Survival and Growth of *Staphylococcus aureus* in Commercially Manufactured Brazilian Minas Cheese

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**ABSTRACT**

The potential for *Staphylococcus aureus* survival, growth and enterotoxigenesis in Minas cheese was studied. Twenty lots of cheese were made with raw and pasteurized milk and with and without starter culture. Cheese milk was inoculated with *S. aureus* strains 100, 243 or 137 and a pooled inoculum at levels of 10^6 to 6 cells/ml. Use of starter, type of inoculum, ripening time and interaction of starter by strain affected significantly the final pH of the cheese (5.22 with starter versus 5.45 without starter). Final moisture ranged from 30.6 to 45.6%. Moisture was affected significantly by *S. aureus* inoculum, type of inoculum, ripening time and interaction of starter by strain affected significantly (P < 0.01) with lot indicating lack of uniformity in salting. Moisture was affected significantly by *S. aureus* inoculum, time of ripening and use of starter (P < 0.05). Final moisture ranged from 30.6 to 45.6%. Moisture was affected significantly by *S. aureus* inoculum, type of inoculum (P < 0.001) and time of ripening (P < 0.05). Use of starter culture had an inhibitory effect on *S. aureus* growth. Use of raw or pasteurized milk did not affect significantly the staphylococcal counts. *S. aureus* growth occurred in all lots made without starter culture. Levels of *S. aureus* greater than (log_{10}) 7 cells/g were observed in 27/47 and 7/46 cheeses made with pasteurized and raw milk, respectively. Enterotoxins A, B and C were detected in 10/16 and 0/4 cheeses made with pasteurized and raw milk, respectively, and more often in cheeses made without starter than with starter culture. This study demonstrated the need for more uniform manufacturing practices, use of starter culture and use of pasteurized milk only.

Cheese is a major dairy product in the Brazilian market. Its consumption is increasing rapidly and some importation estimated at over 14,000 tons per year has been necessary to meet market demands in recent years. Cheese production in Minas Gerais State, Brazil, was 72,400 tons in 1977. This represented approximately 62% of the national cheese production. Minas cheese is a semi-soft cheese consumed in large quantities in Brazil. Most of the cheese produced in Minas Gerais is of this type.

The safety of cheese with respect to foodborne diseases is of great concern around the world. This is especially true in developing nations where production of milk and various dairy products is accomplished under rather unsanitary conditions and poor manufacturing practices.

The problem of cheeseborne staphylococcal food poisoning has received special interest among public health authorities of several countries, including Brazil, because it appears to be more frequent than other types of food poisoning.

Numerous outbreaks of staphylococcal food poisoning due to consumption of cheese have been reported from around the world. Surveys on the prevalence of *S. aureus* in market cheeses around the world indicate that accumulated knowledge has not been fully utilized in the manufacture of such dairy products. High prevalence and high levels of *S. aureus* have been reported. Major factors contributing to the problem are: use of unpasteurized milk with high *S. aureus* counts, ineffective starter culture activity, post-pasteurization contamination of milk and post-process contamination of cheese with staphylococci from human and environmental sources and temperature abuse during handling and storage of the product.

Clinical and subclinical forms of staphylococcal mastitis are very prevalent in dairy herds. Over 30% of clinical and subclinical cases of mastitis in cows supplying milk to the cheese plant where this study was done were due to staphylococci. Staphylococcal mastitis and unsanitary practices in dairies, with milk collection trucks and in processing plants as well as lack of continuous refrigeration especially during the summer months are considered factors responsible for the reported high prevalence of *S. aureus* in raw milk.

Recently Santos and Genigeorgis evaluated the quality of raw and pasteurized milk used for Minas cheese with respect to *S. aureus*. They found a prevalence of 46.9% in 78 raw milk samples collected from 78 producers. *S. aureus* was present in the samples at levels as high as (log_{10}) 5.99 cells/ml. Three of 49
pasteurized milk samples analyzed contained S. aureus at levels of log_{10} 3 to 4.43 cells/ml.

