HEAT PROCESSING OF CREAM THROUGH VACUUM DEODORIZATION EQUIPMENT

1. A COMPARISON OF TANDEM AND TRIPLE VACREATION PROCESSING OF CREAM

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SUMMARY

Tandem and triple vacreation of cream were compared from three aspects, viz. (a) removal of volatile off-flavours, (b) efficiency of bacterial destruction, and (c) loss of butterfat in buttermilk after churning of the cream. The cream used was choice grade, but included three categories, "sound", "fair" and "borderline", within this grade.

The triple system showed an advantage over the tandem system in the removal of volatile off-flavours from "borderline" choice cream, but there were no differences in the quality of butter from "sound" choice and "fair" choice creams.

Both tandem and triple vacreation resulted in satisfactory destruction of bacteria in cream, but there were fewer survivors in the triple vacreated cream.

The butterfat losses in buttermilk derived from the churning of the cream were similar for both treatments.

I. INTRODUCTION

Vacuum deodorization associated with heat treatment has been employed successfully for the processing of cream for buttermaking in several dairying countries for the past three decades. In recent years, McDowall (1955, 1956, 1957, 1959), Scott (1954, 1955, 1956) and Dixon (1957) have examined the theoretical aspects of steam distillation of taints from cream.

The high numbers and varied flora of bacteria in farm-separated, acid cream supplied to Queensland factories, which normally receive the cream four times weekly in summer and thrice weekly in winter, result in much cream containing appreciable quantities of tainting substances of bacteriological origin. In the production of a "choice" grade butter at factories, the high quality cream is selected by sensory grading and subjected to intensive processing to reduce the concentration of taints sufficiently in the treated cream to ensure the production of butter of the desired quality. Lower quality creams are selected, intensively processed and made into first and second grade butters. The relatively low amount of choice grade butter manufactured in Queensland, which fluctuates yearly between 30 and 45 per cent. of total graded manufacture, indicates the severity of the off-flavours in cream produced in the subtropical environment.

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The trend to more intensive forms of cream processing in Queensland factories was reported by Mitchell (1957). His survey revealed an increase in recent years in the number of tandem and triple "Vacreators" and "Cream Treatment Units" and a reduction in the number of flash pasteurizers, volatilizers and solo "Vacreators" used in factories. Observations in factories where triple "Vacreators" are installed have shown that the tandem unit is employed for treating lower acid cream during the months of low production.

As the trend in processing indicated an attempt to improve butter quality through the application of intensive forms of heating and deodorization of cream, experiments were conducted under commercial conditions to compare tandem and triple vacreation treatment of cream.

Bacteriological examinations of cream and butter, organoleptic gradings on fresh and stored butter, peroxide values and copper and iron analyses of butter, and butterfat losses in buttermilk were undertaken.

II. METHODS

The following procedures were adopted in the experimental and analytical work.

Cream Processing Conditions.—As a wide variety of processing conditions is practicable with vacreation treatment of cream, treatments were standardized to conform with normal factory practices. The conditions aimed for in this investigation are listed in Table 1. In each instance, legs of the standard M-type unit were employed for processing.

TABLE 1

PROCESSING CONDITIONS FOR TANDEM AND TRIPLE VACREATION OF CREAM

Processing Conditions	Tandem	Triple
Cream flow (g.p.h.)	800	1,000
Pasteurization temperature (°F), Leg 1	..	200
Pasteurization temperature (°F), Leg 2	208	210
Vacuum conditions (in.), Leg 1	..	12
Vacuum conditions (in.), Leg 2	13	15
Vacuum conditions (in.), Leg 3	29	29
Water flow per condenser (g.p.h.)	2,500	2,500
Condenser water temperature rise (°F), Condenser 1	..	40
Condenser water temperature rise (°F), Condenser 2	50	60
Condenser water temperature rise (°F), Condenser 3	20	20
Treatment intensity (approx.)*	220	300
Total lb steam/gal cream†	2·6	3·4

* Treatment intensity is equivalent to the quantity of heat (water flow (g.p.h.) x temperature rise (°F)) discharged through the water condensers per gal of cream treated.

