PLATES' PRE-COOLING ENHANCES PRESERVATION OF RAW MILK ON FARM LEVEL: A WAY TO IMPROVE BRAZILIAN MILK QUALITY

UTILIZAÇÃO DE PRÉ-RESFRIADOR DE PLACAS EM NIVEL DE FAZENDA: UM CAMINHO PARA A MELHORIA DA QUALIDADE DO LEITE NO BRASIL

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SUMMARY

This study aimed at evaluating the raw milk quality on farm level in Brazil as influenced by a plates' pre-cooling carried out before refrigerated storage in bulk tank. Milk temperature, pH and total bacterial count were quantified. Monitoring was carried out until a constant temperature was reached. Control samples were not pre-cooled. The milk treated with plates' pre-cooler presented in average, temperature of 8.91^{o} C, pH of 6.82 and bacterial count of 4.02 log CFU/mL, while control samples presented in average, temperature of 14.85° C, pH of 6.75 and bacterial count of 4.29 log CFU/mL. Results showed statistically significant differences between quality of pre-cooled and control milk as expressed by the studied parameters, suggesting that pre-cooling is an important way to enhance preservation of raw milk quality.

KEY-WORDS: Bacterial count. Farm. pH. Raw milk.

RESUMO

Este estudo teve como objetivo avaliar como a qualidade do leite cru a nível de fazenda no Brasil pode ser melhorada através da utilização do pré-resfriador de placas antes do seu armazenamento no tanque resfriador. A temperatura do leite, pH e a contagem bacteriana total foram monitorados. O acompanhamento foi realizado desde o início da ordenha até que o leite tenha atingido temperatura constante de resfriamento. As amostras do grupo controle não foram pré-resfriadas. O leite tratado com o pré-resfriador de placas apresentou temperatura média de 8,91^{o} C, pH 6,82 e contagem bacteriana de 4,02 log UFC/mL, enquanto as amostras controle apresentaram em média, temperatura de 14,85^{o} C, pH 6,75 e contagem bacteriana 4,29 log UFC/mL. Os resultados demonstraram estatísticamente diferenças significativas entre a qualidade do leite pré-resfriado e do grupo controle, através dos parâmetros estudados, sugerindo que o pré-resfriamento constitui um importante método para melhorar a preservação da qualidade do leite cru.

PALAVRAS-CHAVE: Contagem bacteriana. Fazenda. Leite cru. pH

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INTRODUCTION

Despite the fact that milk is a highly nutritious food that and ideally suited for growth of pathogenic organisms, the dairy industry has been extremely successful in producing safe and nutritious products. The use of refrigerated storage of raw milk right after milking is strongly responsible for such good results (RUEGG 2003).

In year 2002, Brazil urged development and updating of the milk production chain, which led to the creation of a National Plan for Milk Quality Improvement and a National Net of Laboratories for Milk Quality Control. Although, the milk obtained specially in places that present high ambient temperatures still present an inappropriate hygienic quality, due mainly an inefficient refrigeration system for cooling milk.

Undesirable biochemical reactions between ions present in the milk may be boosted by inappropriate cooling. In order to preserve milk microbiological quality after the milking process, its temperature must be reduced to the refrigeration temperature. On farm, regular addition of fresh warm milk to the tank milk prevents ideal storage conditions, and temperatures during transport and in processing plants are seldom at the refrigeration temperature (MARCHAND et al. 2007). Such feature is usually achieved by conventional refrigeration, where a tank equipped with a cooling jacket receives the milk, and through its walls, heat is transferred from the milk to the jacket until refrigeration temperature is reached. Although, the process of milk cooling can be shortened by using a plates' pre-cooler between milking and refrigerated storage. A plate cooler consists of a series of very thin stainless steel plates, where water flows along one side of each plate and, at the same time, milk flows along the other. Pre-coolers remove heat from milk very quickly due to the large surface area available for heat exchange. Heat is transferred from the milk to the water via the plate. Despite the advantages of the use of plate cooler to assure milk sanity, not all of the farms are equipped with such devices.

