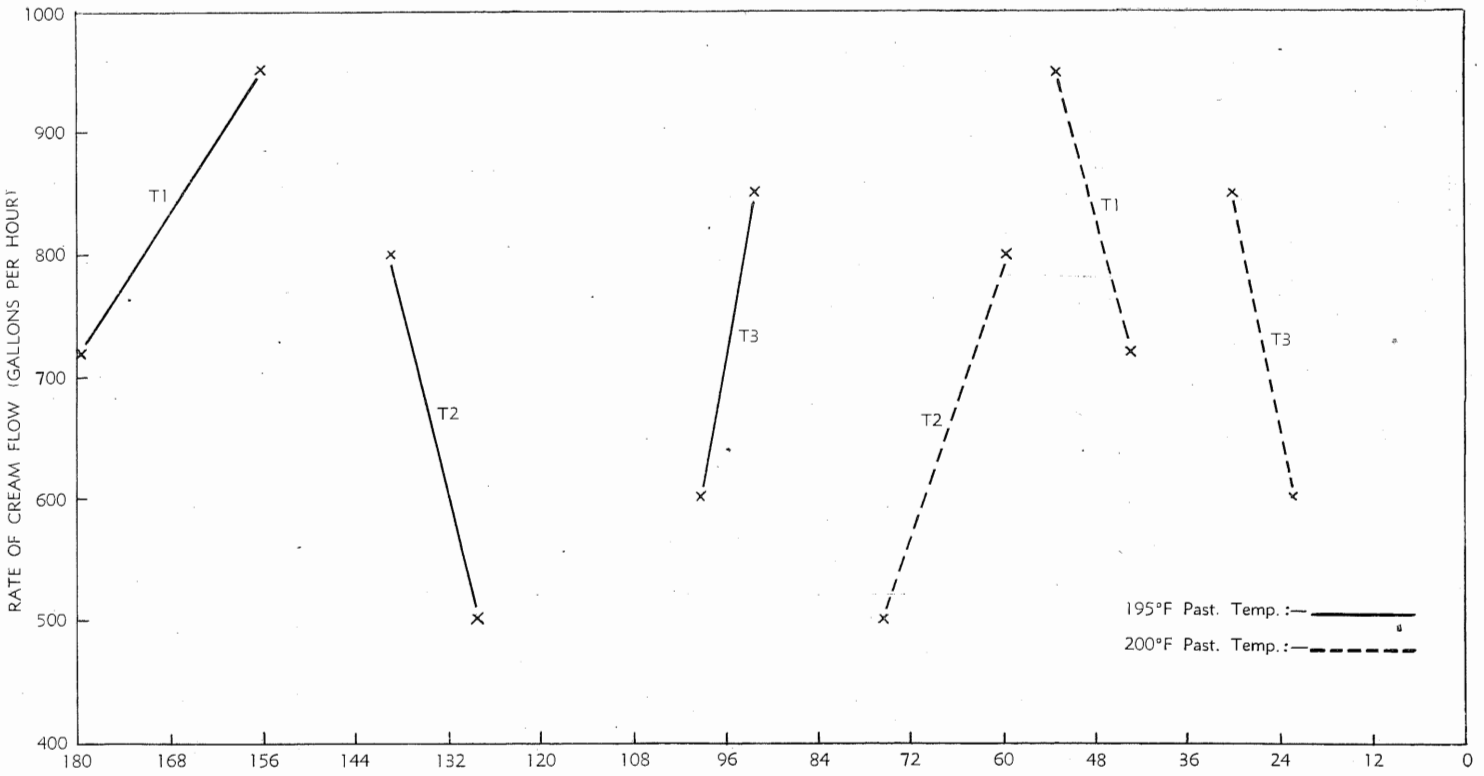

Figure 2.

Rate of Cream Flow and Bactericidal Efficiency.

