**QUEIJO MINAS ARTESANAL PRODUZIDO NA REGIÃO DE CANASTRA: CARACTERÍSTICAS DOS PARÂMETROS DE PRODUÇÃO, QUALIDADE DA ÁGUA E QUALIDADE DO QUEIJO**

**MINAS ARTISANAL CHEESE PRODUCED IN THE CANASTRA REGION: PRODUCTION CHARACTERISTICS AND WATER AND CHEESE QUALITY PARAMETERS**

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**Afiliação**

**RESUMO**

A região da Serra da Canastra é conhecida pela produção do queijo Minas artesanal, denominado queijo Canastra. O objetivo deste estudo foi caracterizar os aspectos microbiológicos e físico-químicos da água e do queijo coletados nas propriedades produtoras de QMA, além de caracterizar os aspectos ambientais do processo de produção do queijo. Nas análises físico-químicas da água, a maior não conformidade foi com cloro residual livre (44,69%). Nas análises microbiológicas, 17,02% das amostras apresentaram não conformidade para os parâmetros *E. coli* e coliforme total. Nas análises microbiológicas do queijo, foram encontradas não conformidades em 7,84% das amostras para coliformes totais e 9,8% para *Staphylococcus* coagulase-positivo. As análises físico-químicas do queijo estavam todas em conformidade. Não foi encontrada associação estatística entre a qualidade do queijo e da água. As fontes de água foram protegidas e as fazendas descartaram adequadamente os resíduos da produção pecuária, esgoto sanitário e lixo. O estudo indica que os produtores precisam melhorar o controle de qualidade do suprimento de água para seus laticínios, cumprir os requisitos de cloro na água e verificar periodicamente o teor de cloro, garantindo que os alimentos produzidos sejam seguros para o consumo humano.

**PALAVRAS-CHAVE:** Parâmetros legais. Qualidade do alimento. Queijo Canastra. Segurança alimentar.

**ABSTRACT**

The Serra da Canastra region is known for the production of a characteristic Minas artisanal cheese, named Canastra cheese. The objective of this study was to characterize the microbiological and physicochemical aspects of the water and cheese collected from the MAC-producing properties, as well as to characterize the environmental aspects of cheese manufacturing. In the physical chemical analyses of the water, the highest non-conformity was for free residual chlorine (44.69%). In the microbiological analyses, 17.02% of the samples showed non-conformity for *E. coli* and total coliform parameters. In the microbiological analyses of the cheese, non-conformities were found in 7.84% of the samples for total coliforms and 9.8% for coagulase-positive *Staphylococcus*. The physicochemical analyses of the cheese were all in compliance. No statistical association was found between the quality of the cheese and the water. The water sources were protected and the farms properly disposed of the waste from cow pens, sanitary sewage, and garbage. The study indicates that producers need to improve the quality control of the water supply for their dairies, fulfill the requirements of chlorine in the water and periodically verify the chlorine content, ensuring that the produced food is safe for human consumption.

**KEY WORDS:** Canastra cheese. Food quality. Food safety. Legal parameters.

**INTRODUCTION**

Minas artisanal cheese (MAC) is produced from raw milk using endogenous microbiota (NÓBREGA, 2007). The Canastra microregion produces a MAC named Canastra cheese (IMA, 2018a). Studies have demonstrated that the microbiological quality of the water used in production influences the microbiological quality of MAC. The presence of a high number of coliforms in the cheese-making water may cause some defects in the food product, such as early blowing defect, which results in the presence of small holes in the cheese. The high incidence of these microorganisms in water is mainly due to environmental contamination or inefficient chlorination (FAROOQ et al., 2008; TRMČIĆ et al., 2016).

The use of chlorinated water is another important aspect that influences cheese quality. Chlorine, if incorporated into water without a safety residue control, impairs the quality of the cheese, as potentially contaminated water may contaminate the cheese-making process. The disinfection of water, equipment, and surfaces is important for the food industry and chlorine-based chemicals are the main disinfectant used; however, during the disinfection process, disinfection by-products (DBPs) are generated. Therefore, the disinfection process results in the presence of DBPs in foods (CARDADOR et al., 2017). Moreover, as the ripening time advances, the cheese loses moisture and the enzymatic processes act on the fat, proteins, and carbohydrates, affecting the presence of DBPs in the final product. One study showed a significant correlation between trihalomethanes (THMs) and fat contents (owing to the lipophilic nature of THMs), and non-volatile haloacetic acids and volatile THMs increase in concentration as the moisture content in cheese decreases during the ripening process due to a concentration effect (CARDADOR et al., 2016).