The measurement of milk pH is carried out in order to provide an indirect measurement the concentration of milk acids, like acid groups of protein, citrates and phosphates, which reflect high rates of microbial reactions and are resultant from the fermentation of lactose by mesophilic bacteria, which is undesirable in the milk used for consumption (PICQUE et al. 1992, FONSECA & SANTOS 2000). The bacterial count constitutes an important indicative of the herd sanity, efficacy of the sanitation system used in the farm, and the appropriate handling techniques of milking and milk storage temperature (HAYES et al. 2001). The Individual Bacterial Count (IBC) is easily measured through an infra-red equipped device, which provides the number of bacteria in a sample, e.g. milk, in small amount of time. Despite the advantages of such method and the fact that it is recommended by international dairy authorities (INTERNATIONAL DAIRY FEDERATION 2004), the unity called Colony Forming Units (CFU) is still widely used to express bacterial count worldwide. Therefore, methods have been proposed to convert IBC in CFU (CASSOLI et al. 2005).

The impairment of milk properties may be caused by inefficient refrigeration at farm. The use of plate pre-coolers for cooling milk, which is a way to overcome such problem, is still not widespread in some regions. Therefore, this study was carried out in order to investigate the potential positive impact of pre-cooling with plate cooler on farm level on physical and chemical parameters usually employed to express raw milk quality, namely temperature, pH and bacterial count.

MATERIAL AND METHODS

The study was carried out during the months of August and September of year 2007, in a milking farm located in Paraná state, Brazil. The milking room was in line with an internationally recognized guide for good dairy farming (INTERNATIONAL DAIRY FEDERATION/ FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS 2004). Bulk tank milk (BTM) was collected in triplicate at ten minutes intervals under two process conditions: 1) after being submitted to plates' pre-cooling; 2) without being submitted to plates' pre-cooling. Pre-cooled milk was passed through a plates' pre-cooler (Type 1600, Bosio, El Trébol, Argentina). The equipment presented thirty stainless plates and a ratio of the flow rate of cooling fluid to milk 2.5:1, which is within the limits recommended by the Australian National Milk Harvesting Centre (2006). The cooling fluid was water at ambient temperature (19 ± 1°C). Milk was collected in the bulk tank, which was fed with warm milk at 8 l/min. (DXCE 3000, DeLaval, Campinas, Brazil). Collected milk was assessed for temperature, pH and total bacterial count. The pH was measured "in loco" through the use of a Metrohm 826® (Metrohm USA Inc., Westburry, NY, United States) pH mobile meter. The electrode was standardized using two buffers (pH 4.0 and pH 7.0) and cleaned after each run using a HCl solution. The pH of the samples was recorded at selected intervals (10 min) until constant temperature. The milk assessed for bacterial count was placed in sterilized 70 mL vials and added with a bacteriostatic agent (Azidiol, BS Pharma, Belo Horizonte, Brazil) composed by 0.11975mg of sodium azide and 0.005 mg of chloramphenicol per mL of solution, and kept immersed in ice until analysis, which was carried out in the same day. Microbiological analysis followed the methods of ISO 21187 (IINTERNATIONAL DAIRY FEDERATION 2004). An IBC BactoCount (Bentley Instruments Incorporated®, Chaska, MN, United States) bacterial counter was used to provide us with the Total Bacterial Count (TBC), expressed in CFU/mL. At 80 minutes of refrigerated storage, warm fresh milk feeding was stopped. From the next monitoring time (90 minutes) on, we estimated the bulk tank capacity for cooling the studied milk. This was made through plotting

temperature versus time (figure 1) and fitting the data with a model. The slope of the curve corresponded to a parameter we called refrigeration coefficient, which represents the amount of units of temperature reduced from the milk per unit of time. In addition, we estimated inactivation of microorganisms, which was expressed as a logarithmic viability reduction, $\log_{10}(N_0/N_t)$, being N_t and N_0, respectively, the final number of survivals (CFU/mL) after the cooling treatments and the initial number of cells (CFU/mL), determined in the sample of milk when it reached the bulk tank. This procedure was performed to both pre-cooled and control milk.

