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STUDIES ON THE CLARIFICATION OF MILK---II

By B. W. HAMMER
and A. J. HAUSER

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
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STUDIES ON THE CLARIFICATION OF MILK—II

By B. W. Hammer and A. J. Hauser.

In a former publication of this station[1] the results obtained in a study of the clarification of milk with the DeLaval clarifier are presented. The data show: first that commonly, altho by no means constantly, the plates poured from clarified milk contained a larger number of colonies than plates poured from unclarified milk of the same lot; this was undoubtedly due to a breaking up of the clumps of organisms and should be spoken of as an apparent increase since the large number of bacteria in the slime indicates that there was actually an elimination of organisms; second, that there was in every case a decrease in the number of cells during clarification; third, that the clarifier slime contained a large number of bacteria and cells in addition to a variable amount of dirt and sometimes red blood cells. The publication pointed out that, while it must be admitted it would be desirable to prevent foreign material from getting into milk, this is impossible for the great bulk of our milk supply because of the increased cost of production and that accordingly clarification of milk followed by efficient pasteurization must be looked upon as a commendable substitution.

Hinkelman[2] reported data secured when milk on the point of souring, water, bouillon cultures of various organisms, milk containing streptococci and milk containing typhoid bacilli were passed thru a De Laval clarifier. In every case there was a reduction in the bacterial content. Hinkelman, "could not help but be convinced of the greater density of the pathogenic organisms, especially the gram positive ones"; he secured greater reductions with the pathogens than with the saprophytes.

Traum and Hart[3] found, "that clarification of milk naturally infected with tubercle bacilli fails to render it innocuous to guinea pigs." These authors examined fourteen samples of clarified milk and all but three produced tuberculosis in all of the pigs inoculated; of these three samples, one caused death by sep-

1. Studies on the clarification of milk. B. W. Hammer, Res. Bull., Ia. Agr. Expt. Sta. 28:17, Ja. 1916
2. Micro-organic weight. Ill. Med. Jr. **29**: 202 Mr. 1916
3. Jr. Am. Vet. Med. Assn. **49** N. S. **2**: 678 Ag. 1916

ticaemia of both pigs inoculated while with each of the other two, one pig died of tuberculosis while the other died soon after inoculation. Of twenty-four samples of unclarified milk all but five produced tuberculosis in all the pigs inoculated; two of the five samples each caused tuberculosis in one pig while the other remained well and the remaining three each caused tuberculosis in one pig while the other died soon after inoculation.

Bohlman[4] compared the bacterial content of milk before and after clarification and in eight cases found a higher count on the clarified milk, the increases varying from 9 to 60 per cent and averaging 27 per cent. This author also reported, "that examinations of representative portions of the sludge showed: moisture 60.0 per cent; solid matter, 40.0 per cent; bacteria per gram, 950,000,000."

McClintock[5] reported data showing the influence of clarification on the bacterial content of milk, three different machines being used. In all but three of the fifty-nine trials there was a reduction in the number of bacteria.

Hastings[6] discussed clarification and objected to ordinances requiring it because they represent instances of the passage under recommendation of health officials of legislation which has no relation to public health.

Parker[7] has recently discussed clarification and reported data (two different machines being used) secured at the Boston biochemical laboratory showing the bacteria per c. c. in unclarified and clarified milk. A number of comparisons showed decreases due to clarification and a slightly larger number show increases.

The action of clarifiers has been discussed in the trade papers and in advertisements and frequently in such a way as to give the reader exaggerated ideas of the value of the process. Experiments[8] have been reported in which sterile milk was inoculated with pathogenic organisms, after which the milk was passed thru a clarifier with the result that all or nearly all of the organisms were eliminated. The use of milk heated to a sterilization temperature for such experiments makes the results entirely valueless from a practical viewpoint because the physical condition of the fat in heated milk is so very different

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4. Milk Clarifiers. Am. Jr. Pub. Health **4**: 854 Ap. 1916; also partly reported in The Creamery and Milk Plant Monthly. **5**: 41 S. 1916
5. An Investigation of Clarification of Milk. The Milk Trade Jr. **4**: 8 Ap. 1916
6. Jr. Am. Med. Assn. **68**: 899 Ap. 24, 1917
7. City Milk Supply. H. N. Parker, p. 256, 1917
8. Further Investigations Upon the Clarification of Milk. J. Arthur McClintock. The Milk Trade Journal. **4**: 64, S. 1916

from that in raw. The fat globule clusters that are present in the raw milk are broken up when temperatures which will effect the sterilization of the milk are employed and accordingly can no longer enmesh and hold back materials which would otherwise be thrown out by the centrifugal force developed.

Milk dealers in general have shown a great deal of interest in clarification and clarifiers have undoubtedly assumed a very important place in the modern milk plant. Certain cities have adopted regulations requiring the clarification of the milk sold within their limits; this has been pointed to as an indication of the value of the process and has thus played an important part in bringing about the increasing use of clarifiers.

Because of the great differences in the construction of the Sharples and DeLaval clarifiers it seemed desirable to continue the studies on clarification by carrying out on the former machine experiments analogous to those carried out on the latter; the results secured on the Sharples machine are presented in the present paper.