† Total steam consumption was estimated from temperature increase in condenser water and cream.

A residual acidity in the pasteurized cream of 0·04 to 0·08 per cent. was the objective during "neutralization" of cream.

Manufacturing conditions and composition of the butter were maintained as similar as possible for comparative churnings to minimize the influence of these factors on butter quality.

Cream Quality.—Raw cream was senses graded by two qualified graders and segregated to provide three distinct categories of choice grade cream designated "sound", "fair" and "borderline" choice. This was done to demonstrate the effect of intensive processing on the removal of off-flavours from creams having varying concentrations of taints.

As a general classification, the initial acidities of the respective categories of choice cream were 0·18 to 0·25 per cent. for sound, 0·26 to 0·35 per cent. for fair, and 0·36 to 0·45 per cent. for borderline.

The main characteristics of the creams selected were:—

(*a*) Sound choice—a clean, nutty flavour, together with a slight acid taste, free from traces of curd.

(*b*) Fair choice—free from strong off-flavours, but with a moderate clean, lactic acid content, or very slight stalish taste due to the age of the cream.

(*c*) Borderline choice—slightly unclean, slightly over-ripe flavour, or cream with trace of cheesy, bitter or stalish off-flavours; slight feed flavours were present in some creams; this cream was characterized by a distinct acid taste.

Every endeavour was made to eliminate from experimental batches creams containing weed taints, but this was found difficult with low-acid fresh cream supplies.

To ensure identical cream quality for paired comparisons, half of each batch of raw neutralized cream was treated through the tandem unit, after which processing was stopped and the machine converted to a triple unit immediately and the remaining portion of the cream treated.

Bacteriological Examinations.—Samples of raw and processed cream were examined for bacteriological content by the milk agar method described by Muller and Nichols (1950) for butter samples. Single plate counts were done on single samples. Because of difficulties in maintaining accurate incubation temperatures, which fluctuated in the range of 28±3°F under field conditions, only a limited number of samples was examined.

The bacteriological content of fresh and stored butter was determined with single plate counts on duplicate samples by the methods specified for the Butter Improvement Service (Muller and Nichols 1950).

Chemical Examinations.—The moisture and salt contents of butter samples were determined by the Kohman (1919) method.

The pH of butter serum was determined by the glass electrode and quinhydrone electrode techniques.

The peroxide value of fresh and stored butter was determined by the ferric thiocyanate method of Loftus Hills and Thiel (1946), with chloroform-methanol solvent and a photoelectric colorimeter.

To ensure that butter quality was not influenced by metallic contamination, samples were analysed for copper and iron content by the wet ashing method of McDowell (1947).

Butterfat Losses.—Total fat lost in buttermilk was estimated by the Udy formula reported by McDowall and McDowell (1949) as suitable for washed butter. Butterfat content of cream to be churned was determined on a 9 g gravimetric sample and the fat content of the subsequent buttermilk by the modified normal butyl alcohol Babcock method (A.O.A.C.).

Butter Grading.—A 56 lb box of bulk butter from each churning was graded fresh and after storage for 6 months at 5-10°F. In addition, a 1 lb pat, double-wrapped in parchment, was examined after storage at 45–55°F for one month. Grading was performed by the State dairy produce grader and butter was scored to the nearest half point.

III. RESULTS

(a) Cream Processing Conditions

As trials were conducted during normal commercial factory operations it was not possible to guarantee complete compliance with listed processing conditions. Variations occurred in the rate of cream flow, flows of 750–850 g.p.h. and 950–1,050 g.p.h. occurring with tandem and triple treatments respectively. This fluctuation resulted in a corresponding variation of the order of 5–10 per cent. in treatment intensity and steam consumption per gallon of cream.

The total churnings prepared were six paired comparisons of sound choice, six paired comparisons of fair choice, and seven paired comparisons of borderline choice quality cream. This involved using 19,000 gal of cream.

(b) Bacteriological Quality of Cream

The results of the bacteriological examination of samples of raw and pasteurized cream are listed in Table 2.