The obtained data were submitted to statistical analysis using Open Office 2.4.0 (Sun Microsystems Inc., Santa Clara, CA, USA) software. Analysis of variance (ANOVA) and Tukey test of means were performed. The 5% confidence level was used. Preliminary logarithmic transformation of the results of microbiological counts was performed to guarantee that the data were independent and normally distributed.

RESULTS AND DISCUSSION

Milk temperature, pH and total bacterial count as measured during the period of time necessary for the milk temperature to stabilize in the bulk tank are showed in table 1, respectively, for pre-cooled and control. At the first measurement, temperature was already lower for pre-cooled milk compared to control, as a result of the plates' pre-cooling. Furthermore, pre-cooled milk temperature became stable at 140 minutes of measurement, while control temperature took 180 minutes to stabilize. Lower temperature is related to more efficient preservation of milk properties. The milk pH stabilized faster (20 minutes) in pre-cooled milk than in control (120 minutes), period during which the milk remained acid. Milk acid pH is caused by acid groups of protein, citrates and phosphates, and reflects high rates of microbial reactions (FONSECA & SANTOS 2000).

Microorganisms' growth and multiplication was inhibited by pre-cooling, since the final bacterial count in pre-cooled milk was 70% lower than that observed in control. The bacterial count constitutes an important indicative of the herd sanity, efficacy of the sanitation system used in the farm, and the appropriate handling techniques of milking and milk storage temperature (HAYES et al. 2001).

The mean value of total bacterial count (4.29 log CFU/mL) in control samples over the 180 minutes of monitoring was close to the result reported by Villar *et al*. (1996) for mesophilic aerobic bacteria. On the other hand, the mean total bacterial count in pre-cooled milk was significantly below (4.02 log CFU/mL), as shown in figure 1. The average of the temperatures measured during refrigerated storage was significantly lower for pre-cooled milk (9.06 °C) as compared to the control (14.91 °C). Such results suggest that pre-cooled milk was less subjected to microbial multiplication, which is boosted by an augment in temperature within the studied ranges. Mesophilic bacteria represent the majority of raw milk microbial flora and are responsible for converting lactose into lactic acid, which impairs milk sensory quality (VILLAR et al. 1996, BUSSE 2000). Such reaction reduces milk pH (FONSECA & SANTOS 2000). The average pH observed in control (6.75) was significantly lower than pre-cooled milk (6.83), inversely matching the results for microbial counts, i.e., the higher the microbial counts, the lower the pH. Such correlation was investigated and the correlation coefficient was found to be negative and significant on 5% level ($r = -0.54$). In fact, all of the investigated parameters correlated significantly with each other (table 2). A positive correlation between temperature and bacterial count suggests that the higher the storage temperature, the higher the number of bacteria in raw milk. At the same time, a negative correlation between temperature and pH was observed. Such result was expected, since higher temperatures are favorable for microorganisms to convert milk components into acid groups, reducing the pH (PICQUE et al. 1992).

The refrigeration capacities of the bulk tank were determined for pre-cooled and control milk. After plotting temperature versus time (figure 2) and trying to fit the data with a mathematical model, we found that the linear model was suitable for this purpose, because it provided high values of determination coefficient both for control and pre-cooled milk. In addition, the slope of the correspondent curve, which yields the refrigeration capacity of the tank in °C/min, is easily given by the angular coefficients of the equations embedded in figure 2. The refrigeration capacity was found to be lower for pre-cooled milk (-0.0943°C/min) compared to control (-0.1612°C/min). Such result is justified by the fact that pre-cooled milk was at a temperature (8°C) closer to the equilibrium temperature (3.6°C) as compared to control (16°C) when warm milk feeding was stopped. Pre-cooled milk was always at lower temperatures than control, which caused storage temperature to be reached first, for the same refrigeration equipment. Thus, pre-cooled milk was all the time more protected against pathogens metabolism than control.

