AIR QUALITY IN FLUID AND MANUFACTURED MILK PRODUCTS PLANTS[1, 2]

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Abstract

Forty responses were obtained from a questionnaire sent to regulatory agencies of market milk and manufactured dairy products of the 50 state governments. Replies indicated that air-borne contamination was considered most important in the commercial processing or manufacture of cultured milks followed by dry milks, cheese, market milks, ice cream, and butter in decreasing order of importance. However, a high percentage of replies signified a lack of knowledge of air-borne contamination in processing or manufacture of dairy products.

Air was sampled using the Casella sampler to ascertain the standard plate count and yeast and mold count in critical product areas of various size dairy plants in nine states. The following results were obtained/ft^3: *(a)* cheese: SPC, >115.7 mean and 3 to >702 range, yeast and mold, 29.1 mean and 1 to 99 range; *(b)* dry dairy products: SPC, 31 mean and 8 to 60 range, yeast and mold, 28.9 mean and 3 to 84 range; *(c)* market milk: SPC, 31.3 mean and 4 to 89 range, yeast and mold, 30.8 mean and 0 to 132 range; *(d)* butter: SPC, 45.2 mean and 11 to 132 range, yeast and mold, 12.3 mean and 4 to 26 range; and *(e)* ice cream: SPC, 16.4 mean and 10 to 25 range, yeast and mold, 8.4 mean and 4 to 16 range.

The most obvious increase in bacteria counts seemed to be caused by an increase in number of people passing close to the sampling probe and a greater amount of dust from unpaved roads adjacent to the plant.

The microbiological quality of air in plants manufacturing dairy products and those processing milk has become of greater concern in recent years. The need for longer storage life, greater emphasis on quality and uniformity, and the necessity to maintain a zero tolerance on pathogenic organisms are contributing factors.

The microbiological content of air is generally regarded with concern if it contacts the dairy product after pasteurization (for example, in filling containers) or during manufacture (as with cheese). Less obvious possibilities of contamination occur if the air carries organisms into the containers or deposits them on equipment surfaces (after sanitizing) that subsequently contact the pasteurized product. Others are air agitation of pasteurized product and head space in storage and balance tanks for pasteurized dairy products. Conceivably certain types of air-borne contamination (bacterial spores) in raw milk could adversely influence the keeping quality of the resulting sterilized products.

The ideal plants from the viewpoint of preventing air-borne contamination would be those that process or manufacture dairy products in a closed system. The next best would be those having ultraclean room practices with no people or as few as possible in the important areas. Until these become feasible, attention will have to be given to eliminating as much air contamination as practical to safeguard against pathogenic and all other undesirable microorganisms.

A literature review reveals many studies on various aspects of air-borne contamination, particularly on methods, numbers and sources of microorganisms, and human shedding. Evaluation of air counts by exposure of petri plates with sterile agar has been used for many years. The limitations resulting from varying air currents and from the very slow settling rate of the smallest microorganisms have resulted in the development of more positive methods. Wells *(19)* used centrifugal force, Berry *(1)* an electrostatic technique, Bourdillon et al. *(2)* a slit sampler, Lemon *(12)* liquid impingement, Silverman and Viles *(16)* filtration, and Kethley et al. *(10)* thermal precipitation.

Fabian *(6)*, in 1927, was one of the first to report on air-borne contamination of a dairy product. With the aeroscope and sedimentation methods he observed that bacterial contamination of ice cream by air was insignificant. The number of bacteria in the air of the ice cream area varied widely during the year (daily mean 0.25 to 69.50/liter). The mold daily mean was 0 to 5.75/liter. Major influencing factors were dry windy weather, open doors and windows, dry floors, and operating machinery.

Grimes et al. *(7)* emphasized the possibilities of air-borne mold infecting cream after pasteurization and butter during packaging. Macy et al. *(13)* reported that during July through April petri plates exposed for 10 min had yeast and mold counts of 0 to 43 and 0 to 25, respectively, in a creamery.