METHODS.

The tests were carried out on a No. 9A Sharples clarifier of a capacity of 950 lbs. per hour, the machine being electrically driven. The samples were collected from a clarifier running in the market milk department, as was the case with the DeLaval machine, so that the results would represent practical rather than laboratory conditions. The bowl, tank and other parts coming in contact with milk were thoroly steamed before assembling and the machine can be eliminated as a source of contamination. The unclarified samples were taken from the tank after the contained milk had been thoroly agitated with a carefully steamed stirrer while the clarified samples were collected as the milk flowed from the machine. The temperature taken in the tank was the recorded temperature of the milk; it usually left the machine at approximately the same temperature at which it entered altho there was sometimes a variation of 1 or 2°F. The speed of the machine was practically always within one revolution of the crank of that recommended.

All the bacterial counts were made by the plate method, agar containing 5 per cent peptone, 3 per cent beef extract and 1.5 per cent agar shreds and with a reaction between +.5 per cent and +1.0 per cent being used as the plating medium. The plates were incubated for 2 days at 37°C and the results recorded represent the average of two plates except in a very few instances where one of the plates was unsatisfactory.

All fat tests were made by the Babcock Method.

RESULTS OBTAINED.

1. Influence of Clarification on the Bacterial Content of Milk.

As in the previous work reported by this station, in discussing the influence of clarification on the bacterial content of milk, increases in the number of colonies developing on the plates will be spoken of as increases in the bacterial content, altho it is recognized that these are only apparent increases due to the breaking up of the clumps of bacteria.

The data obtained with the Sharples clarifier on the influence of clarification on the bacterial content of milk are presented in tables I, II, and III. Table I deals with samples containing less than 100,000 organisms per c. c. originally, table II with samples containing between 100,000 and 500,000 per c. c. originally and table III with samples containing more than 500,000 per c. c. originally.

Fifty-two comparisons of the bacterial content of unclarified and clarified milk were made on milk containing originally less than 100,000 bacteria per c. c. (table I). In one case (2 per cent) the bacterial content before and after clarification was the same, in eight cases (15 per cent) there was a decrease during clarification varying from 2 to 43 per cent and averaging 16 per cent, while in the remaining 43 cases (83 per cent) there was an increase varying from 1 to 767 per cent and averaging 85 per cent. Considering the 52 comparisons there was an average increase in the bacterial content during clarification of 68 per cent.

Nine comparisons were made on milk containing originally from 100,000 to 500,000 bacteria per c. c. (table II); in seven cases (78 per cent) there was a decrease varying from 9 to 55 per cent and averaging 19 per cent while in only two cases (22 per cent) was there an increase, one of 27 per cent and one of 44 per cent, the average being 35 per cent. If the nine comparisons are considered, there was an average decrease in the bacterial content during clarification of 7 per cent.

Thirty-two comparisons were made on milk containing originally over 500,000 bacteria per c. c. (table III); in 17 cases (53 per cent) there was a decrease varying from 1 to 31 per cent and averaging 14 per cent, while in 15 cases (47 per cent) there was an increase varying from 31 to 50 per cent, and averaging 13 per cent. If the entire 32 comparisons are considered there was an average decrease in the bacterial content during clarification of 1 per cent.

From the data presented in tables I, II, and III, it is evident that with the Sharples clarifier, as with the DeLaval clarifier, clarification of milk commonly results in an increase in the number of colonies developing on agar plates. In view of the fact

that the clarifier slime contains large numbers of bacteria, this is an apparent rather than a true increase and is due to the breaking up of clumps of bacteria during the agitation in the clarifier. As a consequence of the breaking up of the masses of bacteria a clump, which before clarification would have given rise to only one colony on a plate used in determining the number

TABLE I—BACTERIA PER C. C. BEFORE AND AFTER CLARIFICATION.

Original Count Under 100,000 per c. c.

Temperature of Milk	Percentage of Fat in Milk	Bacteria per c. c. Before Clarification	Bacteria per c. c. After Clarification	Percentage Change in Number
53	4.0	38,000	43,000	13
63	4.2	92,500	88,000	— 5
54	3.6	19,500	11,500	— 4
60	4.0	37,500	40,500	8
45	4.0	12,500	13,500	8
46	4.3	29,500	20,000	—32
45	5.0	10,000	13,500	35
46	4.6	12,000	16,000	33
53	4.0	63,000	78,000	24
44	----------	41,000	39,000	— 5
47	----------	33,000	50,000	52
55	4.0	73,500	59,500	—19
75	4.1	64,000	83,500	30
63	4.1	52,000	29,500	—43
65	4.1	81,000	120,500	49
45	4.6	8,400	17,250	105
45	4.6	10,950	10,700	— 2
46	3.9	4,500	10,350	130
45	5.2	6,800	10,050	48
43	3.8	3,100	7,200	132
41	4.6	6,250	7,550	21
64	3.4	41,000	50,000	22
40	----------	15,700	23,050	47
53	----------	6,900	40,000	480
53	----------	7,750	19,250	148
70	3.8	9,800	10,950	12
64	4.2	19,750	21,600	9
46	4.7	4,300	11,100	158
47	4.7	11,450	14,900	30
61	3.8	4,050	8,500	110
43	3.9	2,400	4,400	83
65	4.0	6,400	55,500	767
53	4.0	8,050	21,850	171
53	3.8	27,500	39,950	45
63	3.8	29,500	29,500	0
53	3.9	22,600	34,650	53
66	3.8	12,800	27,950	118
43	4.9	11,050	20,400	85
46	4.5	10,500	56,000	43
40	3.4	60,000	60,500	1
56	3.7	23,000	38,000	65
67	----------	17,250	18,450	7
47	----------	13,850	11,200	—19
43	----------	37,500	46,000	23
60	3.7	46,000	69,000	50
62	----------	29,000	38,000	31
68	----------	55,500	64,000	15
51	----------	94,000	114,000	21
46	4.4	5,100	9,200	80
50	----------	8,600	23,500	173
47	----------	18,150	25,550	41
45	----------	13,300	24,550	85