According to Saraiva et al. (2012), just over half of the producers demonstrated some control over water use, such as chlorination control or periodic physicochemical and microbiological analyses. It is also worth noting that all wastewater from the process should be treated; however, it was instead tossed on the ground without any treatment, thus, contributing to environmental contamination.

The production of MAC is socially and economically important to the state of Minas, and studies regarding the characteristics of the producers and their food products are important for strengthening the food chain and informing political legislation. Thus, this study aimed to characterize Canastra cheese producers registered at the Instituto Mineiro de Agropecuária (IMA) – Brazil; evaluate the qualities of the water used and cheese produced; and verify the relationship between the microbiological and physicochemical quality parameters of the water and cheese.

**MATERIALS AND METHODS**

For this study, an observational, ecological, cross-sectional study was performed using a secondary database, containing information from the years 2016 and 2017 on the qualities of the water and cheese from three cities in the Canastra microregion, which makes up part of the sectional office of the IMA, located in Bambuí – MG. The cities included in the study were Bambuí, Medeiros, and Tapiraí. The IMA is responsible for the inspection of animal products from the state of Minas Gerais, among other activities.

During the study in 2016 and 2017, 33 cheesemakers were registered with the IMA and were included in the study. The characteristics obtained from the production and analyzed were set using the legal legislation for MAC production (IMA, 2018b).

The parameters obtained were as follows:

* Microbiological and physicochemical analyses of water: chlorine, free residual chlorine, color, hardness, iron, nitrate, nitrite, odor, pH, turbidity, *E. coli*, total coliforms, and heterotrophic bacteria.
* Microbiological and physicochemical analyses of the cheese: total coliforms, thermotolerant coliforms, coagulase*-*positive *Staphylococcus*, *Listeria monocytogenes*, and *Salmonella* spp.
* Origin of the water used in the cheese factory: water source (well or COPASA-MG ([sanitation company of Minas Gerais]).
* Up-to-date vaccinations for foot-and-mouth disease (FMD) and Brucellosis.
* Annual brucellosis and tuberculosis examinations of the cattle.
* Mastitis diagnostic tests (California mastitis test and mesh-screen or black background mug test).
* Adequate destination of dairy washing water.
* Adequate destination of cheese whey.
* Adequate destination of garbage.
* Destination of sanitary sewage.
* Number of animals on the properties.
* Information related to water source: if the water source is protected from animal access, if the water is channeled from the source to the tank, if the water is filtered and chlorinated before reaching the water tank, if the water tank is conserved and protected, if the water tank is cleaned as recommended by the Manual of Good Manufacturing Practices (GMPs) (every six months), and if the chlorine dosage and pH of the water are checked daily.

Data on the cheese and water quality were organized into two categories: conformity (within the legal parameters) and non-conformity (outside the legal parameters). The other parameters were also characterized according to the legal parameters (conformity and non-conformity). The statistical analyses were performed using R statistical software (R CORE TEAM, 2018). After verifying the normality of the data using the Shapiro–Wilk test (SHAPIRO & WILK, 1965), a Pearson correlation analysis was performed between the results of conformity and non-conformity from the microbiological and physicochemical analyses of cheese, water, and the other results to assess the relationship between these variables.

Univariate analysis was performed using the chi-square test (χ2) or Fisher’s exact test to determine the variables associated with the microbiological and physicochemical parameters of both the cheese and water, using a significance level of *P* ≤ 0.05 (ZAR, 2010). Correspondence analysis (GREENACRE & BLASIUS, 2006) was used to study the interactions between the parameters of cheese (coliforms and coagulase-positive *Staphylococcus*) and water (odor, turbidity, residual chlorine, coliforms, and *Escherichia coli*). In the correspondence analysis, the relationship between the categories was represented in a two-dimensional graph. The relationship between the selected parameters was demonstrated by visualizing in the graph which variables were grouped or plotted closer to each other.

**RESULTS AND DISCUSSION**

Only complete analyses of each property in each year were considered; therefore, data from 47 microbiological and physicochemical analyses of water and cheese were obtained from 33 registered properties. The characteristics of production were also accessed and analyzed. The results of the physicochemical and microbiological analyses of water are summarized in Table 1.

The physicochemical analyses of the cheeses were all within the standard. The results of the microbiological analyses of the cheeses are shown in Table 2. There was no association between the parameters analyzed from the cheese and water samples.

The properties had an average of 114 animals each, ranging from 4 to 345. The other parameters analyzed are shown in Table 3.

