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Relationship of season with milk characteristics, yield, and shelf life of cheese in a hot climate

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ABSTRACT

Objective: the objective of the study was to identify whether there is a relationship between the environmental conditions of high temperature and humidity with the parameters of cheese yield and shelf life of Oaxaca-type cheese, made throughout two different times of the year, delimited by environmental temperature, in the Mexicali Valley, Baja California, Mexico.

Design/Methodology/Approach: from January to November, ambient temperature and relative humidity, characteristics of the milk used at the time of reception (temperature, acidity, density, somatic cell count and microorganism count), yield, and shelf life of the cheese were recorded. These variables were related to season (summer and winter) and to different Temperature and Humidity Index– THI intervals. An analysis of variance was performed, also, the relationship among sets of variables by Pearson correlation, and the multiple mean difference with the Tukey test ($p \leq 0.05$).

Results: significant differences were observed in the density, acidity, temperature, somatic cell count and cheese yield of milk due to the effect of the time of year. In addition, an 11% decrease in cheese yield was found as the maximum THI exceeded 77 units. The shelf life showed positive significant difference ($p \leq 0.05$) when milk was pasteurized, but it was not affected by the THI.

Limitations/Implications of the study: this study was limited to a single period of analysis; so, it is necessary to monitor, and include additional milk quality variables.

Conclusions: heat environmental conditions negatively impact the characteristics of the milk, therefore reducing the yield of Oaxaca-type cheese. The microbiological characteristics are unfavorable during the hot season; the pasteurization of milk is the main factor that increases the shelf life of the cheese.

Keywords: Temperature and Humidity Index-THI, performance, heat stress, shelf life.

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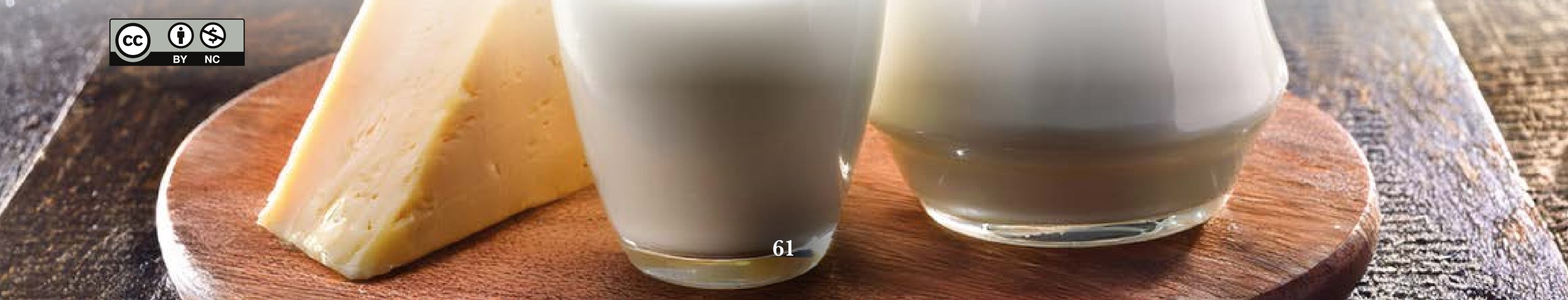
INTRODUCTION

The state of Baja California ranks as the fourteenth state with the highest milk production in the Mexican Republic, producing up to 192 thousand liters of milk per year (SIAP, 2019), while the Mexicali Valley is the main producer (Pérez Soto and Godínez Montoya, 2018). In this area there are climatic characteristics that hinder the production and industrialization of milk, since it has a hot desert climate with average maximum temperatures above 40 °C in summer, whereas in winter the environmental temperature is significantly lower (García, 2004).



Milk production is an activity that is influenced by multiple factors, and the alteration of any of these affects the quantity or quality of the milk produced (Ferreira *et al.*, 2018). High temperatures coupled with relative humidity are factors that can cause heat stress to cattle (De Rensis & Scaramuzzi, 2003). It causes an increase in respiratory and heart rate, sweating and vasodilation, resulting in a decreased dry matter intake, therefore decreasing milk production and quality (Ferreira *et al.*, 2018). Such variability in milk quality limits industrialization, livestock management should then focus on reducing heat stress (Pragna *et al.*, 2017).