Forty-one trials showed an average of 166.5 (range of 18-516) bacteria per hr on 90 mm petri plates in the butter area of a plant *(14)*. The results for market milk and cheese areas were, respectively, 185.9

[1]Paper presented at the 55th Annual Meeting of the International Association of Milk, Food, and Environmental Sanitarians. St. Louis, Missouri, August 18-22, 1968.

[2]Michigan Agricultural Experiment Station Journal Article No. 4523.

with a range of 7 to 734 and 144.7 with a range of 12 to 686. The yeast counts in the three areas averaged 4.5 and varied from 0 to 43. The molds averaged 54.4 with a minimum of 2 and a maximum of 302 per hr exposure. The authors concluded there was little seasonal variation in numbers of bacteria, yeast, or molds and little difference between outdoors and indoors in plate counts.

Cerna *(5)* observed a range of 1 to 550 bacterial colonies per plate for 10-min exposure in European dairies. Labots *(11)* also ascertained air-borne counts in European dairies. He observed an average of 18 colonies per liter with a slit sampler and 300 per petri plate per min. Perry et al. *(15)* investigated the lactobacilli in the air of seven creameries and found $<1/ft^3$ to $>65/ft^3$.

More recently Heldman et al. *(9)* and Hedrick et al. *(8)* reported a total mean daily average of 27 bacteria/5 ft^3 with a mean daily range of 9.4 to 52.5 for 315 samplings in a dairy plant. Mold count was 67.9 for total daily mean with a mean daily range of 7.2 to 334.4. The yeast counts were lower. The average of the daily mean was 10.3 and the mean daily range was 1.4 to 30.0 for 282 samplings involving six days. Two years later, Sunga et al. *(17)* found that the average bacteria count of the air in the same areas of the dairy plant had increased to 58/5 ft^3. This increase was attributed to more dust from new building construction close to the plant.

Cannon's *(3)* viable non-mold count was 92.3 ± 149.6/ft^3 in the air of 10 fluid milk plants. The viable mold count was 51.3 ± 108.0/ft^3. The counts varied widely among the plants and within individual plants.

Cannon and Reddy *(4)* observed that the correlation coefficient between viable particles in air (Anderson sampler) and sedimentation (5 min standard petri plates and agar) was 0.797. They calculated that with a viable count of 87/ft^3 the contamination rate of 500 gal of milk in 1,000-gal horizontal storage tank was 0.011 microorganisms/ml/hr by sedimentation and 0.139/ml by aspiration.

The species of organisms in dairy plant air have received only limited research attention. Fabian *(6)* stated that most of the bacteria in the air in the ice cream area were peptonizers, alkali producers, or inert. A few were weak acid producers. Since humans are known to be a major source of microorganisms in dairy plant air, Sunga et al. *(18)* isolated bacteria shed from the arms and hands of four dairy plant workers. Of the 256 organisms identified, 55.4% were cocci, 41.4% rods, and 3.2% yeasts. *Sarcina flava, Peptococcus prevotii, Sarcina aurantiaca, Sarcina hansenii, Staphylococcus epidermidis* and *Sarcina lutea* occurred most frequently among the 13 species of cocci isolated. *Alcaligenes marshallii, Alcaligenes bookeri, Pseudomonas synxantha, Pseudomonas iodinum, Pseudomonas fluorescens* and *Corynebacterium striatum* were the most common rods of the 18 species identified.

The principal sources of air-borne microorganisms in dairy processing and packaging areas are human shedding, floor drains, ventilation systems, supplies, unsanitary storage rooms, and the outside atmospheric conditions, e.g. congestion and dust *(8)*.

This report presents the responses of state officials regarding the importance of air in contaminating dairy products and the suggested maximum limits for microbiological content of air in market milk, cultured milk, cheese, butter, ice cream, and dry milk areas and/or plants. The results of standard plate counts and yeast and mold counts on air in market milk, cheese, butter, and dry milk areas of dairies in nine states will be presented.

EXPERIMENTAL

A question sheet was prepared and mailed to the state dairy regulatory officials of each state. If two agencies were involved, for example, one for market milk and another for manufactured products, each received the questionnaire. The appropriate officials were asked to check the importance of air-borne microorganisms as a source of contamination in *(a)* milk and cream area: "very___, medium___, slight___, not important___, or don't know___." Space was provided for suggesting the air-borne bacteria count be limited to: "___/ft^3 or ___colonies/10 min sterile agar plate exposure or no limit necessary___." The information was requested also on air-borne yeasts and molds.