The potential of S. aureus growth during the manufacturing of various types of cheeses has been studied extensively in various parts of the world (7,12,14,16,17,19,20,24,36,38,42,44-46,50,51). These studies demonstrated that the probability for S. aureus to initiate growth and produce enterotoxins in cheese during manufacturing is dependent on a variety of factors. It has been demonstrated that the higher the numbers of staphylococci in milk used for cheese making, the higher will be the probability that staphylococci will overcome the inhibitory environment of milk and grow during cheese making (7,38,42,47). Also, the higher the number of competing microorganisms in the milk, the easier will be inhibition of staphylococcal growth (12,17,38). Use of an active, young lactic acid starter culture at the right level will minimize the potential of staphylococcal enterotoxigenesis (16,17,24,36,45,52). The inhibitory effect of starter culture on growth of S. aureus during cheesemaking is a complicated one. It is mediated by the production of acid as well as other growth and environmental parameters (16,30,36,45).

In most instances, staphylococci decrease continuously during aging of cheese (12,17,36,44). Starter activity and salting are major contributing factors to this decrease (16,17,50). In cheese in which starter activity is below normal, the staphylococci continue to multiply during the first weeks of ripening (17,36).

Failure to detect staphylococci in epidemiologically suspect cheeses is no guarantee of the absence of enterotoxins. On the other hand, the presence of S. aureus does not mean the presence of enterotoxin (17,24,46,47). Enterotoxins produced during cheese manufacturing are expected to remain toxic in the product for a long time (17,47,49).

Unsanitary practices during cheesemaking and further handling of cheeses until they reached the consumer, as well as temperature abuse during storage, are not uncommon in developing nations where use of refrigeration is limited. Under such conditions, contamination of cheeses with S. aureus from human and environmental sources and growth to dangerous levels is possible (30,32).

The present article reports the effect of certain processing parameters on growth of S. aureus and enterotoxigenesis during Minas cheese manufacture under commercial conditions. The findings of two closely related studies on the prevalence of S. aureus in raw and pasteurized milk used for Minas cheese making (39) and the presence and growth of S. aureus in Minas cheese whey have been reported recently (40).

MATERIALS AND METHODS

Minas cheese manufacture and inoculation

Two batches of pasteurized milk at 32°C were poured into individual stainless steel insulated cheese tanks. To batch A of milk 1.5% commercial Streptococcus lactis and Leuconostoc cremoris starter culture was added (Christian Hansen, Denmark) at a level of 7.17 Cells/ml milk. Fifteen min later commercial rennet enzyme diluted in 10% NaCl solution was added to the milk at a level of 1:40,000 along with CaCl 2 to accomplish a level of 0.05%. Next a thoroughly mixed S. aureus culture was added to the milk at an inoculum level of log_{10} 4 to 6 cells/ml. The second batch (B) of milk was prepared the same way but without starter culture. After 40-45 min of incubation at 32°C there was good coagulum formation. The coagulum was then cut with stainless steel cheese knives (horizontal and verticle blades), and mixed for 15 min at 34-36°C. After a second curd mixing of 5 to 10 min and draining, about 70% whey was separated. The curd was placed into round hoops of 1-kg capacity for molding and pressing. Automatic pressing of the curd lasted for 90 min at 15°C. Then the cheese was salted by submersion into 20% NaCl (w/v) solution at 12-14°C for 14 to 16 h. Ripening of the cheeses lasted for 28 days at 14 to 16°C and 85% relative humidity.

Starter culture preparation and inoculation

S. lactis and L. cremoris cultures from commercial Christian Hansen stock which have been used successfully in cream fermentation for buttermaking, were inoculated into milk for cheesemaking. To reach adequate lactic acid development, an inoculum size of 1.5% (w/v) of 24-h starter culture was added to the milk 10-15 min before cheese processing started.

To keep the culture fresh, a subculture was prepared daily in sterilized skimmed milk and incubated at room temperature for the next day's inoculum. Culture purity was checked by plating on APT agar (Difco) and acidity was determined by the Dornic titratable method. The lactic acid production yield recommended was 85-90 Dornic, and the CFU/ml was always higher than log_{10} 8 cells/ml.

Staphylococcal inoculum

S. aureus strains 100, 137 and 243 producing enterotoxins A, C and B, respectively, were obtained from the collection of Dr. C. Genigeorgis, University of California, Davis, and used for cheese inoculations. The strains preserved in lyophilized form were grown in brain heart infusion (BHI) broth (Difco) initially, and subcultured in BHI broth for 12-16 h at 37°C. Cells from the subculture were used as an inoculum for raw and pasteurized milk at the desired levels.