Also, during the season of high temperatures, bovine mastitis is another recurring problem that occurs more frequently during the months of higher temperature and humidity. Therefore, it is important to focus on an adequate milking routine, good management of the cow and its environment, as well as the milking equipment and tools (Ferreira *et al.*, 2018). Otherwise, the composition, characteristics and properties of the milk will be altered, affecting the industrialization of the product (Souto *et al.*, 2008). Contamination of milk occurs at the time of extraction and contact with the environment, especially in milking facilities with poor hygienic conditions and exposure to high temperatures (Vitali *et al.*, 2016). In fact, a high content of microorganisms reduces the shelf life of milk and modifies its organoleptic characteristics (Larionov *et al.*, 2019).

The real danger of bacterial contamination lies in the presence of toxigenic (toxin-producing) bacteria such as *Staphylococcus aureus* or pathogens such as *Salmonella* sp., *Brucella* spp. or *Mycobacterium tuberculosis* (Ferreira *et al.*, 2018). It is for all of the above that the objective of the study was to identify whether there is a relationship among, the environmental conditions of high temperature and humidity, and the parameters of cheese yield and shelf life of Oaxaca-type cheese (a type of cheese manufactured with pasta filata process) made throughout two different seasons, delimited by the environmental temperature.

MATERIALS AND METHODS

The study was conducted at a production unit for Oaxaca-type cheese, located in the Mexicali Valley, Mexico, between January and November 2021. Climate classification of the region is hot desert climate (BWh) with 72 mm of average annual precipitation, and two distinctive (hot and cold) climate seasons (García, 2004).

Environmental Data

The daily environmental data during the study were obtained with a temperature and humidity recorder (TESTO 174H), used to determine maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity. Based on the environmental data obtained, the Temperature and Humidity Index (THI), the maximum THI (THI*max*) and the minimum THI (THI*min*) were calculated according to the formula described by Vitali *et al.* (2009):

$$THI = (1.8 \times AT + 32) - (0.55 - 0.55 \times RH) \times [(1.8 \times AT + 32) - 58]$$

where *AT* is the ambient temperature (°C) and *RH* is the relative humidity.

Milk Parameters evaluated

Samplings for the determination of parameters were implemented in accordance with the Mexican Standard NOM-110-SSA1-1994. The milk used to make this Oaxaca-type cheese comes from a single producer of milk from Holstein cattle. Upon receiving the milk, temperature, pH (HI1271, Hanna Instruments), and density (Quevenne, Nahita) were recorded. Subsequently, the Wisconsin test (WMT) (Thompson and Postle, 1964) was performed to estimate the number of somatic cells (CCS) in milk. Milk yield (%) was determined by the amount of milk needed to produce 1 kg of Oaxaca-type cheese (Oliszewski *et al.*, 2002).

Microbiological determinations were carried out monthly before cheese production, in accordance with NOM-243-SSA1. The counting of aerial mesophiles was carried out by serial decimal dilutions and plate counting; for *Escherichia coli* by the most probable number (MPN) technique (NOM-112-SSA1-1994) and the presence of *Salmonella* sp. was determined in 25 g of sample according to NOM-243-SSA1-2010. The calculation of the shelf life of the cheese was made according to the method described by Carrillo-Inungaray and Mondragón-Hernández (2011), taking monthly samples of cheese that were stored at refrigeration temperature (4 °C) until unfavorable organoleptic changes were observed.

Statistical Analyses

Variables under study were related to season (summer and winter) and also to different THI intervals. Each interval amplitude represents different environmental heat stress conditions, where THI lower than 72 indicates no heat stress, 72-77 moderate heat stress, 78-87 high heat stress, and greater than 88 means extreme heat stress.

Variable records were analyzed by analysis of variance, the relationship between variables by Pearson correlation and the multiple means difference with the Tukey test ($p \leq 0.05$); this is an alpha-type error (α) probability less than or equal to 5%. The statistical software used was SAS® 9.4.