Figure 3 shows the microorganisms' inactivation as calculated by previously described methods. Results show that pre-cooling enhances inactivation in about 322%. Raw milk is best stored at lower temperatures to avoid problems with the processed UHT milk after several months of storage at ambient temperature (HARYANI *et al*. 2005). Refrigeration is effective in control of certain undesirable microorganisms, such as the enteric microflora (TAVARIA et al. 2005). Refrigeration helps preserving and generating characteristic flavor to milk and dairy products (DAHL *et al.* 2000).

Figure 4 shows the amount of microorganisms in milk as influenced by pre-cooling plus cooling or cooling itself (control). The shape of the obtained curves obtained suggests that pre-cooling plus cooling is far more severe in reducing the microbial population in milk than cooling itself. Even though in the beginning of refrigerated storage the amount of microorganisms was similar, as cooler milk was fed

into the tank (pre-cooled sample), the microflora was being killed and, thus, the bacterial population was being reduced.

Results suggest that pre-cooling on farm level is a way to reduce bacterial development and consequently, to preserve milk and derived products general quality. Therefore, pre-cooling is a way to fulfill the needs of improving quality of Brazilian milk, by enhancing its preservation right after milking. Nevertheless, it is important to assure milk safety through the whole production chain in order to provide high quality dairy products for consumers.

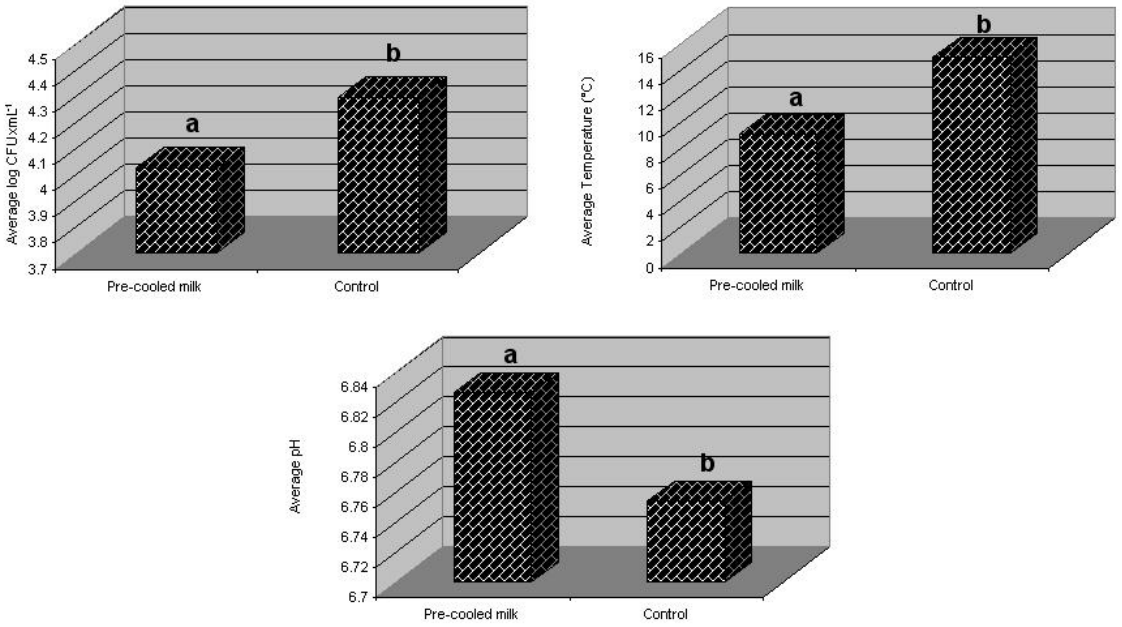

Figure 1 - Average total bacterial count, temperature and pH in control and pre-cooled milk.