Cheese samples and sampling procedures

Immediately after manufacturing and salting, cheese of 0.8 to 1.2-Kg weight as well as cheeses ripened for 7 to 28 days were taken to the dairy plant laboratory. All samples were wrapped in aluminum foil to protect them from dehydration and were kept under refrigeration until analyzed, usually within 20-25 min. The same sampling procedure was used for fresh soft cheese and semi-hard cheese to establish a consistent and adequate technique in which all surface and inner layers were sampled (45).

Microbiological analysis

From each cheese sample 25 g were weighed aseptically into sterile pint Mason jars. 225 ml of sterile water was added and the mixture was serially with sterile peptone water. and the appropriate dilutions were plated on PCA. (PCA, Difco) and incubated at 37°C for 2-3 days; staphylococci on mannitol salt agar (Difco) and incubated at 37°C for 2 days as well as on plate count agar (PCA, Difco) and incubated at 37°C for 24 h. After 24-h incubation the PCA plates were overlaid with toluidine-blue DNA agar, and incubated at 37°C for 4 h to test for nuclease production by the different colonies (25). Tellurite polymyxin egg yolk agar (TPEY, Difco) and Baird-Parker agar (Merek) were also used for staphylococcal count determination. Coagulase production was determined on coagulase agar plate (CAP) (45). Using a sterile loop, presumptive S. aureus colonies from the various selective and PCA/DNA media were transferred to CAP. The plates were incubated for 24 h and read at 12, 18 and 24 h.

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Experimental design

Staphylococcal strains 100, 137 or 243 were used for inoculation of pasteurized milk at two levels in the presence or absence of starter culture. A total of 12 lots of Minas cheese were manufactured. In a second set of experiments, raw or pasteurized cheese milk was inoculated with a mixture of the three strains at two levels in the presence or absence of starter culture. Eight lots of Minas cheese were prepared this way.

Physico-chemical changes during cheese ripening

Manufacturing conditions for inoculated cheese milk were the standard conditions used by the plant of the ILCT for commercial Minas cheese manufacturing. Ripening of the manufactured cheese was accomplished by the short 28-day maturation method. Minas cheese has a slight acid flavor, soft texture with mechanical eyes due to its long coagulation procedure and the low temperature of 15 °C during curd pressing for 90 min. The salting operation which occurs during the 14 to 16 h after pressing assures NaCl diffusion into cheese to accomplish the desired flavor.

Changes in pH, NaCl percentage, brine percentage and moisture percentage observed during ripening of the 20 lots of cheese used in the inoculation experiments are represented in Fig. 1. We consider as the zero day of ripening the time immediately after the end of salting operation; this is 16-19 h from the beginning of cheesemaking. The pH of the cheese decreased with time. Cheese made with or without starter culture had a 28-day pH mean of 5.22 and 5.45, respectively. Statistically, the pH data (as well as the NaCl %, brine % and moisture % data) were analyzed using the three-way analysis of variance (37). The three factors studied were type of S. aureus inoculum, use of starter culture and time of ripening (initial versus final). Only the data from the cheese made from pasteurized milk were included in the analysis. A significant effect of the type of S. aureus inoculum, starter culture, time of ripening and the interaction of strain by starter culture on the pH of the cheese was found. The significant interaction of strain and starter culture suggests that the effect on pH of using a starter culture (as opposed to not using a starter culture) differs depending on the type of strain used for inoculation.

RESULTS

pH Determination

For milk samples, pH was checked with the potentiometer already adjusted for standard pH. For cheese samples, 10 g of cheese were weighed, placed in a mortar and homogenized together with 10 ml of distilled water before measuring the pH on a Beckman pH meter.

Enterotoxin assay

The enterotoxins were extracted from 100-g cheese samples according to the method of Reiser et al. (35) with some modifications (Genigeorgis, unpublished). The extracts were lyophilized and kept at -20 °C until analysis. To detect enterotoxins the cheese extracts were first reconstituted with 100 ml of standard phosphate buffered saline solution (pH 7.2, 0.15 M) (PBS), and next filtered through Whatman No. 1 filter paper. Recovery of the toxins from the clear cheese extracts (50-ml volume) was accomplished by affinity chromatography, as described by Genigeorgis and Kuo (11). Highly specific enterotoxin A, B and C antibodies were first treated with pepsin to destroy the Fc part (22) of the molecules before attachment to Sepharose-4 B (Pharmacia, Uppsala). Previous studies indicated that affinity chromatography can recover at least 0.1 μg of enterotoxin added to 100 g of food (21). Enterotoxin recovered by affinity chromatography was first lyophilized for concentration. The lyophilized material was dissolved in 0.25 ml of PBS and then tested for enterotoxin using the microslide technique (6).