RESULTS AND DISCUSSION

The average environmental conditions recorded during the study are shown in Table 1. These values were typical of the geographical area. Relative humidity was similar during most of the study period; whereas two seasons could be highlighted, delimited by the ambient temperature. Hot season occurred from April to early November, in which the maximum ambient temperature was around 50 °C. In July and August average THI*max* were recorded above 88 units, evenly reaching THI*max* greater than 92 which represents extreme heat stress.

The observed properties of milk are shown in Table 2. Significant differences were found when the THI*max* exceeded 77 units. The temperature of the milk at the time of reception showed significant differences when the ambient temperature was higher ($p \leq 0.05$). At the ranch, the milk is stored in a cooling tank throughout milking, until it is sent to the cheese plant; however, during transport the cold chain is not maintained, which causes the milk to be subjected to a higher temperature. During days with a

Table 1. Monthly averages of ambient temperature, relative humidity and Temperature and Humidity Index (THI) in the area of the production unit.

Month	Relative humidity (%)			Temperature (°C)			THI		
	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum
January	39.2	18.6	63.9	15.4	7.2	20.9	58.9	49.8	64.8
February	28.9	19.5	56.2	17.9	8.5	24.0	61.9	51.3	67.8
March	27.5	16.2	53.3	19.2	9.9	24.7	62.8	52.8	68.1
April	22.2	13.5	44.6	25.6	15.5	32.2	69.1	58.6	75.3
May	23.2	11.3	50.7	27.6	17.5	35.2	71.7	61.2	79.1
June	24.7	9.2	49.1	33.3	23.5	41.2	77.8	67.5	85.3
July	36.6	16.2	59.5	34.9	28.4	41.1	81.8	74.2	88.5
August	37.1	13.1	65.1	34.6	27.3	41.0	81.5	72.6	88.2
September	34.8	15.6	62.0	32.2	23.8	38.7	78.2	69.2	85.3
October	27.5	15.4	49.7	24.1	15.5	30.7	68.3	59.0	75.2
November	36.4	14.8	60.8	22.0	14.2	29.2	66.5	56.8	75.7

maximum THI*max* above 78, the minimum average ambient temperature was 19 °C, which influenced the recorded temperature.

The pH was significantly lower ($p \leq 0.05$) when the ambient temperature was higher. Likewise, both milk density and cheese yield showed significant differences ($p \leq 0.05$) at the highest THI*max*. Cheese yield was reduced by about 10% when THI*max* was above 88 (Table 2).

The microbiological count of milk, and the shelf life of cheese are shown in Table 3. The presence of *Salmonella* sp. was not detected. In the aerobic mesophile count, a significant difference was found between the two seasons; it was lower during the cold season; while there were no differences in *E. coli* content between seasons ($p \leq 0.05$). On the other hand, the count of aerobic mesophiles and *E. coli* exceeded the maximum limit established in the Mexican standard NOM-243-SSA1-2010.

The SCC (somatic cells count) was significantly higher ($p \leq 0.05$) in the hot season; which placed the milk of the hot season within the quality class 2, but the cold season milk was placed within quality class 1, in accordance with the standard proposal PROY-NMX-F-700-COFOCALEC-2012. In addition, it is indicated that the milk with the best quality

Table 2. Average temperature, density, and pH of the milk at time of reception in the cheese production unit; and cheese yield of the milk used according to environmental conditions.

THI*max*	Temperature (°C)	Density (g/cm^3)	pH	Cheese yield (L Kg^{-1})
<72	10.2 ± 0.2^b	1.0311 ± 0.0014^a	6.63 ± 0.02^a	10.2515 ± 0.3292^c
72-77	10.8 ± 0.3^b	1.0308 ± 0.0019^a	6.32 ± 0.03^a	10.3280 ± 0.4893^c
78-87	15.6 ± 0.6^a	1.0282 ± 0.0034^b	5.52 ± 0.06^b	10.9110 ± 0.7351^b
>88	16.2 ± 0.8^a	1.0248 ± 0.0035^c	5.42 ± 0.08^b	11.3758 ± 0.6888^a

^{a,b,c} Means in columns with different literals indicate significant difference, Tukey ($p < 0.01$)
THI*max*: maximum temperature and humidity index.