TABLE 2

BACTERIOLOGICAL QUALITY OF RAW AND PROCESSED CREAM
(Colonies per millilitre)

Cream Quality	No. of Samples								
	Raw Cream (,000,000)			Tandem Treatment (,000)			Triple Treatment (,000)		
	<100	100–300	>300	<30	30–100	>100	<30	30–100	>100
Sound choice ..	..	4	6	4	5	1	8	1	1
Fair choice ..	..	..	4	2	..	2	2	2	..
Borderline choice	..	..	6	3	3	..	5	1	..
Totals ..	..	4	16	9	8	3	15	4	1

As a consequence of the limiting testing procedures described, an accurate total bacterial count of cream was not obtained for all samples examined. Results are therefore grouped in ranges. With identical creams it was found that triple processing with its double-heat treatment gave a greater bacterial kill than occurred in the single-heat treatment of tandem vacreation.

(c) Chemical Results

A summary of the chemical analyses of cream and butter from comparative churnings is listed in Table 3.

TABLE 3

MEAN CHEMICAL COMPOSITION OF CREAM AND BUTTER FOR TANDEM AND TRIPLE VACREATION

Chemical Property	Sound Choice		Fair Choice		Borderline Choice	
	Tandem	Triple	Tandem	Triple	Tandem	Triple
Residual cream acidity (%)	0·06*	0·06*	0·07†	0·07†	0·06‡	0·07‡
Butter serum pH (quinhydrone)	7·5*	7·5*	7·4†	7·3†	7·4‡	7·3‡
Butter serum pH (glass electrode)	7·5*	7·5*	7·4†	7·3†	7·4‡	7·3‡
Peroxide value (fresh) ..	0·03	0·03	0·03	0·03	0·03	0·03
Peroxide value (1 mth) ..	0·05	0·05	0·04	0·06	0·05	0·06
Peroxide value (6 mth) ..	0·12	0·16	0·18	0·21	0·24	0·37
Copper (p.p.m.)	0·2*	0·2*	0·2†	0·2†	0·2‡	0·2‡
Iron (p.p.m.)	1·1*	0·8*	1·0†	1·0†	1·0‡	1·2‡
Moisture (%)	15·6	15·8	15·7	15·7	15·7	15·7
Salt (%)	1·1	1·1	1·2	1·2	1·1	1·1

* Mean of 5 of 6 total churnings.
† Mean of 4 of 6 total churnings.
‡ Mean of 5 of 7 total churnings.

These results show a close similarity between treatments, with the exception of peroxide values for butter stored for six months, where values from triple treatment were higher.

Moisture distribution in all butters as determined by the Muller (1952) technique was satisfactory.

(d) Bacteriological Quality of Butter

The bacteriological quality of experimental butters is summarized in Tables 4, 5 and 6.

Coliform and yeast and mould counts in fresh and stored butters were rather high. As total count determinations on cream indicated adequate heat treatment, the presence of these micro-organisms indicated post-pasteurization contamination. The physical condition of the internal surfaces of the wooden butter churn barrels used in the manufacture of the trial churnings was somewhat open along the stave joins and the contamination probably occurred from this source despite intensive cleaning procedures.

No significant change in bacteriological condition between fresh and 4-week-old samples was evident in any of the three grade categories for both tandem and triple treatment.

Between fresh and 6-month storage samples there was significant decline in the population of yeast and mould organisms for sound choice triple treatment. A similar significant decline was found in the coliform and the yeast and mould contents for fair choice triple treatment, and in the total count, coliform and yeast and mould organisms with triple processing of borderline choice cream.

With tandem vacreation treatment there was a significant decline between fresh and 6-month storage butters in the coliform and yeast and mould counts for all classes of cream. In addition, a significant reduction in the total count was obtained for tandem treatment of fair choice cream.

With the exception of three counts—viz. the total count and casein digester content of 6-month storage butter from sound choice cream, and the yeast and mould population in the 4-week borderline choice sample—there was no significant difference in the bacteriological content of butters prepared from the tandem and triple treatments of the same cream.