Correspondence analysis was used to study the interaction between the results of the analysis of 35°C coliforms, thermotolerant coliforms, and positive-coagulase *Staphylococcus* in the cheese and the results of odor, turbidity, residual chlorine, total coliforms, and *E. coli* in the water. In the correspondence analyses, the relationship between the categories was represented in a two-dimensional graph (Figure 1). The relationship between the selected parameters was demonstrated by visualizing in the graph which variables were grouped or plotted closer to each other. Figure 2 demonstrates the results considering the parameters of Figure 1 but separates the results of chloride non-conformity as above or below the legal limit.

The most important non-conformity found was related to free residual chlorine. According to the legislation, the content of free residual chlorine must be between 0.2 and 2 mg/L (MINISTÉRIO DA SAÚDE, 2011). Of the 21 water samples that were found to be outside the standard required by current legislation, 16 were above the chlorine limit allowed, and the other five were below the limit. Two properties were above the chlorine standard in 2016 and below in 2017, which demonstrates a lack of control in the use of chlorine for water treatment. The nine properties that showed non-conformity for the odor parameter had a chlorinated water odor and chlorine analysis above the standard. This relationship is demonstrated in the correspondence analysis, of which chlorine above the limit was plotted near non-conformity odor.

According to Freitas et al. (2001), free residual chlorine values below 0.2 mg/L justify the increase in the presence of *E. coli* in the water, confirming that chlorine has a beneficial effect on the elimination of bacteria. Although no association was found between residual chlorine and the presence of coliforms and *E. coli* in the cheese, the correspondence analysis indicates that chlorine below the limit is related to the non-conformity of *E. coli* and total coliforms in the water (Figure 2). A study evaluated cheese available on the market for presence of coliforms and key pathogens and investigated the coliforms present to assess their likely sources and public health relevance. The results suggested that the majority of *Escherichia* isolates detected in cheese samples are an actual direct or indirect fecal contamination of cheese and that raw milk is a very important source of coliforms in cheese made from unpasteurized milk (TRMČIĆ et al., 2016), such as Canastra cheese.

There are also risks that come with the use of chlorine above the standard in water disinfection. Excess chlorine can generate DBPs and cause the contamination of trichloromethanes (TCM) in the cheeses. Milk and dairy products have acetoin, diacetyl, and other methyl ketones that can react with chlorine and form TCM, a substance considered to be carcinogenic (SIOBHAN et al., 2012; CARDADOR et al., 2016, 2017). In Brazil, there is no legislation for the quantification of TCMs in food. Research carried out in Ireland has shown that the addition of chlorine to the milking wash water increases the amount of TCM present in the milk (SIOBHAN et al., 2012).

The presence of iron at levels above the standard may have a natural origin, referring to the region’s soil having high concentrations of iron, or it may be an indicator of anthropogenic pollution, as the presence of dumps and ditches can increase the concentration of iron in the water (FREITAS et al. 2001). Regarding the pH of the water, it is known that the soil in each region interferes with this parameter, in addition to the presence of industrial waste (SILVA et al. 2010). All of the samples that showed a pH < 6 were from cities without industries, suggesting that the region’s soil may have influenced this non-conformity.

Water turbidity above the limit can indicate a high presence of organic and/or inorganic matter in suspension, and these particles serve as shelter for microorganisms. Therefore, the water used for food production must be filtered (KAMIYAMA & OTENIO, 2013) and the non-conformity with the parameter may be due to the non-periodic replacement of the filters; according to legislation for cheese makers, the use of a filter is mandatory when the microbiological or physical chemical analyzes of the water show non-conformities. (Ima, 2018b).

*E. coli* is normally found in the intestines of animals and humans, but can cause enteric disease and other syndromes in its hosts, highlighting the importance of its control for public health (TORRES, 2017). Our study found some water samples positive for this bacterium; the correspondence analysis indicates a relationship between the non-conformity of chlorine in the water and the presence of *E. coli* and coliforms in water. In a study of dairy farms in Minas Gerais, the results of the microbiological analyses of the quality of the water used for cleaning milking areas and utensils showed that all of the water samples were outside of the drinking standard limits (PEREIRA & ARAÚJO ET AL., 2009). This parameter is important for guaranteeing the safe use of water, since it is used in the production of cheese. Moreover, washed rind cheese showed a 4 times higher risk of coliform detection than cheese without treated rind (TRMČIĆ et al., 2016), and Canastra cheese is washed rind cheese, reinforcing the importance of water quality.

Ripening is carried out according to the legislation, which recommends 22 days of maturation for the Canastra microregion, and uses raw milk, which is confirmed by the conformity of phosphatase and peroxidase results (IMA, 2017).