TABLE II—BACTERIA PER C. C. BEFORE AND AFTER CLARIFICATION.

Original Count from 100,000 to 500,000 per c. c.

Temperature of Milk	Percentage of Fat in Milk	Bacteria per c. c. Before Clarification	Bacteria per c. c. After Clarification	Percentage Change in Number
65	4.5	102,500	130,000	27
63	4.8	415,000	350,000	—16
65	----------	150,500	215,000	44
64	3.9	264,000	241,000	— 9
39	3.9	106,000	94,000	—11
54	4.2	142,000	116,000	—18
50	3.4	197,500	166,500	—16
54	3.5	189,000	171,000	—10
45	----------	126,000	56,500	—55

TABLE III—BACTERIA PER C. C. BEFORE AND AFTER CLARIFICATION.

Original Count Over 500,000 per c. c.

Temperature of Milk	Percentage of Fat in Milk	Bacteria per c. c. Before Clarification	Bacteria per c. c. After Clarification	Percentage Change in Number
66	----------	1,790,000	1,685,000	— 6
63	----------	3,490,000	2,920,000	—16
62	----------	1,075,000	1,240,000	15
62	----------	1,380,000	1,610,000	17
51	3.5	2,810,000	2,325,000	—17
57	4.0	1,410,000	1,130,000	—20
55	4.0	2,795,000	2,480,000	—11
63	3.8	3,405,000	2,355,000	—31
66	4.0	5,345,000	4,280,000	—20
70	3.8	5,100,000	6,000,000	20
56	----------	6,055,000	5,670,000	— 6
59	----------	3,815,000	4,305,000	13
64	4.0	3,400,000	3,520,000	4
66	3.9	18,150,000	14,600,000	—20
50	4.1	1,090,000	990,000	— 9
51	3.6	6,130,000	5,125,000	—16
62	3.5	10,330,000	8,990,000	—13
52	----------	16,000,000	17,050,000	7
63	----------	15,900,000	16,300,000	3
36	----------	23,950,000	22,050,000	— 8
37	----------	34,100,000	29,600,000	—13
42	----------	9,200,000	9,500,000	3
52	----------	4,000,000	4,950,000	24
54	3.3	9,900,000	10,550,000	7
65	3.2	12,400,000	18,600,000	50
66	----------	17,350,000	19,900,000	15
60	----------	10,350,000	11,050,000	7
52	----------	9,350,000	7,750,000	—17
48	----------	16,100,000	16,700,000	4
52	3.5	20,900,000	22,000,000	10
73	3.8	855,000	697,000	—18
----------	----------	6,000,000	5,950,000	— 1

TABLE IV—CELLS PER C. C. BEFORE AND AFTER CLARIFICATION.

Temperature of Milk	Percentage of Fat in Milk	No. Cells Before Clarification	No. Cells After Clarification	Percentage of Cells Thrown Out
55	4.0	292,000	159,000	46
63	3.8	194,000	143,000	26
66	4.0	280,000	135,000	52
70	3.8	372,000	215,000	42
56	----------	290,000	122,000	58
65	----------	640,000	476,000	26
59	----------	725,000	386,000	47
64	3.9	810,000	322,000	60
64	4.0	940,000	496,000	47
75	4.1	404,000	217,000	46
66	3.9	519,000	384,000	26
53	4.0	196,000	168,000	14
55	3.9	322,000	147,000	54
63	4.2	237,000	185,000	22
50	4.1	329,000	255,000	22
54	3.6	202,000	103,000	49
60	4.0	218,000	165,000	24
45	4.0	274,000	141,000	49
46	4.3	240,000	156,000	35
45	5.0	122,600	66,000	46
46	4.6	104,000	80,000	23
53	4.0	291,000	243,000	16
39	3.9	316,000	259,000	11
44	----------	196,000	98,000	50
47	----------	170,000	135,000	21
54	4.2	239,000	84,000	65
65	4.1	205,000	122,000	40
45	4.6	228,000	160,000	30
45	4.6	247,000	200,000	19
46	3.9	324,000	123,000	62
45	5.2	322,000	72,000	78
51	3.6	115,000	68,000	41
62	3.5	191,000	105,000	45
73	3.8	191,000	100,000	48
64	3.8	270,000	194,000	28
43	3.8	117,000	65,000	44
41	4.6	178,000	121,000	32
64	3.4	97,000	62,000	36
52	4.4	75,000	45,000	40
40	----------	289,000	173,000	40
43	----------	265,000	128,000	52
53	----------	207,000	155,000	25
53	----------	250,000	182,000	27
70	3.8	573,000	340,000	41
64	4.2	225,000	141,000	37
46	4.7	377,000	234,000	38
47	4.7	262,000	155,000	41
61	3.8	90,000	56,000	38
43	3.9	165,000	66,000	60
60	3.8	611,000	317,000	48
65	3.7	533,000	248,000	53
65	4.0	88,000	55,000	37
53	4.0	135,000	72,000	47
53	3.9	87,000	51,000	41
66	3.8	84,000	50,000	40
43	4.9	393,000	239,000	39
56	3.7	351,000	243,000	31
58	3.5	207,000	89,000	57
57	3.2	127,000	47,000	63
50	3.4	721,000	261,000	64
54	3.5	406,000	238,000	41
60	3.7	858,000	354,000	59
62	----------	666,000	520,000	22