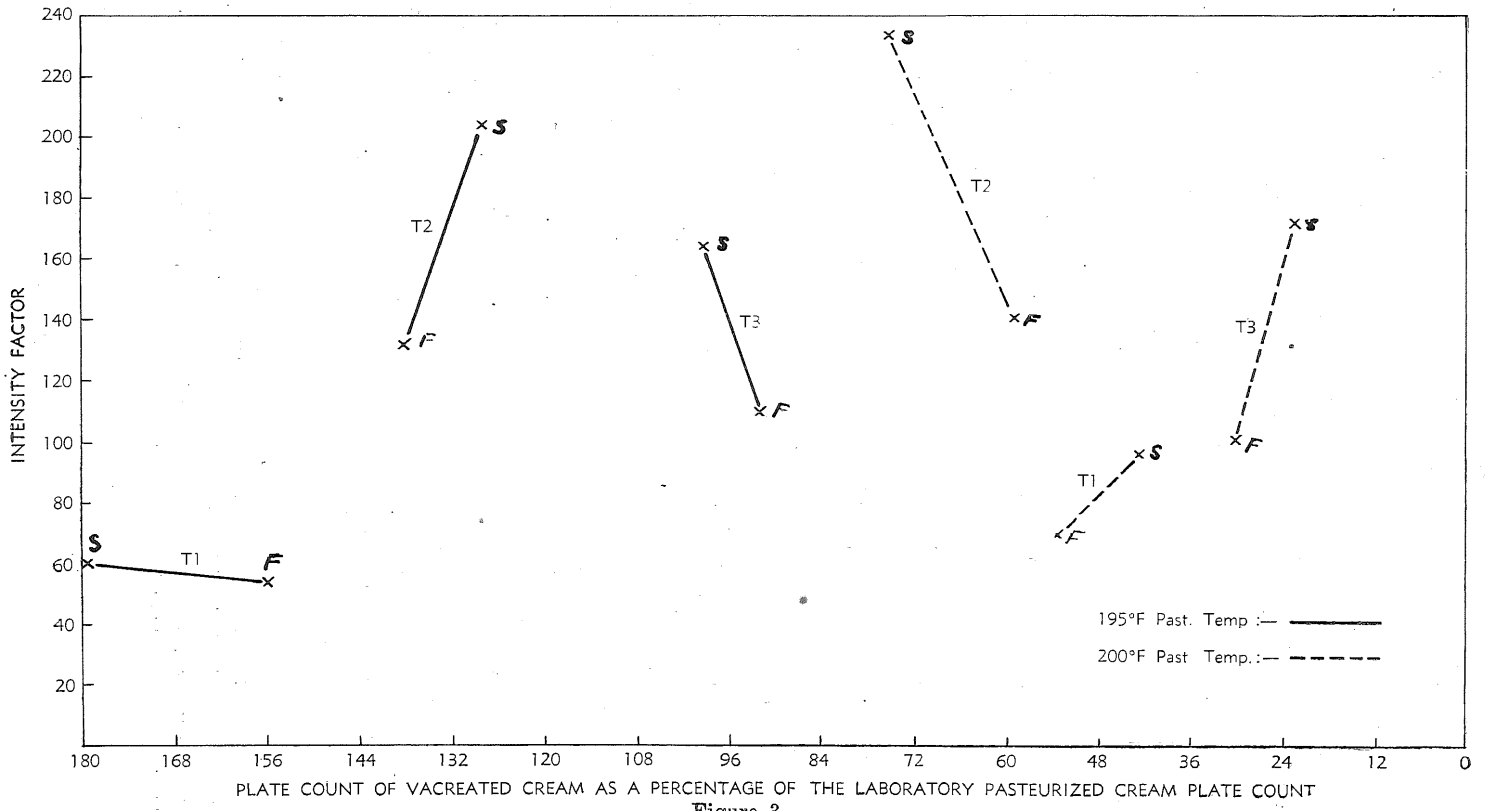

Figure 3.

Intensity Factor and Bactericidal Efficiency.

The number of gallons of water per hour through the condenser is given by the water pressure and would have been 2,090 in these trials. The temperature rise between the incoming and outgoing water of the condenser is given in Table 3 and is fairly constant for corresponding pasteurizing temperatures in each trial. Thus if the figures for 200 deg. F. pasteurizing temperatures are examined it will be seen that, though the intensity factor is altered considerably by the changing rates of cream flow, the change in the plate count of the pasteurized cream is not significant. This is further illustrated in Figure 3, where the variations of the lines from the vertical can be considered as random.

CONCLUSIONS.

The results obtained show that, of the factors considered likely to result in a high survival of thermoduric bacteria during pasteurization in a single unit vacreator, the only two having an appreciable influence are the pasteurizing temperature and the bacteriological quality of the raw cream.

In the case of the pasteurizing temperature, the results also show that a considerable loss in bactericidal efficiency occurs for each degree below about 200 deg. F. and that the corresponding gain in efficiency by pasteurizing above 200 deg. F. is not so great. It would appear that 200 deg.-202 deg. F. could be taken as a temperature range to achieve reasonably good results with a single unit vacreator.

The bacteriological quality of the raw cream is not necessarily related to the grading quality of the cream, all cream used in the experiments being of choice quality. There are no means available in factory practice for selecting cream of good bacteriological quality, so it would appear necessary to rely on the pasteurizing temperature alone to achieve good bacteriological results in pasteurized cream.

While it has been shown that misuse of the equilibrium valve, the rate of cream flow and the intensity of cream treatment have no apparent influence on the bacteriological results, it should be stressed that these three factors are of considerable importance in the second phase of vacreation, namely, the deodorization of cream and consequent improvement in the grading qualities of the resultant butter.

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