Coliforms are indicative of hygiene issues, and thermotolerant coliforms of fecal contamination. In this study, there were few cheese samples that were outside the parameters for total coliforms and thermotolerant coliforms. In the Alto Paranaíba microregion, Fernandes et al. (2011) found that all cheeses analyzed had microbiological standards outside of the legislation and, therefore, were prohibited for human consumption. In the microregion of Triângulo, Ferreira et al. (2011) found that 70% of the analyzed cheese samples were above the legal parameters for total coliforms and 80% for thermotolerant coliforms. According to Sant’anna et al. (2018), who conducted a study in the Canastra region, although some improvements have been made, the development of cheese manufacturing in the region is necessary. MAC from the Canastra microregion is made from raw milk product, and negative results for *Listeria monocytogenes* and *Salmonella* spp. are important to guarantee a safe food product.

Coliforms present in cheese may contribute to the final quality of cheese and, although coliforms may have positive effects on the quality of raw milk cheese, the isolation of *Escherichia* suggests fecal contamination. *Listeria* species can persist in food and dairy processing environments and washed rind cheese presents the highest risk of contamination with different *Listeria* species. Furthermore, pathogen testing improve ability to detect actual public health hazards since *E. coli*-negative samples may still test positive for *L. monocytogenes* (TRMČIĆ et al., 2016).

The number of animals in the properties studied varied from 4 to 345, which indicates the heterogeneity of the herd sizes, which may be reflected in the diversity in the forms of production and quality control of the final product, results which are important for improving the legislation and inspection of the food product.

MAC producers must vaccinate cattle against brucellosis and FMD. All of the properties studied were vaccinated against FMD. For brucellosis, all females between three and eight months of age must be vaccinated, but improvement in the use of the available vaccine is needed. Vicentini et al. (2013), in a survey of cheese producers in Campo das Vertentes (MG), demonstrated that 96% of producers vaccinated cattle against FMD and 80% against brucellosis.

Mastitis control in bovine milk-producing herds used for the production of MAC is important because of the existence of several pathogenic microorganisms related to the disease that can be transmitted by milk, such as *Staphylococcus aureus*, *Streptococcus agalactiae*, *Pseudomonas* sp., *Actinomyces pyogenes*, *Serratia* sp., and *Corynebacterium bovis* (LAFFRANCHI et al., 2001).

As for the data related to the management of the water used, it is difficult for the producer to control the quality of the water. In the registered properties participating in the research, all of the water sources were protected from animals and the water undergoes filtration before reaching the reservoir tank, where it is chlorinated. However, only one property controls the chlorine content in the water. In a study carried out in the Canastra microregion, all the producers stated that the destination of the water waste is the land itself (SARAIVA et al., 2012), which is also the case in this research. The results of our study highlight the need for more public policies to help producers improve their production practices, to produce a safer food product and protect the environment and water resources.

This study found that 4.3% of the farms surveyed did not have pigs and dumped the whey on the land close to the cheese factory. The use of pig farming concomitantly with cheese production contributes to environmental preservation, economic stability, and the strengthening of small producers (SÁ et al., 2012), since it is an alternative destination for the cheese whey.

Correspondence analysis indicates visual trends, demonstrating possible relationships between variables. The correspondence analysis indicates that the presence of *E. coli* in the water is related to the presence of coliforms. This result is common in water analysis, since they can have the same source of contamination. Some properties did not clean the water tank, promoting contamination. In addition, failures in the chlorination process could also affect the presence of these microbiological hazards, as well as the odor of water. These results prove the importance of hygiene processes in the water tanks and the control of the chlorination process, which can influence both the sensory characteristics of the product and the microbiological quality of the water used in the manufacturing of the cheese. Our results did not find an association between the microbiological parameters of the water and cheese; however, the findings of thermotolerant coliforms in the cheese and the turbidity of the water were plotted in same quadrant in both figures, indicating that these parameters might be related. Therefore, the parameters of odor, residual chlorine, thermotolerant coliforms in the cheese, and turbidity of the water are related. Moreover, the presence of 35°C coliforms and positive-coagulase *Staphylococcus* in the cheese may be associated, indicating problems in the cheese-making process and failures in GMPs, since no relationships were found with the water quality, suggesting that cheese quality is related more to the cheese handlers and the cleaning process in the factory.

It can be concluded from the correspondence that chlorination interferes with water microbiological and odor parameters, and water filtration might be reflected in cheese microbiological parameters. GMP and cheese-making failures, on the other hand, could result in cheese quality problems, especially the presence of coliforms and positive-coagulase *Staphylococcus*, resulting in changes in the characteristics of the cheese and possibly even contamination for humans.