(e) Butterfat Losses

The fat lost in the buttermilk was estimated as the total fat lost from the cream churned. Results for the two treatments and three categories of cream are depicted graphically in Figure 1. The average increases in total fat loss for triple treatment of + 0·11 per cent., + 0·04 per cent., and + 0·06 per cent. for sound, fair and borderline choice creams, respectively, as compared with the tandem treatment creams, are considered to be of no practical significance.

TABLE 4

BACTERIOLOGICAL QUALITY OF FRESH BUTTERS

Cream Quality	Bacteriological Quality (colonies/ml)							
	Total Count (Mean) (,000)		Casein Digesters (Mean) (,000)		Coliforms (Mean)		Yeasts and Moulds (Mean)	
	Tandem	Triple	Tandem	Triple	Tandem	Triple	Tandem	Triple
Sound choice ..	119 ± 15	132 ± 33	7 ± 1	10 ± 2	15 ± 2	18 ± 5	272 ± 61	300 ± 35
Fair choice ..	200 ± 28	196 ± 21	11 ± 2	9 ± 1	49 ± 9	71 ± 18	518 ± 109	373 ± 66
Borderline choice	152 ± 32	204 ± 38	8 ± 1	9 ± 1	38 ± 14	73 ± 22	353 ± 65	376 ± 63

TABLE 5

BACTERIOLOGICAL QUALITY OF BUTTER STORED FOR SIX MONTHS AT 5–10°F

Cream Quality	Bacteriological Quality (colonies/ml)							
	Total Count (Mean) (,000)		Casein Digesters (Mean) (,000)		Coliforms (Mean)		Yeasts and Moulds (Mean)	
	Tandem	Triple	Tandem	Triple	Tandem	Triple	Tandem	Triple
Sound choice ..	43 ± 8	160 ± 46	5 ± 1	9 ± 3	0	16 ± 11	50 ± 13	63 ± 16
Fair choice ..	107 ± 27	179 ± 34	10 ± 1	10 ± 1	3 ± 1	5 ± 2	116 ± 52	155 ± 48
Borderline choice	103 ± 33	96 ± 23	10 ± 1	8 ± 1	2 ± 1	3 ± 1	131 ± 53	115 ± 46

TABLE 6

BACTERIOLOGICAL QUALITY OF BUTTER STORED FOR FOUR WEEKS AT 45–55°F

Cream Quality	Bacteriological Quality (colonies/ml)							
	Total Count (Mean) (,000)		Casein Digesters (Mean) (,000)		Coliforms (Mean		Yeasts and Moulds (Mean)	
	Tandem	Triple	Tandem	Triple	Tandem	Triple	Tandem	Triple
Sound choice ..	129 ± 29	158 ± 33	9 ± 2	9 ± 2	12 ± 3	10 ± 2	403 ± 110	506 ± 115
Fair choice ..	203 ± 39	196 ± 30	8 ± 1	8 ± 2	51 ± 14	35 ± 7	346 ± 62	358 ± 114
Borderline choice	121 ± 21	148 ± 31	10 ± 1	9 ± 2	17 ± 3	16 ± 5	416 ± 81	214 ± 53

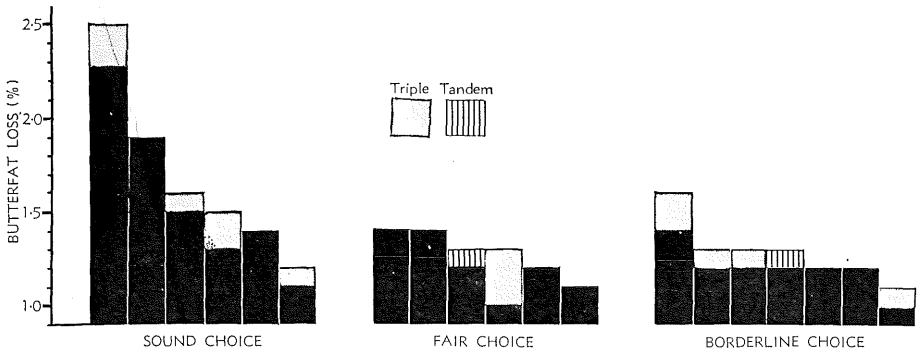

Fig. 1.—Histograms showing butterfat losses in creams of various qualities submitted to triple and tandem vacreation. (Common butterfat loss represented by solid area.)