of organisms, gives rise to several colonies and an apparent increase in the number of bacteria is thus effected. It is evident that the numbers and types of clumps have a very important influence in determining the nature and extent of the changes in the bacterial content as a result of the clarification and accordingly the results obtained with different clarifiers cannot be compared unless the trials with the various machines are made with milk from the same lots. It is worthy of note, however, that in our experiments the Sharples clarifier gave a much higher percentage of increases in the milk with a fairly low original count (83 per cent when the original count was under 100,000 per c. c.) than in the milk with a high original count (22 per cent where original count was from 100,000 to 500,000 per c. c. and 47 per cent where it was over 500,000 per c. c.). The data given in tables I, II and III indicate that there is no definite relationship between the effect of clarification and such factors as the percentage of fat or the temperature of clarification. This lack of relationship was also noticed in the previously reported studies on the DeLaval clarifier and indicates that other factors, such as the number and size of the clumps are of greater importance in determining the influence of clarification on the bacterial content than are the factors here considered.

2. Influence of Clarification on the Cell Content of Milk.

The influence of clarification with the Sharples clarifier on the cell content of milk was studied by determining the number of cells present before and after clarification; the cell determinations were made by the Doane-Buckley method, the samples of milk being heated before centrifuging. The results obtained are presented in table IV.

In all of the 63 samples of milk studied, clarification caused a decrease in the cell content. The percentage of cells thrown out varied from 11 to 78 per cent and averaged 41 per cent. There seems to be no definite relationship between the percentage of cells removed and such factors as the temperature of clarification or the per cent of fat present. Because of the influence of temperature on the viscosity of milk, it would be expected that clarification would be less efficient at the lower temperature and in agreement with this table IV shows one test in which with a temperature of 39°F. only 11 per cent of the cells were removed; however the next trial gave an elimination of 50 per cent of the cells with a clarification temperature of 44°F. So the relationship between the temperature of clarification and the number of cells removed is far from direct. The number and structure of the fat globule clusters in all probability play a very

important part in retaining cells and other materials during clarification and these factors undoubtedly overshadow the influence of temperature.

The cell content of the unclarified milk varied from 75,000 to 940,000 per c. c. and averaged 308,788 per c. c. while the cell counts on the clarified milk varied from 45,000 to 520,000 per c. c. and averaged 187,635 per c. c.; the difference between the average cell content per c. c. of the unclarified and the average cell content per c. c. of the clarified milk was 131,143.

3. The Numbers of Bacteria and Cells Present in Clarifier Slime.

The number of bacteria and leucocytes per gram was determined in 14 samples of clarifier slime. The gram samples were weighed out on a same platform scale instead of on a chemical balance because it seemed desirable to sacrifice accuracy in weighing in order to minimize the loss of water and contamination from the air. Each sample was weighed on a sterile paper which rested on a larger sterile paper and was transferred to the dilution water by transferring the smaller paper. The cell counts were made by means of a Thoma-Zeiss blood cell counting apparatus on the suspension resulting from adding the gram sample to 100 c. c. of sterile water. The results secured on the clarifier slime are presented in table V.

The bacterial content of the slime ran from 7,800,000 to 5,210,000,000 per gram. The bacterial content of the milk from which each lot of slime was secured was rated in a general way as high, medium or low, the rating being based on the bacterial content of one or more samples from each run and previous knowledge of the sanitary quality of the milk furnished by the producer. The bacterial content of the milk rated as high was over

TABLE V—BACTERIA AND LEUCOCYTES IN CLARIFIER SLIME.