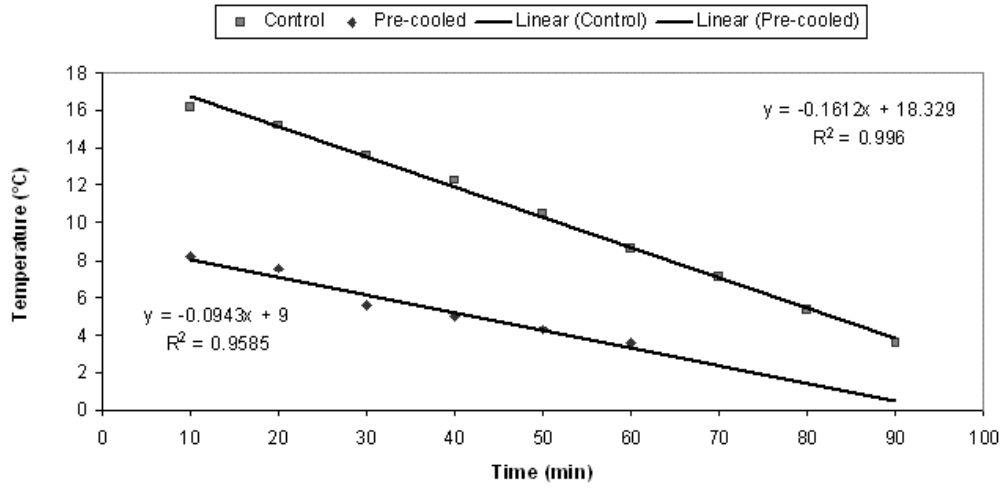

Figure 2 - Changes in BTM temperature during refrigerated storage as fitted by linear models.