The two high losses for sound choice creams for both treatments were from creams with residual pH levels slightly higher than other churnings (e.g. 7·6-7·8, in contrast with 7·4) and from creams with butterfat contents 2-3 per cent. lower than normal. These factors probably accounted for the higher losses.

(f) Butter Grading

Grading results for all churnings, together with a general comment on defects, are summarized in Table 7.

As the amount of butter scored true-to-grade is a factory criterion for assessing the suitability of cream grading and processing techniques, grading results for this investigation were reported also in this manner.

It was found that there was little difference in the mean points score and the number of true-to-grade churnings with butter from sound and fair choice cream after tandem and triple treatments. This similarity was evident for both fresh and stored butters.

A better quality butter, both fresh and stored, was manufactured from borderline choice cream processed in the triple unit than from similar cream treated in the tandem unit. While the mean points score of fresh samples for both treatments was similar, the one true-to-grade churning for tandem treatment in contrast to the four true-to-grade churnings for triple treatment indicated that this cream processed by the tandem treatment yielded a butter slightly lower than choice quality.

Although every endeavour was made to eliminate weed taints from raw cream supplies, two churnings of sound choice and one churning each of fair and borderline choice contained weed off-flavours. This incidence of taint in the small number of trial churnings prepared in each cream class influenced the comparative nature of the trial treatments both in the number of true-to-grade churnings and in the mean points score.

TABLE 7

BUTTER GRADING RESULTS OF CREAMS PROCESSED BY TANDEM AND TRIPLE VACREATION

Cream Quality	Storage Conditions	Total Churnings	Butter Quality					
			True to Grade		Mean Points Score		Grading Comments	
			Tandem	Triple	Tandem	Triple	Tandem	Triple
Sound choice ..	Fresh	6	3	4	92·6	92·8	Trace to very slight weed (2)	Trace to very slight weed (2)
Fair choice ..	..	6	5	5	93·0	92·8	Very slight weed (1)	Very slight weed (1)
Borderline choice	..	7	1	4	92·4	92·6	Very slight to slight unclean Very slight stale Very slight weed (1)	Very slight unclean Very slight stale Very slight weed (1)
Sound choice ..	6 months at 5–10°F	6	2	1	92·1	92·3	Very slight weed (1) Very slight unclean Slight stale	Very slight weed (1) Very slight unclean Very slight stale
Fair choice ..	..	6	1	1	92·1	92·0	Very slight to slight unclean Very slight to slight stale	Very slight to slight unclean Slight stale
Borderline choice	..	7	1	1	91·4	92·1	Very slight to slight unclean Very slight to slight stale Trace fermented Very slight weed (1)	Very slight to slight unclean Slight stale
Sound choice ..	4 weeks at 45–55°F	6	1	2	92·1	91·9	Very slight weed (1) Very slight stale Very slight unclean	Very slight weed (1) Very slight to slight stale
Fair choice ..	..	6	3	3	92·3	92·4	Slight unclean Slight stale in 3 churns Very slight weed (1)	Very slight unclean Very slight stale in 3 churns Very slight weed (1)
Borderline choice	..	7	0	3	91·2	92·0	Very slight to slight unclean Very slight to slight stale Very slight weed (1)	Very slight to slight stale Very slight weed (1)

IV. DISCUSSION

(a) Pasteurization Efficiency

The results of the bacteriological quality of pasteurized cream in this investigation support the findings of Muller (1951). He reported satisfactory bactericidal efficiency when temperatures in excess of 200°F were used for processing cream in a solo "Vacreator". The lower counts obtained in cream after processing in the tandem unit (a combination of a solo heating unit and a deodorization cooling section) at a temperature of 208°F indicated that these temperatures are adequate for pasteurization of cream for buttermaking. Pin-point colonies on the agar plates characterized the surviving organisms, which were considered to be inert thermoduric bacteria.