Rating of Bacterial Content of Milk	Bacteria Per Gm.	Leucocytes Per Gm.
High*	5,000,000,000	173,000,000
Low**	7,800,000	362,000,000
Low	16,750,000	270,000,000
High	3,455,000,000	125,000,000
High	3,485,000,000	110,000,000
Low	7,800,000	267,000,000
High	4,200,000,000	57,000,000
Low	11,050,000	252,000,000
Low	11,700,000	584,000,000
Medium***	700,000,000	397,000,000
High	5,210,000,000	658,000,000
Medium	83,500,000	376,000,000
Low	28,500,000	306,000,000
Medium	157,000,000	369,000,000

*High—over 500,000 per c. c.
**Low—probably under 100,000 per c. c.
***Medium—probably between 100,000 and 500,000 per c. c.

500,000 per c. c., of that rated as medium probably between 100,000 and 500,000 and of that rated as low probably under 100,000 per c. c. It would be expected that the bacterial content of slime from milk running high in bacteria would be higher than from milk running low in bacteria but it is evident that the amount of dirt, the number of cells, etc., might influence very materially any expected relationship. In the results presented in table V, there is a very evident direct relationship between the bacterial content of the slime and that of the milk from which the slime was secured. No such relationship existed in the data secured on the DeLaval clarifier; whether this lack of relationship was due to the interference of constituents of the slime other than bacteria, it is impossible to say.

The number of leucocytes per gram of slime varied from 57,000,000 to 658,000,000. It is evident that the leucocyte content of the milk would be a very important factor in determining the leucocyte content of the slime, altho the presence of other constituents in the slime in excessive amounts would necessarily tend to lower the leucocyte content.

4. Influence of Clarification on the Numbers of Bacteria Present after Pasteurization.

The influence of clarification on the numbers of bacteria present after pasteurization was studied by collecting samples before and after clarification in thoroly steamed bottles, capping the bottles with sterilized crown seals, immersing them during one of the regular runs of the pasteurizing vat used in the market milk department and then determining the numbers of bacteria present, either immediately after cooling or after holding the samples several hours in ice water. The final package method of pasteurization was employed to eliminate the agitation incident to other methods of pasteurization which might have affected the bacterial count by the breaking up of clumps of bacteria. The results obtained are presented in table VI.

In 14 (70 per cent) of the 20 comparisons, the bacterial content of the clarified pasteurized milk was higher than that of the unclarified pasteurized milk, in four (20 per cent) it was lower, and in the remaining two (10 per cent) comparisons the bacterial content of the clarified pasteurized milk was the same as the bacterial content of the unclarified pasteurized milk. In a considerable number of the comparisons the differences between the bacterial content of the clarified pasteurized and unclarified pasteurized milks were so small that they were very likely the result of experimental error; the decreases due to clarification varied from 5 to 200 bacteria per c. c., while the increases varied from 5 to 5,250 per c. c.

TABLE VI—INFLUENCE OF CLARIFICATION ON THE NUMBER OF BACTERIA PRESENT AFTER PASTEURIZATION.

Bacteria per c. c. when Unclarified	Bacteria per c. c. when Clarified	Influence of Clarification
205	255	50*
385	330	— 5*
340	140	—200
330	360	30
55	55	30
125	145	20
1195	1205	10
345	350	5
45	45	0
165	285	120
55	55	0
45	35	—10
750	6000	5250
105	200	95
85	115	30
290	195	—95
320	535	215
50	130	80
70	95	25
100	255	155

*No sign, an increase; —, a decrease.

It will be seen from table VI that in general the counts on the pasteurized milk ran very low. This is due to the very efficient method of pasteurization employed and to the quality of the raw milk used. While the bacterial content of the milk before pasteurization was not determined, a good idea of this was furnished by a determination of the bacterial content of milk supplied by the same producer on the same day and it was evident that, with two exceptions, the bacterial content of the raw milk was under 100,000 per c. c. while commonly it was under 40,000 per c. c. Since in the majority (83 per cent) of the tests carried out on milk running under 100,000 bacteria per c. c., clarification caused an apparent increase in the number of bacteria, it would be expected that in most of the comparisons the bacterial content of the clarified pasteurized milk would be higher than that of the unclarified pasteurized milk. In 70 per cent of the 20 comparisons the bacterial content of the pasteurized milk was increased by clarification. This, considering the smaller number of trials and the fact that in two instances the bacterial content of the milk before clarification was considerably above 100,000 per c. c., agrees reasonably well with the percentage (83 per cent) representing the cases in which the bacterial content of milk containing originally under 100,000 per c. c. was increased by clarification. There was a decrease in the bacterial content of the clarified pasteurized milk as compared with unclarified pasteurized milk in 20 per cent of the trials, and with milk containing less

than 100,000 bacteria per c. c. clarification caused a decrease in the bacterial content in 15 per cent of the comparisons; the percentages in which clarification had no influence were 10 per cent for the pasteurized and 2 per cent for the raw.

While the influence of clarification alone on the milk referred to in table VI was not studied, the influence of clarification was usually determined on two lots of milk supplied by the same producer on the same day. Ordinarily clarification had the same general effect in these trials as both clarification and pasteurization (as reported in table VI) when compared with pasteurization alone and commonly, altho by no means constantly, big percentage increases due to clarification, were accompanied by big increases due to clarification and pasteurization over pasteurization alone.