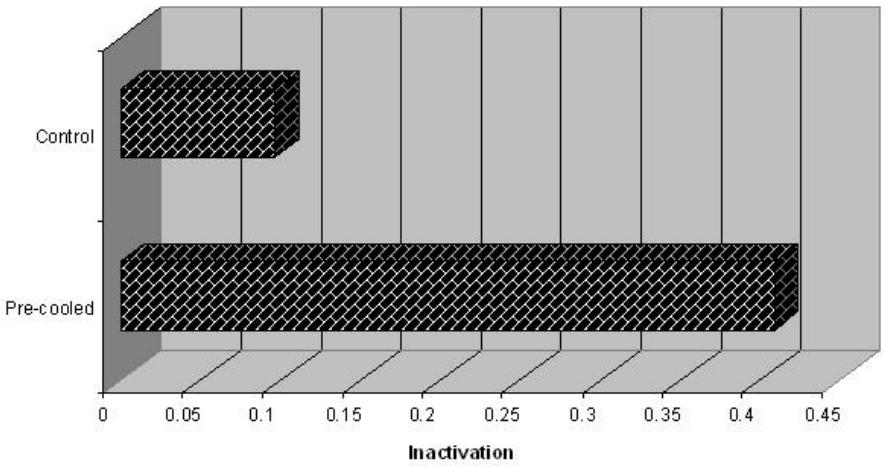

Figure 3 - Microorganisms inactivation by pre-cooling system

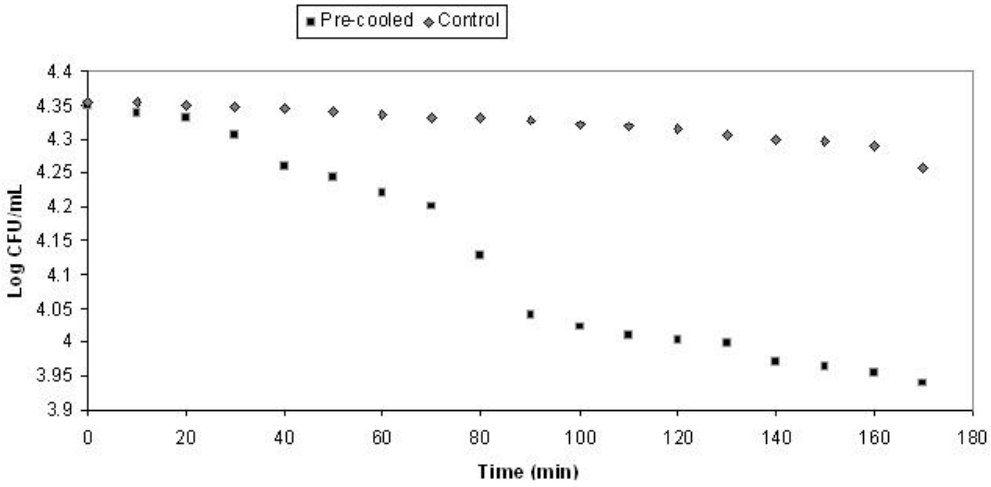

Figure 4 - Amount of microorganisms in milk at BTM in pre-cooled and control systems

Table 2 - Correlation coefficients for the studied milk parameters

Parameter	TBC	pH	Temperature
TBC	1	-	-
pH	-0.54*	1	-
Temperature	0.81*	-0.74*	1

*Significant on 5% level.

Table 1 - Milk temperature, pH and total bacterial count for pre cooled and control milk as measured until milk reached storage temperature.

Parameters	**Time of refrigerated storage (min)**																	
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
									Pre cooled milk									
T (°C)	21.23^{a}	20.77^{a}	16.13^{b}	13.17^{c}	12.10^{cd}	10.97^{cd}	9.70^{def}	10.47^{de}	8.17^{efg}	7.53^{fgh}	5.57^{ghi}	5.00^{hi}	4.33^{i}	3.60^{i}	3.60^{i}	3.60^{i}	3.60^{i}	3.60^{i}
pH	6.67^{a}	6.81^{b}	6.86^{b}	6.85^{b}	6.84^{b}	6.84^{b}	6.85^{b}	6.83^{b}	6.83^{b}	6.83^{b}	6.84^{b}	6.83^{b}	6.83^{b}	6.83^{b}	6.83^{b}	6.83^{b}	6.83^{b}	6.83^{b}
TBC (CFU/mL)	4.29^{a}	4.23^{a}	4.21^{ab}	4.14^{abc}	4.07^{bcd}	4.03^{cd}	3.95^{de}	3.93^{de}	3.83^{ef}	3.72^{fg}	3.71^{fg}	3.70^{fg}	3.69^{fg}	3.69^{fg}	3.66^{g}	3.66^{g}	3.65^{g}	3.64^{g}
									Control samples									
T (°C)	22.40^{a}	22.33^{a}	21.50^{ab}	20.60^{b}	19.17^{c}	18.50^{cd}	17.60^{de}	17.10^{ef}	16.70^{ef}	16.17^{fg}	15.23^{g}	13.60^{h}	12.30^{h}	10.50^{i}	8.63^{j}	7.07^{k}	5.33^{l}	3.60^{m}
pH	6.63^{a}	6.64^{a}	6.68^{b}	6.71^{bc}	6.72^{cd}	6.72^{cd}	6.74^{de}	6.76^{ef}	6.79^{fg}	6.79^{fg}	6.79^{fg}	6.80^{g}	6.80^{g}	6.80^{g}	6.80^{g}	6.80^{g}	6.80^{g}	6.81^{g}
TBC (CFU/mL)	4.37^{a}	4.36^{ab}	4.36^{ab}	4.36^{ab}	4.35^{abc}	4.35^{abc}	4.32^{abcd}	4.31^{abcde}	4.30^{abcde}	4.30^{abcde}	4.28^{bcde}	4.28^{bcde}	4.27^{cde}	4.25^{de}	4.24^{def}	4.23^{def}	4.22^{ef}	4.17^{f}

Note: T: temperature; TBC: total bacterial count

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