Similar information was asked for *(b)* cultured milk area, *(c)* cheese area, *(d)* butter area, *(e)* ice cream area, and *(f)* dry milk area. Suggested sources of original contamination also were requested when air-borne contamination was considered important.

The Casella sampler with standard plate count agar or acidified potato dextrose agar was used to ascertain the microbiological content of dairy plant air in nine states (Indiana, Iowa, Michigan, Minnesota, Montana, North Dakota, South Dakota, Washington, and Wisconsin). Variation in size, type, and location (in relation to industrial, residential, and rural areas) of dairy plants was obtained. Sampling was conducted without advanced notice to management. In general, the weather was hot and the relative humidity medium to high.

In the market milk area of the plant the sampling probe was placed within a few inches of the exposed cartons or bottles ahead of filling. The probe was located close to, but 6 in. higher than the vat for sampling air during the manufacture of Cottage or Cheddar cheese. In the butter area, the air was sampled close to the packaging in bulk cartons or near the printing of retail packages. In the ice cream area, the sampling of air was near (within 12 in.) the container filling activity. The probe in dry milk plants was placed near the bag filling or retail package filling operation.

The sampling was in duplicate for standard plate counts and for yeast and mold counts and consisted of 1 ft^3 of air per sampling. Although the testing was confined to these four tests per product area, it varied in time of day among

TABLE 1. SURVEY OF STATE OFFICIALS ON AIR-BORNE MICROBIOLOGICAL CONTAMINATION IN DAIRY PRODUCTS

	Market milks	Cultured milks	Cheeses	Butter	Ice creams	Dry milks
Importance of air-borne contamination:						
Very	5.3%	51.6%	16.7%	6.7%	6.3%	16.7%
Medium	26.3	9.7	20.0	10.0	25.0	30.0
Slight	15.8	3.2	6.7	16.7	25.0	3.3
Not important	10.5	0	0	10.0	6.3	0
Don't know[a]	42.1	35.5	56.7	56.7	37.5	50.0
Total respondents	38	31	30	30	32	30
Suggested maximum limits:						
Bacteria/ft^3	15 (2)[b]	10-500 (3)	20 (2)	20 (2)	20 (2)	15 (2)
Bacteria/10 min	5-25 (8)	0-100 (11)	5-25 (6)	10-25 (4)	5-100 (9)	5-100 (8)
No limit necessary	– (6)	– (4)	– (5)	– (7)	– (7)	– (5)
Yeast and molds/ft^3	15 (2)	0-10 (3)	20 (2)	20 (2)	20 (2)	15 (2)
Yeast and molds/10 min	2-15 (7)	0-20 (10)	5-20 (6)	5-20 (4)	2-10 (7)	2-15 (6)
No limit necessary	– (7)	– (4)	– (5)	– (7)	– (8)	– (5)

[a]Didn't know or omitted a reply.

[b]Number in parentheses is the number of replies.

plants from the initial filling through clean-up at the end of the operation. For cheese the sampling occurred at any period from setting the milk until packaging of Cottage cheese or placing the Cheddar curd in the hoops. The agar plates for standard plate count were incubated at 32 C (48 hr) and at 21 C (5 days) for the yeast and mold count.

RESULTS AND DISCUSSION

Survey of state officials

The results represent 40 state officials who replied and are presented in Table 1. Approximately one-third to more than one-half of the respondents didn't know or omitted a reply to the questions on importance of air-borne contamination for the six dairy product areas. This high percentage probably results from the scarcity of certain product processing plants within some states. A number of officials reported that there were no butter plants or dry milk plants within the state. Some indicated a scarcity of cheese plants. Another reason may be the lack of practical information on the effect of air-borne microorganisms as a source of contamination for dairy products, especially market milk and ice cream. The emphasis of air-borne contamination has been mostly limited to aseptic packaging of sterilized fluid products and as a source of bacteriophage in culture and starter preparation. But, recently the importance of air-borne microorganisms in dry milk areas has been receiving much attention to emphasize *Salmonella*-free products. There is a lack of obvious reasons for the officials giving greater importance to air-borne microorganisms in ice cream areas of the plant than the butter areas.