5. The Clarifier Slime.

Bacteria and cells are present in clarifier slime in large and extremely variable numbers. In addition clarifier slime contains materials foreign to milk, such as dirt, hair and bits of grain, which commonly gain entrance during milking and handling of the milk. As with the DeLaval clarifier, red blood cells were occasionally observed in the slime when the milk passing thru the machine showed no evidence of blood to the usual examination. Clarifiers are undoubtedly very efficient in removing materials foreign to milk, but that such materials are not completely removed is shown by sediment tests run on clarified milk. Ordinarily such tests demonstrate the presence of slight amounts of sediment. The presence of small amount of sediment in clarified milk is also evident when such milk is centrifuged after being heated as in the determination of the number of cells contained. The sediment present in clarified milk is undoubtedly retained by being enmeshed by the fat globule clusters, the low specific gravity of the fat more than compensating for the increased specific gravity of the sediment; it is likely also that with certain materials the specific gravity is not high enough to carry the materials to the wall of the bowl.

The amount of slime per 100 pounds of milk was found to be extremely variable as was the case with the DeLaval clarifier. This is to be expected because of the varying amount of care used by different producers and also by the same producer on different days.

6. Influence of Clarification on the Creaming Ability.

The influence of clarification with the DeLaval clarifier on the creaming ability has already been reported by this station[9], the

[9]Studies on the Creaming Ability of Milk, B. W. Hammer. Res. Bull. Ia. Agr. Expt. Sta. 31:79, Jan., 1916.

creaming ability as measured in tubes held in ice water was slightly less with the clarified than with the unclarified milk but the decrease was so small in amount that it was of no importance from the standpoint of bottled milk.

The effect of clarification with the Sharples clarifier on the creaming ability was studied by holding the milk in Nessler tubes filled to a depth of nine inches and also by holding milk in bottles; in either case standard conditions (ice water temperature and a holding period of approximately 24 hours) were employed, altho in a few instances the holding period was increased to 48 hours. The unit used in recording the depth of the cream layer in tubes was the sixteenth of an inch and the readings were recorded only to the nearest half unit.

The influence of clarification on the creaming ability of raw milk allowed to cream in tubes is shown in table VII. In three (14 per cent) of the 21 comparisons clarification had no effect, while in 18 (86 per cent) of the trials it caused decreases varying from .5 to 3 and averaging 1.6 sixteenths of an inch; if the total

TABLE VII—INFLUENCE OF CLARIFICATION ON THE CREAMING ABILITY—RAW MILK.

Depths of Cream Layer in Sixteenths of an Inch.

Unclarified	Clarified	Unclarified	Clarified
24.5	22.0	23.0	23.0
20.0	19.5	19.0	19.0
24.0	23.0	21.0	19.5
22.5	19.5	20.0	18.5
25.0	22.0	17.0	16.0
19.0	17.5	20.5	19.5
21.5	21.5	18.5	18.0
19.0	17.5	24.0	22.5
21.0	19.5	19.0	17.5
24.0	21.0	19.5	18.0
19.0	18.0		

TABLE VIII—INFLUENCE OF CLARIFICATION ON THE CREAMING ABILITY—PASTEURIZED MILK.

Depth of Cream Layer in Sixteenths of an Inch.

Unclarified	Clarified	Unclarified	Clarified
25.0	23.0	26.5	25.0
20.0	19.0	22.5	21.5
26.0	25.0	24.0	24.0
22.5	20.5	22.5	22.5
22.5	22.0	24.5	22.5
25.0	25.0	21.5	21.0
23.0	21.5	21.5	20.5
23.5	23.5	24.0	22.5
21.0	20.5	19.5	18.5
23.0	22.0	19.0	19.0
21.5	20.5	19.0	19.0

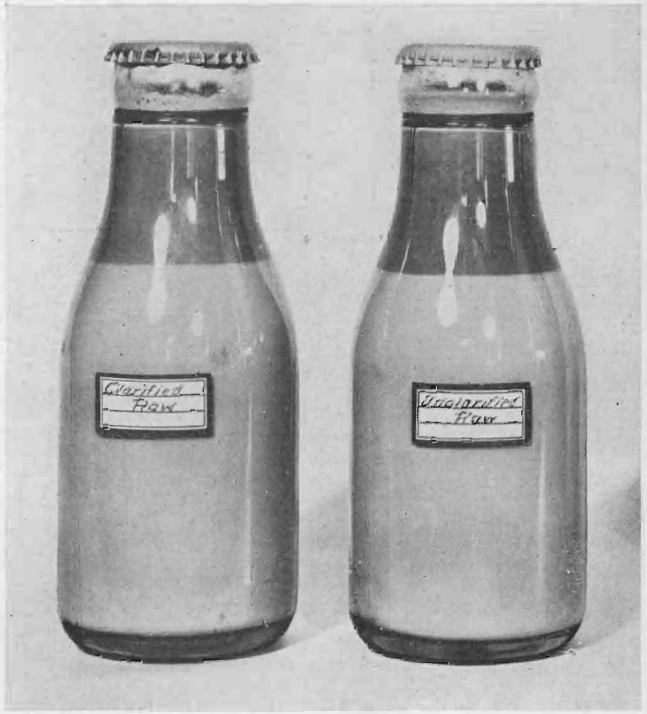

FIG. 1. Cream Layers in a Bottle of Raw Unclarified and a Bottle of Raw Clarified Milk of the Same Lot.