Sodium chloride and brine determination

The salt content of cheese samples was determined by means of Quantab chloride titrator strips (Ames Company, Elkhart, IN), as recommended by the manufacturer (15). From the values for moisture content and percent NaCl the percent brine was computed (15).

Moisture determination

Moisture content was determined by drying 4-5 g of cheese in a vacuum oven at 100 ± 1 °C for 4 h (15).

Figure 1. Mean and range values of certain important chemical characteristics of Minas cheese made with and without starter culture and analyzed during the ripening period. Data based on 20 lots of cheese.

Final NaCl content (%) of cheese lots ranged from 1.9 to 6.9%. The statistical analysis indicated the NaCl content was not affected by the use of a starter culture and that the final NaCl content did not differ from the original NaCl content at the P = 0.05 level. Significant differ-
ences in NaCl content were found among cheeses made with different S. aureus inocula (P < 0.01). These findings may be indicative of the lack of uniform procedures during the salting operation. In addition, draining of whey and temperature stabilization may affect the final salt content of the cheese.

Final moisture content (Fig. 1) ranged from 30.6 to 45.6%. The statistical analysis revealed highly significant type of S. aureus inoculum and time of ripening effects (P < 0.01) and significant starter culture effect (P < 0.05) upon moisture content.

Variations among lots are due to lack of uniformity during the cheese pressing operation (pressing rate, time). The higher observed initial levels of moisture in lots made without starter culture are probably due to the effect of pH on water holding capacity of milk proteins. Variations in brine concentrations are presented in Fig. 1.

Effects of Minas cheese manufacturing upon S. aureus survival and growth

Figure 2 presents the initial inocula of S. aureus strains 100, 137 and 243 in cheese milk and their levels during the cheese ripening period. In Fig. 2, data are based on two inoculations per strain in cheese made with and without starter culture. Numbers are mean values of S. aureus counts determined on PCA/DNA/CAP and Baird-Parker/CAP agars.

Figure 3 presents the initial levels of two pooled inocula of strains 100, 137 and 243 inoculated into pasteurized and raw cheese milk as well as the levels of S. aureus in cheeses made with or without starter culture.

The staphylococcal count data were analyzed statistically, using the three-way analysis of variance (37). The three factors studied were milk treatment group, use of starter culture and time of ripening. There were five milk treatment groups: pasteurized milk inoculated with strain 100, with strain 137, with strain 243 and with a mixture of strains, 100, 137 and 243, and raw milk inoculated with a mixture of the three strains. The analysis considered data recorded at days zero, 7, 14, 21 and 28 of the ripening period. The analysis revealed no statistically significant interactions (two-way or three-way). The milk treatment group and use of starter.
culture effects were highly significant (P < 0.001). The time of ripening effect was significant (P < 0.05).

The lowest staphylococcal count of \( \log_{10} 4.7 \) cells/g was obtained both at day 21 and day 28, and the highest staphylococcal count of \( \log_{10} 6.3 \) cells/gram was recorded at both day 7 and 14 of the ripening period. This difference was statistically significant (P < 0.05). The staphylococcal count recorded at day zero \( \log_{10} 5.2 \) cells/g was intermediate and not statistically different from the highest and lowest counts at the P = 0.05 level. Multiple comparisons procedure for identifying differences between sample means showed that the growth of strain 137 in pasteurized milk was significantly greater then that observed when the other two strains were used singly (Fig. 2). Furthermore, when the mixture of three strains was inoculated into either pasteurized or raw milk, an elevated growth pattern very similar to (not significantly different from) that obtained when using strain 137 singly was observed. The counts obtained when using the mixture in raw milk were not statistically significantly different from those recorded when using the mixture in pasteurized milk. Both counts were significantly different from the count observed when either of the other two strains was used singly in pasteurized milk. The above comparisons were made using Duncan’s method (8) and using a significance level equal to 0.05.

Total plate counts for the 20 cheese lots sampled are presented in Fig. 4 and Fig. 5. Statistical analysis of TPC indicated the following: no significant effect of use of starter culture and time of ripening upon TPC (P > 0.05); a significant effect of \( S. \) aureus inoculum type upon TPC (P < 0.05).