The greater bactericidal effect of the triple vacreation demonstrated in this trial could be a consequence of the increased time-temperature conditions of treatment. However, as the counts obtained on cream treated in the tandem unit were considered satisfactory, no practical advantage in pasteurization can be claimed for the more intensive treatment.

(b) Deodorization Efficiency

Efficiency of taint removal in multiple-vessel "Vacreator" deodorization equipment has been expressed by Scott (1954) in terms of the following formula.

$$\text{Percentage taint remaining} = 100 \times \frac{1}{1 + \frac{mv}{L}}$$

where m = equilibrium constant
v = outflow of steam (lb/hr)
L = inflow of liquid (lb/hr)

He has further proposed (Scott 1959) equilibrium constants of $m = 15$-20 for creams in which taints are highly volatile (sound choice), $m = 10$ where taints are of average volatility (fair choice), and $m = 5$ for creams characterized by taints of low volatility which are often associated with acid cream or poor quality cream.

Applying these theoretical considerations to the conditions of treatment in this investigation, the following residual taint concentrations were calculated.

Processing Treatment	Cream Quality	Percentage of Initial Taint Remaining
Tandem	Sound choice ..	15
	Fair choice	24
	Borderline choice ..	43
Triple	Sound choice ..	7
	Fair choice	13
	Borderline choice ..	30

Organoleptic grading results on fresh and stored butters manufactured from sound and fair choice creams revealed no difference in quality for tandem and triple treatment. With the exception of three weed-tainted consignments, eight of the nine remaining fresh churnings of sound and fair choice cream scored true-to-grade. Riddett *et al.* (1939) reported similar findings on New Zealand butters, where with finest quality cream the more intensive deodorization obtainable with tandem vacreation in comparison with flash-pasteurization made no significant difference in the resultant butter quality. This suggests that where weed flavour is absent, carry-over of taint contamination into processed creams of concentrations up to 25-30 per cent. of the initial level will pass undetected by senses grading in fresh butters. As the partial distribution coefficients between butterfat and serum of the various tainting substances are unknown, the quantity present in the subsequent butter could not be calculated. With borderline choice creams, triple vacreation ensured a greater number of churnings of butter scoring choice rating. Because of the small number (7) of comparative churnings available, this advantage has been examined in further trials and results will be reported in a subsequent paper. With tandem treatment, four of six degraded churnings scored 92½ points, indicating that the estimated level of taint contamination retained, viz. 40 per cent., was a threshold concentration for down-grading.

Butter deterioration in storage was generally greater with lower quality creams. The overall loss of points score of 0·5 to 1·0 points with butter from borderline choice creams was of a slightly lower order than that reported by Crittall (1957) of 1·5 to 2·0 points in investigations with choice creams of similar quality.

The influence of the relatively high bacterial content on the quality of stored butter is unknown. However, all butter exhibited a satisfactory dispersion of moisture when manufactured and in this condition the bacterial population should not impair the flavour of butter to any marked extent.

Along with increased steam consumption with triple vacreation of cream, it was possible to treat the cream at a much faster rate and maintain butter quality. This is an economic consideration where large total quantities of cream must be processed daily.

(c) Butterfat Losses

Dolby (1957) reported that breaking-up of fat globules occurs in those parts of the "Vacreator" where a mixture of steam and cream attains a high velocity. Levels of fat lost in the buttermilk for the two treatments of the same cream in this trial were similar. However, a comparison of lb of steam injected per lb of cream in the pasteurization legs of the two treatments revealed a close similarity (Table 8) and could explain the identical level of losses with the two treatments. The conditions of turbulence obtained in Leg 1 and Leg 2, respectively, of the triple unit were of a similar magnitude to those applied in the single pasteurization leg of the tandem unit.

TABLE 8

QUANTITY OF "WASH" STEAM USED IN TANDEM AND TRIPLE VACREATION

Treatment	lb "wash" steam/lb cream			
	Pasteurization Leg 1	Pasteurization Leg 2	Cooling Leg 3	Total
Tandem	..	·16	·06	·22
Triple	·10	·15	·05	·30

A similar quantity of flash steam was generated in the cooling section of both machines.

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