FIG. 2. Cream Layers in a Bottle of Pasteurized Unclarified and a Bottle of Pasteurized Clarified Milk of the Same Lot.

21 comparisons are considered there is an average decrease of 1.4 sixteenths of an inch.

Table VIII shows the influence of clarification on the creaming ability of pasteurized milk allowed to cream in tubes. Clarification had no effect on the creaming ability in six (27 per cent) of the 22 trials while in 16 (73 per cent) it caused decreases varying from .5 to 2 and averaging 1.2 sixteenths of an inch; clarification caused an averaged decrease in the depth of the cream layer of .9 sixteenths of an inch if the total 22 comparisons are considered.

Clarification had little influence on the depth of the cream layer of either raw or pasteurized milk allowed to cream in bottles. Fig. 1 shows the cream layers in a bottle of raw unclarified and a bottle of raw clarified milk of the same lot while Fig. 2 shows the cream layers in a bottle of pasteurized unclarified and a bottle of pasteurized clarified milk of the same lot.

A saturated alcoholic (95%) solution of sudan 3[10] was added to the samples before holding in order to make the fat layers more distinct. From the figures, which show typical results, it is evident that clarification has very little effect on depth of the cream layer on milk allowed to cream in bottle.

7. Influence of Clarification on Keeping Quality of Milk.

One of the advantages claimed for clarified milk is that it will keep longer than unclarified milk of the same lot. Since with a large proportion of the samples of milk clarified with the Sharples clarifier there was an apparent increase in the number of bacteria it seemed advisable to test out this point by comparing the acid development in clarified and unclarified milk of the same lot held under the same conditions for various periods of time. The samples used were collected under careful conditions and commonly were those that had been used in studying the influence of clarification on the bacterial count. Room temperature was adopted for the holding temperature. In all but two or three comparisons the samples were held in containers of the same shape and filled to approximately the same depth so that the influence of the air supply could be eliminated. The titrations were made after a certain amount of curdling had taken place; in a very few comparisons coagulation was complete at the time of titration.

Out of 26 comparisons made, the clarified and unclarified milk showed the same acidity after holding in three (12 per cent); the clarified milk showed a higher acidity than the unclarified in 13 (50 per cent), while the clarified milk showed a lower

[10]Studies on the Creaming Ability of Milk. B. W. Hammer. Res. Bull. Ia. Agr. Expt. Sta. 31:69, Jan., 1916.

acidity in 10 (38 per cent). Where the acidities of the clarified and unclarified milk were not in entire agreement the differences were in some instances so small that they could easily have represented experimental error while actual differences were too small to be of any importance. It is possible that with longer holding periods greater differences in acidities might have developed, but from the standpoint of variations in the keeping quality the acidities at the time coagulation begins are more important than later ones.

Since a large number of bacteria are present in the clarifier slime it is reasonably certain that as far as actual numbers go there is a decrease of bacteria in all clarified milk; the decreased number of organisms should presumably result in a slower development of acid. Another factor of possible importance, however, from the standpoint of the development of acid is the breaking up of the clumps. It seems probable that if the organisms are in clumps many of them, particularly those near the centers of the clumps, would have less opportunity for development than if the clumps were broken up and the organisms more uniformly distributed thruout the milk. It is undoubtedly true that each of these factors may be of varying importance in different lots of milk; and while it seems likely that in many instances they would tend to balance each other it is entirely possible that either one might be considerably more important than the other.

By comparing influence of clarification on the number of bacteria developing on plates and on the rate of acid development, it was evident that there was no very close correlation. The only point of apparent significance is that where clarification caused a slower acid development and bacterial counts had been made these were very high, being up in the millions in all cases. From data secured in various lines of experimentation, it seems probable that milk with such high counts is less likely to contain a

TABLE IX—BACTERIAL CONTENT OF PASTEURIZED CLARIFIED AND PASTEURIZED UNCLARIFIED MILK.

Bacteria per c. c.

Pasteurized Clarified		Pasteurized Unclarified	
255	205	55	55
330	335	35	45
140	340	6000	750
360	330	200	105
85	55	115	85
145	125	195	290
1205	1195	535	320
350	345	130	50
45	45	95	70
285	165	255	100

Colums 2 and 3 should be transposed

proportionately large number of clumps and under such conditions the breaking of the clump and consequent more uniform distribution of the organisms would be of less significance than in milk with a comparatively large number of clumps.

From the data presented it is evident that clarification has no influence of practical importance on the keeping quality of milk. In comparisons in which a difference in acidity was found, examination, made before the milk was shaken up, showed approximately the same depth of curd in nearly all cases; in the very few cases in which a difference in the depth of the curd was observed, the difference was entirely too small to be of practical value. Clarification cannot be depended upon under ordinary conditions to increase the time that milk can be held, and improvement in the keeping quality can not legitimately be claimed for clarification.

DISCUSSION.