**DISCUSSION**

Use of starter culture is important to the physico-chemical and microbiological characteristics of Minas cheese. The starter culture bacteria ferment lactose of milk and decrease the pH to about 5.9 within the first 18 h of processing and to 5.1-5.2 during ripening. These bacteria are not very tolerant to the amount of salt used in Minas cheese-making, and their numbers decrease substantially within the first 48 h of processing. Starter culture and thermoduric bacteria are expected to contribute to the flavor characteristic of the cheese. The low pH affects the water holding capacity of the cheese, and thus the final moisture content of the product. When the use of starter was omitted, the mean final pH of the cheese was 5.5. This higher pH results in lower moisture loss during the beginning of the ripening stage.

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**Figure 4.** Total mesophilic aerobic counts of Minas cheese during ripening. Cheese milk inoculated with three \( S. \) aureus strains at two levels. Cheese made with or without use of starter culture.

**Figure 5.** Total mesophilic aerobic counts of Minas cheese during ripening. Cheese made with raw or pasteurized milk and with or without starter culture. Cheese milk inoculated with a pool of \( S. \) aureus strains 100, 137 and 243 at two levels.
Successful fermentation and rapid pH decrease are critical in the safety of cheese with regard to foodborne pathogens, and especially *S. aureus* 

The wide range of final NaCl and brine content of cheese indicates the need for better standardization of manufacturing practices. The NaCl content of the cheese has a significant inhibitory effect upon growth of starter culture bacteria, which decreased in numbers after salting. The final moisture of Minas cheese prepared with starter was within the levels expected and recommended by the dairy regulation in Brazil.

Total numbers of organisms in the cheese remained at high levels during the ripening period. The flora was composed of bacteria other than those of the starter. *S. aureus* contribution to the TPC ranged from less than 1% to 88%, and in most instances represented less than 1% of the TPC.

Cheese milks inoculated with *S. aureus* strains 100, 137 and 243 and a pool of the three strains at levels of (log 10) 4.23/ml and higher permitted growth of the pathogens in all lots made without starter culture. Of the 47 ripening cheese samples analyzed, 27 (57%) had *S. aureus* counts of over (log 10) 7 cells/g. In cheese made with starter culture, only 7 (15%) of 46 samples had staphylococcal counts greater than (log 10) 7 cells/g.

Two additional inoculation experiments were performed using *S. aureus* strain 243 at levels of (log 10) 2 and (log 10) 2.84/ml of pasteurized milk with and without starter culture. No detectable staphylococcal growth was observed in any of the cheese samples inoculated with (log 10) 2 cells/g and analyzed during the ripening period. Staphylococci inoculated at the (log 10) 2.84/ml level were able to grow in the presence of starter culture to levels greater than (log 10) 4.9 and, in the absence of starter culture, to levels greater than (log 10) 6.81 cells/g (Table 1).

Of the 16 batches of cheese made with pasteurized milk and inoculated with *S. aureus* strains, 10 (68%) supported enterotoxin production, as detected in the ripened product (Table 2). Enterotoxin production was

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**TABLE 1.** Influence of *S. aureus* level on growth and survival of coagulase-positive staphylococci in Minas cheese during ripening.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>0</th>
<th>7</th>
<th>14</th>
<th>21</th>
<th>28</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Staph</td>
<td>TPCa</td>
<td>Staph</td>
<td>TPCa</td>
<td>Staph</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Starter</td>
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<td>7.96</td>
<td>0</td>
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</tr>
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<td>0</td>
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<tr>
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<td>5.68</td>
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**TABLE 2.** Production of enterotoxin in Minas cheese made with pasteurized or raw milk, with or without starter culture, and inoculated at the cheese milk stage with three *S. aureus* strains.

<table>
<thead>
<tr>
<th>Type of inoculum</th>
<th>Initial inoculum (log cells/ml)</th>
<th>Maximum inoculum (log cells/g)</th>
<th>Enterotoxin</th>
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<td>5.44</td>
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<td>-</td>
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<td>5.69</td>
<td>8.40</td>
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a (log 10) cells/g.
bPooled inoculum composed of strains 100, 137 and 243 at equal levels.
cCheeses made with raw milk.
observed in cheese samples inoculated at the cheese milk stage with an inoculum of (log_{10}) 4.23 cells/ml. In all but one sample, enterotoxin production resulted from S. aureus growth to at least (log_{10}) 5.12 cells/g. Toxin was detected in one sample with a maximum growth of 4.24 cells/g. This is quite a low level of cells to produce detectable enterotoxin. None of the four cheeses made with raw milk and inoculated at the cheese milk stage with a maximum of (log_{10}) 5.69 cells/g supported enterotoxin production. This may be due to an effective inhibition of enterotoxigenesis by the normal milk flora. Of the 10 toxic cheese samples, four were made with starter culture and six without use of starter culture.