Table 3. Average microbiological characteristics and shelf life of milk used for cheese production, and shelf life of Oaxaca-type cheese.

	Time of year	
	Heat	**Cold**
Total aerobic mesophiles[1], (log UFC g^{-1})	6.46^{a}	5.98^{b}
E. coli[2], (MPN g^{-1})	3.5^{a}	3.2^{a}
Salmonella sp[3]	Absent	Absent
Somatic cell count, WMT (SCC×1000)[4]	479^{a}	233^{b}
Shelf life, pasteurized milk, (days)	18.3 ± 0.3^{a}	18.6 ± 0.4^{a}
Shelf life, unpasteurized milk, (days)	6.8 ± 0.7^{b}	7.1 ± 0.6^{b}

[a,b,c] Means within rows with different lettering indicate significant difference. Tukey ($p<0.05$)
[1] Maximum limit: 5 log UFC g^{-1}, NOM-243-SSA1-2010
[2] Maximum limit: 3 NMP g^{-1}, NOM-243-SSA1-2010
[3] Maximum limit: Absent, NOM-243-SSA1-2010.
[4] SCC×1000: Class 1: <400, Class 2: 401-500, PROY-NMX-F-700-COFOCALEC-2012

is that of the cold season. In regard to the shelf life of cheese, no difference was observed by season, but there was statistical difference in terms of the milk used, whether it was pasteurized or not.

A positive correlation was observed for milk density in regard to THI; and negative correlations for THI to cheese yield, and for cheese yield to milk density (Table 4).

Milk yield in order to make the pasta filata cheese of Oaxaca-type is one of the main problems in the Mexicali Valley region, as it varies throughout the year. This yield is reduced when the temperature and relative humidity are high; in this study, an average reduction of 11% was determined. Cheese yield was mainly affected by milk quality, which in turn is affected by the heat stress that cows suffer. In addition, high temperatures promote bacterial growth that can lead to bovine mastitis and chemical deterioration of milk (Vitali *et al.*, 2016).

The high count of aerial mesophiles indicates that there are hygienic deficiencies in the execution of milking (Souto *et al.*, 2008). Likewise, Larionov *et al.* (2019) indicated that subclinical bovine mastitis or poor milking increases aerobic mesophilic counts. On the other hand, greater *E. coli* contamination was expected during the hot season, but in this study no differences were found between seasons. In this sense, Medved'ová *et al.* (2020) observed that within the natural microbiota of milk there are several bacterial species that have an antagonistic effect, which could limit the growth of *E. coli*. However, according to

Table 4. Pearson correlation coefficients of the association of the Temperature and Humidity Index (THI) with milk density and cheese yield, in the manufacture of Oaxaca-type cheese.

	ITH	**Density**	**Cheese yield**
ITH	1	0.6185^{a}	-0.59439^{a}
Density	0.6185^{a}	1	-0.64267^{a}
Cheese yield	-0.59439^{a}	-0.64267^{a}	1

[a] $p<0.0001$

what was found in both periods, the limit indicated by the Mexican standard NOM-243-SSA1-2010 was exceeded.

One of the reasons why microbiological counts were higher in the hot season may be due to the fact that the temperature of the milk was higher, as a result of high ambient temperature that favored the proliferation of microorganisms. According to Ndraha *et al.* (2018), the temperature of milk should remain below 4 °C to prevent the proliferation of microorganisms. It is important to consider that the microorganisms composing the natural microbiota of milk have the ability to modify milk characteristics (Ferreira *et al.*, 2018).

Regarding yield, it can be considered that it was lower during the periods when there was higher THI. Pragna *et al.* (2017) mentioned that the physicochemical characteristics of milk can modify cheese yield, especially due to the acidification, flocculation and degradation of caseins and microbiological activity. However, heat stress also affects these parameters due to the physiological changes in the cattle, which is reflected in the quality of the milk, evaluated through milk density.