In the study of clarification with the Sharples clarifier, the same general effects on the milk were secured as in the study of clarification with the DeLaval clarifier. Variation in the results obtained with the two machines cannot be considered to be of any significance since different lots of milk were used with the different machines.

With the methods of production which the expense of improvements make necessary for the bulk of the milk supply, a certain amount of foreign material is certain to get into milk. While every one admits it would be preferable to prevent the entrance of this foreign material, such a procedure is impossible without very materially increasing the cost of production. Accordingly it seems desirable to follow the practical system of removing as much of this material as possible and then make the milk safe by efficient pasteurization. Clarification affords a satisfactory method of removing the larger particles of foreign material but even with clarification not all can be eliminated.

Clarification has recently been adversely criticised because it enables the dealer to take very dirty milk and give it the appearance of milk produced under careful conditions. If clarification is to result in a decrease in the amount of care given by the producers, it should certainly be discouraged but it seems as unreasonable to prohibit clarification because a few unscrupulous dealers may use it to make filthy milk salable as to prohibit pasteurization because certain dealers repasteurized. There should be sediment standards for unclarified milk just as there are bacterial standards for milk that is to be pasteurized.

In the partial removal of the foreign material from milk there seems to be an advantage that cannot be ignored from the aes-

thetic standpoint. While clarification cannot be expected to improve the keeping quality of milk or to make it safe as far as possible pathogens are concerned, it can give it a much more pleasing appearance and thus result in an increased consumption. The elimination of body cells also is desirable from an aesthetic viewpoint altho within certain limits they are normal constituents of milk and it would be extremely difficult to prove them harmful. The improvement in the appearance of milk as a result of clarification is as legitimate as the use of attractive cartons for butter.

CONCLUSIONS.

1. The results obtained with the Sharples clarifier show that plates poured from clarified milk commonly show larger numbers of colonies than plates poured from unclarified milk of the same lot. Increases in the numbers of colonies developing must be considered as apparent increases due to the breaking up of the clumps of organisms because some organisms are removed by being thrown into the clarifier slime.

2. There is no definite relationship between the effect of clarification on the bacterial count and such factors as the temperature of clarification and the percentage of fat. It is probable that the numbers and types of clumps of organisms determine whether there will be an increase or a decrease as a result of clarification.

3. Fifty-two comparisons of the bacterial content of clarified and unclarified milk were made on samples containing originally less than 100,000 bacteria per c. c. In one case (2 per cent) the bacterial content was not influenced by clarification, in eight cases (15 per cent) there was a decrease during clarification varying from two to 43 per cent and averaging 16 per cent while in the remaining 43 cases (83 per cent) there was an increase varying from one to 76 per cent and averaging 85 per cent. Considering the 52 comparisons there was an average increase of 68 per cent.

4. Nine comparisons were made on milk containing originally from 100,000 to 500,000 bacteria per c. c.; in seven cases (78 per cent) there was a decrease varying from 9 to 55 per cent and averaging 19 per cent while in two cases (22 per cent) there was an increase, one of 27 per cent and one of 44 per cent, the average being 35 per cent. Considering the nine comparisons there was an average decrease of seven per cent.

5. Thirty-two comparisons were made on milk containing originally over 500,000 bacteria per c. c.; in 17 cases (53 per cent) there was a decrease varying from 1 to 31 per cent and averaging 14 per cent while in 15 cases (47 per cent) there was

an increase varying from 3 to 50 per cent and averaging 13 per cent. If the entire 32 comparisons are considered there is an average decrease of one per cent.

6. In 63 comparisons of the cell content of clarified and unclarified milk, clarification caused a decrease of from 11 to 78 per cent, the average being 41 per cent. The average cell content of the unclarified milk was 308,778 and that of the clarified 177,635 per c. c. There was no relationship between the percentage of cells thrown out and the original cell content, the percentage of fat or the temperature of the milk.

7. Fourteen samples of clarifier slime were studied as to the numbers of bacteria and cells contained. The bacterial content varied from 7,800,000 to 5,210,000,000 per gm. and the cell content from 57,000,000 to 658,000,000 per gm. Slime with a high bacterial content generally came from milk with a high bacterial content.

8. Clarified pasteurized milk gave a higher bacterial content than unclarified pasteurized milk in 14 (70 per cent) of 20 comparisons; in four (20 per cent) it gave a lower bacterial content, while in two cases (10 per cent) there was no difference. Here, also, the higher bacterial content in the clarified pasteurized milk is undoubtedly due to the breaking up of clumps.

9. The amount of slime per 100 lbs. of milk was extremely variable due to variations in the care used by the different producers and by the same producer on different days.

10. Clarification slightly reduced the creaming ability, as determined in tubes held in ice water, of both raw and pasteurized milk. The influence was too small to be of practical importance in milk allowed to cream in bottles.

11. Clarified and unclarified milk showed the same acidity after holding in three (12 per cent) of 26 comparisons, in 13 (50 per cent) the clarified milk showed the higher acidity while in 10 (38 per cent) the clarified milk showed the lower acidity. The clarification of milk cannot be considered to improve the keeping quality of milk under ordinary conditions.