**CONCLUSION**

This study found that registered producers of MAC in the Canastra microregion need to improve their control over the water supply of their cheese factories, fulfilling the requirements of checking the chlorine content in the water daily and conducting annual water analyses. GMPs also need attention, because the microbiological analyses of the final product showed non-conformities for the coliform parameter and positive-coagulase *Staphylococcus*, which are indicative of failures in GMPs.

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**Table 1.** The results of the physical, chemical, and microbiological parameters analyses of the water from the registered cheese properties in the Canastra microregion, collected from properties in the municipalities of Bambuí, Medeiros, and Tapiraí in the years 2016 and 2017.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Conformity | | Non-conformity | |
| Number of analyses | % | Number of analyses | % |
| Chlorine | 47 | 100 | 0 | 0 |
| Free residual chlorine | 26 | 55.32 | 21 | 44.69 |
| Color | 44 | 93.62 | 3 | 6.38 |
| Hardness | 47 | 100 | 0 | 0 |
| Iron | 43 | 91.49 | 4 | 8.51 |
| Nitrate | 47 | 100 | 0 | 0 |
| Nitrite | 47 | 100 | 0 | 0 |
| Odor | 38 | 80.85 | 9 | 19.15 |
| pH | 39 | 82.98 | 8 | 17.02 |
| Turbidity | 45 | 95.74 | 2 | 4.25 |
| *E. coli* | 39 | 82.98 | 8 | 17.02 |
| Total coliforms | 39 | 82.98 | 8 | 17.02 |
| Heterotrophic bacteria | 47 | 100 | 0 | 0 |

**Table 2.** The results of the microbiological analyses of the cheeses collected from properties in the municipalities of Bambuí, Medeiros, and Tapiraí in the years 2016 and 2017.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Conformity | | Non-conformity | |
| Number of analyses | % | Number of analyses | % |
| Total coliforms | 43 | 91.49 | 4 | 8.51 |
| Thermotolerant coliforms | 45 | 95.74 | 2 | 4.26 |
| *Staphylococcus* | 45 | 95.74 | 2 | 4.26 |
| *Listeria* | 47 | 100.00 | 0 | 0.00 |
| *Salmonella* | 47 | 100.00 | 0 | 0.00 |

**Table 3.** The parameters of production obtained by the IMA for the registered cheesemakers in the Canastra microregion in 2016 and 2017.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Conformity | | Non-conformity | |
| Number | % | Number | % |
| Brucellosis vaccination | 44 | 93.62 | 3 | 6,38 |
| FMD vaccination | 47 | 100.00 | 0 | 0.00 |
| TCM | 24 | 51.06 | 23 | 48.94 |
| Mesh-screen or black background mug test | 40 | 85.11 | 7 | 14.89 |
| Protected water source | 47 | 100.00 | 0 | 0.00 |
| Piped water from the source to the dairy | 47 | 100.00 | 0 | 0.00 |
| Filtered water | 47 | 100.00 | 0 | 0.00 |
| Chlorinated water | 47 | 100.00 | 0 | 0.00 |
| Water tanks in suitable conditions | 47 | 100.00 | 0 | 0.00 |
| Water tank cleaned every 6 months | 46 | 97.87 | 1 | 2.13 |
| Sufficient water flow | 46 | 97.87 | 1 | 2.13 |
| Producer checks daily for pH and chlorine of water | 1 | 2.13 | 46 | 97.87 |
| Semester analysis of water | 34 | 72.34 | 13 | 27.66 |
| Destination of stable garbage | 47 | 100.00 | 0 | 0.00 |
| Destination of milking wash water | 47 | 100.00 | 0 | 0.00 |
| Destination of the dairy washing water | 41 | 87.23 | 6 | 12.77 |
| Destination of cheese whey | 45 | 95.74 | 2 | 4.26 |
| Garbage destination | 47 | 100.00 | 0 | 0.00 |
| Destination of sanitary sewage | 47 | 100.00 | 0 | 0.00 |

Mapa com linhas pretas em fundo branco

Descrição gerada automaticamente

**Figure 1.** Correspondence analysis for the analyzed variables. The two-dimensional representation explains 61.69% of the total variation, with 34.72% explained by the first dimension, and 26.97% by the second dimension. Related variables are plotted on the graph next to each other.

Mapa cinza com texto preto sobre fundo branco

Descrição gerada automaticamente

**Figure 2.** Correspondence analysis for the analyzed variables. The two-dimensional representation explains 57.97% of the total variation, with 30.6% explained by the first dimension, and 27.37% by the second dimension. The related variables are plotted on the graph next to each other.