In addition, according to Vitali *et al.* (2016) and Fusco *et al.* (2020), the incidence of bovine mastitis is higher when there are conditions of high temperature and humidity, which also affect yield. In this study, the incidence that condition was not evaluated, since the milk producer does not perform periodic tests for bovine mastitis. However, indirectly it can be inferred in the storage tank via the CSS. In this study it was found that CSS was higher in the hot season, which could also justify the reduction in yield.

It may be thought that a high somatic cell count (SCC) has a negative influence on cheese yield; however, Moradi *et al.* (2021) reported that the simple fact of obtaining a high SCC does not indicate low yield. But there are various factors that can affect yield, mainly microbial activity and diseases such as bovine mastitis. Pragna *et al.* (2017) mentioned that SCC has a direct influence on cheese yield; during the hot season, it was observed that SCC was higher, although due to the type of test performed, since it was implemented in samples from several milk batches, it could not be directly related to the incidence of bovine mastitis.

In certain months, the lower milk density directly affected cheese yield because of the lower count of total solids (Stankov *et al.*, 2022). Although THI, milk density and cheese yield are correlated, Pragna *et al.* (2017) indicated that although high THIs affect cows in regard to milk production and reduce its quality characteristics, the full process is much more complex. Therefore, studies focusing on each parameter are required to better determine how those parameters are related.

CONCLUSIONS

Hot environmental conditions negatively impact the characteristics of milk, thus reducing yield of Oaxaca-type cheese. Higher ambient temperatures and relative humidity records are climatic factors that can modify the microbiological characteristics of milk and cheese, impacting cheese yield and shelf life.

In order to obtain better yield and longer shelf life in regions where the Temperature and Humidity Index is high, heat stress mitigation measures are required. For example, by implementing a hygienic milking method, pasteurizing milk, and establishing an efficient cold chain system.

REFERENCES

Alharbi, Naiyf S., Jamal M. Khaled, Shine Kadaikunnan, Ahmed S. Alobaidi, Anwar H. Sharafaddin, Sami A. Alyahya, Taghreed N. Almanaa, Mohammad A. Alsughayier, and Muhammed R. Shehu. 2019. Prevalence of *Escherichia Coli* Strains Resistance to Antibiotics in Wound Infections and Raw Milk. *Saudi Journal of Biological Sciences 26*(7):1557-62. doi: 10.1016/j.sjbs.2018.11.016.

Carrillo-Inungaray, María Luisa, and Francisco Manuel Mondragón-Hernández. 2011. Estudio de Vida Útil Del Queso Asadero. *Revista Salud Pública y Nutrición 12*(3).

Ferreira, S., ML. de Souza, and R. Carvalho. 2018. Evaluation of Milk Sample Fractions for Characterization of Milk Microbiota from Healthy. *PLoS ONE 13*(3):257-65. doi: https://doi.org/10.1371/journal.pone.0193671.

Fusco, Vincenzina, Daniele Chieffi, Francesca Fanelli, Antonio F. Logrieco, Gyu Sung Cho, Jan Kabisch, Christina Böhnlein, and Charles M. A. P. Franz. 2020. Microbial Quality and Safety of Milk and Milk Products in the 21st Century. *Comprehensive Reviews in Food Science and Food Safety 19*(4):2013-49. doi: 10.1111/1541-4337.12568.

García, Enriqueta. 2004. Modificaciones Al Sistema de Clasificación Climática de Köppen (Para Adaptarlo a Las Condiciones de La Republica Mexicana). 5a ed. edited by I. de Geografía. México: Instituro de Geografía-UNAM.

Larionov, Gennady, Vladimir Semenov, Dastanbek Baimukanov, Nikolay Kosyaev, Ivan Alekseev, Dmitry Nikitin, and Amanbay Karynbayev. 2019. The Role of Plant Preparations in Improving the Safety and Quality of Milk in Subclinical Mastitis of Cows. *The Bulletin 1*(377):151-61. doi: 10.32014/2019.2518-1467.18.