Numerous officials mentioned that one principal consideration in evaluating the importance of air-borne contamination was the extent of product exposure. Closed systems would be expected to eliminate air contamination. One official indicated that establishing standards based upon number of organisms present in the air was not realistic with the type of operation in the dairy industry. Some officials emphasized that the species of organisms were much more important than the numbers.

Common sources of microorganisms in the air mentioned most often in the replies were "excessive traffic (human) in processing areas," "clothing of personnel," "dust," "outside air or surrounding environment," and "ventilation system" (failure to maintain filters or ducts). "Cartons in storage" was mentioned as a source for several dairy products. In specific reference to air contamination of dry milks additional suggestions included "dirty ledges, unclean walls and ceilings," and "floor drains."

Only two or three respondents proposed a standard plate count or yeast and mold count limit based upon the volume of air (ft^3). A few more suggested maximum limits based on exposure of agar plates

TABLE 2. MICROORGANISM COUNTS ON AIR IN DAIRY PLANTS

Product	Number of plant areas	Number of colonies	Range	Mean
Butter	6	SPC	11- 132	45.2
(near packaging)		Y&M	4- 26	12.3
Cheeses	14	SPC	3->702	>115.7
(near vats or packaging)		Y&M	1- 99	29.9
Dry milks	9	SPC	8- 60	31.0
(near bagging or retail carton packaging)		Y&M	3- 84	28.9
Ice cream	5	SPC	10- 25	16.4
(near packaging)		Y&M	4- 16	8.4
Market milks	14	SPC	4- 89	31.3
(near fillers)		Y&M	0- 132	30.8

TABLE 3. PROPOSED TENTATIVE LIMITS FOR AIR-BORNE COUNTS IN DAIRY PLANT AREAS

		No./ft³ or less				
Rating		Butter	Cultured milks, creams and unripened cheeses	Ripened cheeses	Dry milks	Market milks and creams
Good	SPC	10	5	10	8	5
	Y&M	5	4	12	5	2
Poor	SPC	50	35	50	40	40
	Y&M	25	20	50	35	34

(petri) for 10 min. A large per cent of the respondents did not believe they had sufficient data to propose limits for the air of the six product areas. The strictest limit was 0 bacteria per 10 min of plate exposure in cultured milk area with the highest suggested maximum of 100. Suggestions ranged from 5 to 25 for market milk area; 5 to 25 for cheese; 10 to 25 for butter areas and 5 to 100 for ice cream and dry milk areas. The maximum of 500/ft³ suggested by one official for cultured milk is difficult to rationalize in comparison to the stricter limits set in other product areas and especially in view of the fact that the official marked air-borne contamination control as very important for cultured milk.

The maximum yeast and mold counts proposed were all within the range of 0 to 20 per 10 min of exposure, but varied for each product area.

Air-borne counts in dairy plant areas

Results of the standard plate counts and yeast and mold counts (Casella sampler) on the air in 23 plants (48 product areas) in nine states are presented in Table 2. Air in the cheese areas had the highest mean standard plate count and the lowest mean was in ice cream areas with dry milk second. The low average for dry milk areas probably reflects the recent emphasis on more thorough sanitation to reduce the possibility of *Salmonella* contamination. As might be anticipated, the highest mean yeast and mold count was in the air of the Cheddar cheese manufacturing areas, but the lower counts in the Cottage cheese areas resulted in a mean for cheeses that was comparable to the market milk and dry milk areas.

A study of microorganism counts of the air in relation to plant conditions—physical, sanitary, human activity, and environment—indicates some general correlations. A large amount of human activity near the air sampling probe usually caused higher bacterial counts. A high dust content in air from unpaved roads adjacent to the plant seemed to cause high counts in plants without a filtering system for inlet air. In general, the large new dairy plants with good sanitation had lower air-borne counts than the small crowded plants in old buildings.