Tatini et al. (47) found that in Colby and Cheddar cheeses made normally, (log_{10}) 7.17 cells/g and (log_{10}) 7.44 cells/g staphylococci and higher were associated with enterotoxin production. If the starter culture failed to perform properly, then toxic cheeses could result if (log_{10}) 6.47-6.69 staphylococci/g were present. These findings were substantiated by additional studies with Brick and Swiss cheese (47). More recently, Schouwenburg-van Foeken et al. (42) associated enterotoxin A, B and C production in Gouda cheese made under normal starter culture activity with S. aureus growth to levels above (log_{10}) 7.47 cells/g.

The level of S. aureus present in milk is a determining factor of its growth during cheesemaking. This study demonstrated that the higher the initial S. aureus count, the higher the probability of good growth. This is in agreement with previously published data (7,43,45,46, 50). Recent investigations on the prevalence of S. aureus in raw and pasteurized milk used for Minas cheesemaking indicated a prevalence of 46.9% in raw milk and about 6.2% in pasteurized milk. What is even more important is that S. aureus was present in raw milk at levels greater than (log_{10}) 3 cells/ml in all positive samples, with some samples having counts of (log_{10}) 5.99 cells/ml. Pasteurized milk samples had S. aureus counts as high as (log_{10}) 4.43 cells/ml (39). When such milk is to be used for Minas cheesemaking, growth of S. aureus to dangerous levels and enterotoxin production cannot be excluded, as the data of Table 2 indicate.

Brazilian standards require pasteurization of any milk to be used for cheesemaking. There are no staphylococcal standards for raw milk used routinely for cheesemaking as type C milk (minimum 3% fat and TPC after pasteurization of less than 1.5 x 10^9/g). The S. aureus standard for type C pasteurized milk is set at zero. In a S. aureus prevalence study, we found no S. aureus (detection level higher than 100 cells/g) present in 50 Minas cheese market samples made of pasteurized milk. This is in agreement with a Canadian survey (49). Yet Minas cheese made from unpasteurized milk illegally is not uncommon in the market.

Strain variations with regard to their ability to overcome inhibitory processing parameters have been observed in this study. This is in agreement with the literature (11,45). Staphylococci are generally poor microbial competitors. Some people believe that staphylococcal food poisoning is the result of an absence of effective microbial competition between the food flora and staphylococci (13,45,52). Use of an effective starter in cheesemaking is considered critical. This is indicated by the significantly lower S. aureus numbers in Minas cheese made with rather than without starter. Parameters contributing to the function of starters may result in staphylococcal problems in cheeses. The importance of starter with regard to the safety of cheeses has been demonstrated repeatedly (45,46,52). In one instance, starter failure in cheese resulted in staphylococcal food poisoning outbreaks in a wide geographic area of the U.S. with considerable cheese condemnation by regulatory agencies (52).

With regard to Minas cheese manufacturing, it should be noted that starter culture failure may be due to not only low activity, bacteriophages or antibiotics, but also to an inhibitory factor of salting the cheeses. The commercial starter culture used for Minas cheese was found to be a non-salt tolerant starter. Extensive death of the starter was observed immediately after the salting operation. With this decrease and elimination of effective microbial competition, S. aureus could multiply to dangerous levels during the ripening period. Fortunately, presence of salt-tolerant thermoduric bacteria in the cheese minimizes this possibility under routine commercial manufacturing conditions. Temperatures of 34-36 C used for Minas cheese processing may also play a role in decreasing the competitive effect of starter. The starter grows better at 21 C while S. aureus multiplication is enhanced at the more optimum processing temperature of 35-36 C.

This study demonstrated the need for more uniform manufacturing practices in Minas cheesemaking and the need to use a starter and pasteurized milk to minimize the possibility of S. aureus growth. Finally, there is a need to establish good manufacturing practices in the processing plants.

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