Medveďová, Alžbeta, Martina Koňuchová, Karolína Kvočiková, Ivana Hatalová, and Ľubomír Valík. 2020. Effect of Lactic Acid Bacteria Addition on the Microbiological Safety of Pasta-Filata Types of Cheeses. *Frontiers in Microbiology 11*(December):1-16. doi: 10.3389/fmicb.2020.612528.

Moradi, Mehran, Abdullah Khalid Omer, Roghayieh Razavi, Sima Valipour, and Jonas T. Guimarães. 2021. The Relationship between Milk Somatic Cell Count and Cheese Production, Quality and Safety: A Review. *International Dairy Journal* 113. doi: 10.1016/j.idairyj.2020.104884.

Ndraha, Nodali, Hsin I. Hsiao, Jelena Vlajic, Ming Feng Yang, and Hong Ting Victor Lin. 2018. Time-Temperature Abuse in the Food Cold Chain: Review of Issues, Challenges, and Recommendations. *Food Control* 89:12-21. doi: 10.1016/j.foodcont.2018.01.027.

Oliszewski, R., Rabasa, A., Fernández, J., Poli, M., y Núñez de Kairúz, M. 2002. Composición química y rendimiento quesero de la leche de cabra Criolla Serrana del noroeste argentino. *Zootecnia Tropical, 20*(2), 179-189.

Pérez Soto, Francisco, and Lucila Godínez Montoya. 2018. Políticas Públicas y Comercio Agropecuario En México. 1a ed. edited by ASMIIA A.C.

Pragna, Prathap, P. R. Archana, Joy Aleena, Veerasamy Sejian, Govindan Krishnan, Madiajagan Bagath, A. Manimaran, V. Beena, E. K. Kurien, Girish Varma, and Raghavendra Bhatta. 2017. Heat Stress and Dairy Cow: Impact on Both Milk Yield and Composition. *International Journal of Dairy Science 12*(1):1-11. doi: 10.3923/ijds.2017.1.11.

De Rensis, Fabio, and Rex John Scaramuzzi. 2003. Heat Stress and Seasonal Effects on Reproduction in the Dairy Cow - A Review. *Theriogenology 60*(6):1139–51. doi: 10.1016/S0093-691X(03)00126-2.

Souto, Luís I. M., Clarice Y. Minagawa, Evelise O. Telles, Márcio A. Garbuglio, Marcos Amaku, Ricardo A. Dias, Sonia T. Sakata, and Nilson R. Benites. 2008. Relationship between Occurrence of Mastitis Pathogens in Dairy Cattle Herds and Raw-Milk Indicators of Hygienic-Sanitary Quality. *Journal of Dairy Research 75*(1):121–27. doi: 10.1017/S0022029907002907.

Stankov, Stanko, Hafize Fidan, Tatyana Balabanova, Eva Dimitrova, and Salam A. Ibrahim. 2022. Evaluation of the Qualitative Parameters of Raw Sheep's Milk with the Potential for the Production of Traditional Artisanal Cheese. *BIO Web of Conferences* 45:01004. doi: 10.1051/bioconf/20224501004.

Thompson, D. I., and D. S. Postle. 1964. The Wisconsin Mastitis Test – an Indirect Estimation of Leucocytes in Milk. *Journal of Milk and Food Technology 27*(9):271–75. doi: 10.4315/0022-2747-27.9.271.

Vitali, A., U. Bernabucci, A. Nardone, and N. Lacetera. 2016. Effect of Season, Month and Temperature Humidity Index on the Occurrence of Clinical Mastitis in Dairy Heifers. *Advances in Animal Biosciences 7*(3):250-52. doi: 10.1017/s2040470016000315.

Vitali, A., M. Segnalini, L. Bertocchi, U. Bernabucci, A. Nardone, and N. Lacetera. 2009. Seasonal Pattern of Mortality and Relationships between Mortality and Temperature-Humidity Index in Dairy Cows. *Journal of Dairy Science 92*(8):3781-90. doi: 10.3168/jds.2009-2127.