A thorough investigation under practical conditions is needed to determine the effect of various numbers of air-borne microorganisms in the critical areas of the dairy plant on the processed and manufactured products. The need for legal standards is certainly debatable at this time. However, tentative guidelines on the microorganism content of air in the dairy plant might be useful as an index of certain sanitary conditions and for minimizing adverse effects on quality and/or keeping quality of dairy products, especially the cultured products.

On the basis of the limited data available from dairy plant testing of air-borne counts, values in Table 3 are suggested as a guide in areas where product contamination from air can occur.

As more becomes known about the specific product contamination from air-borne microorganisms and the total effects on each dairy product, revision of the limits may be warranted.

ACKNOWLEDGMENT

Sincere appreciation is expressed to the management of the dairy plants involved for their excellent cooperation in obtaining air-borne counts and to the state dairy and health officials for their replies to the survey.

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ASSOCIATION AFFAIRS

REPORT OF THE 3-A SYMBOL COUNCIL—1967-1968

This is the first time, in a number of years, that it has become necessary to report that the number of 3-A Symbol Council authorizations in effect has declined during the preceding 12 months. At the 1967 Annual Meeting it was reported that five authorizations covering manually-operated bulk milk dispensers were still tentatively in effect, because of residual inventories of dispensers built to 3-A Sanitary Standards in hands of manufacturers, although those standards had been rescinded as of April 20, 1967. The Board of Trustees of the Council decided that authorizations automatically terminated on the date the 3-A Sanitary Standards were rescinded. Consequently, rebates of fees covering the intervals between April 20, 1967 and the date on which authorizations normally would have expired were made to five authorization holders. These authorizations should not have been included in the 1967 column of the tabulation in last year's report. One initial authorization has been issued for each of the following types of equipment; automotive milk transportation tanks, fittings, and batch pasteurizers. Five fabricators of farm bulk milk tanks have discontinued their manufacture since the last renewals were issued. And one manufacturer of pumps, one fabricator of carton fillers and sealers, and one manufacturer of a valve, have relinquished their authorizations. As a result of these issuances, automatic termination of authorizations, and relinquishments the number of authorizations in effect on July 31, 1968 is lower by 9 than it was on August 1, 1967; totalling 142 as compared with 151. A tabulation of authorizations in effect on those two dates, by equipment category, is appended to this report. Rosters of holders of authorizations, as of August 20, 1967 and of February 20, 1968, were published in the September, 1967, and March, 1968, numbers of the Journal. The roster as of August 20, 1968 will no doubt appear in the Journal of September, 1968.

The Board of Trustees of the Council has held only one meeting during the interval covered by this report. At that meeting, held prior to the October, 1967, Omaha meeting of the 3-A Sanitary Standards Committees, several matters of interest to Association members were considered.

One was an application for an authorization covering a pump of the plunger type, normally operated at a pressure considerably lower than those at which homogenizers operate, and having a quite different application. The 3-A Sanitary Standards for pumps pertain only to rotary pumps, and those for homogenizers may be applied to "high-pressure pumps of the plunger type." The trustees decided that no existant 3-A Sanitary Standards provide a basis for the issuance of an authorization covering a pump of the type in question.

The 3-A Sanitary Standards for stainless steel automotive milk transportation tanks do not provide for their compartmentalization. It is, however, conventional practice among Canadian fabricators of farm milk pick-up tanks to assemble, in one outer shell, two or three separate tanks or compartments, with all outlets terminating in the rear cabinet. Reasons cited for this design are increased traction under partial loads, and other advantages. This type of construction necessitates long outlet passages from the forward compartments. Compartment outlet pods illustrated in drawings are of various design, and the effectiveness of the washing of those several designs, as well as of the long passages, is subject to question. It must be realized that the 3-A Sanitary Standards do not make the installation of equipment for circulation washing and sanitation mandatory.

The Secretary of the Council took the position that compartmentalized milk transport tanks do not conform to the 3-A Sanitary Standards for that equipment, but did issue authorizations, limited to single compartment tanks, to six Canadian fabricators. The Trustees supported that position.