Enterobacter hormechie- A etiological agent for bovine mastitis identified through PCR method and sequencing

Abstract

Mastitis is an important disease at the global level. With the steep rise in cases of bovine mastitis, it has become a matter of concern. It is responsible for nearly 70 per cent of the losses in milk production in India and also poses a significant public health risk. Diagnostic methods in field conditions are rather too crude relying mainly on the apparent symptoms. Diagnostic kits available for field conditions for mastitis fail to give accurate indications about the causative agents, thus increasing antibiotic resistance. Although, molecular methods are not economical, but available as a reliable diagnostic tool for early and accurate assessment of etiological agents. Current study deals with the usage of PCR PCR-based diagnostic method coupled with sequencing to find out the causative agent for mastitis in milk sample. In the present study, presence of *Enterobacter hormechie,* was confirmed using PCR method. Sequencing was used to find the base sequence and phylogenetic tree of the causative agent. The 16S rRNA gene-based DNA Barcoding of the bacteria found in milk revealed that cattle is infected with Enterobacter hormaechei bacteria. The presence of Enterobacter hormechie is also a matter of concern due to public health importance. More research should be done in future with greater number of sample for prevalence of microorganisms from the same region.

Key words- Mastitis, Primer, Enetrobacter hormechie, sequencing, PCR, phylogenetic tree

Introduction

Mastitis refers to inflammation of the mammary gland. It includes a wide variety of causative agents. The etiological agents include gram-positive, and gram-negative bacteria, viruses, and mycoplasma or can also be environmental, for example, *Escherichia coli*, coagulase-negative *Staphylococcus*, *Enterococcus* spp., *Streptococcus uberis* in nature (Cheng *et. al.,* 2020). Depending upon the degree of inflammation, bovine mastitis can be classified as clinical, sub-clinical, and chronic mastitis. Clinical mastitis can further be sub-divided into per-acute, acute, and sub-acute depending on degree of the inflammation. Ironically, sub-clinical mastitis, which shows no visible abnormality in the udder or milk, but decreased milk production with an increase in the somatic cell count (Abebe *et. al.,* 2016) accounts for more financial losses in the herd than do clinical cases. Therefore, early diagnosis of mastitis is necessary so that the quarters of udder don’t get fibrosed. Environmental mastitis is mainly associated with the gram-negative bacteria Enterobacteriaceae. The Enterobacteriaceae family has more than 50 genera and over 200 species. Out of 50 genera, *Escherichia coli*, *Klebsiella*, Enterobactor, Serratia and Proteus are frequently isolated from dairy environment. Thus, identification and characterization of Enterobacteriaceae in dairy production system is necessary to understand the importance of these bacteria as causative agent for mastitis.

Diagnosis of mastitis based on clinical observations is the most common diagnostic method in field condition. Other commonly used methods are identification of the infectious agent, somatic cell count/somatic cell score and other . However, culture and polymerase chain reaction are the modern method for the diagnosis of an intramammary infection, although, both methods have their advantages and disadvantages (Adkin *et. al.,* 2018). Disadvantage in this method is, high cost while the advantage is the accurate and early diagnosis which is necessary in the wake of increasing antibiotics resistance due to its indiscriminate use and also to ensure complete treatment of animal. Nowadays, molecular techniques such as 16S rRNA sequencing is the gold standard technique for identification of bacteria. Therefore, the quality of microbial identification is the key task to control mastitis in veterinary clinical management. With this hypothesis, present study aimed to identify the causative agent of bovine mastitis using PCR technique and sequencing.

Material and methods

The animals were screened and selected from organized dairy farm in and around Hazaribagh and Ramgarh District, Veterinary Clinical Complex (RVC) and Instructional Livestock Farm Complex, College of Veterinary Science and Animal Husbandry, Kanke, Ranchi. Selections of the animals were done on the basis of History and physical and clinical examination of udder. Indirect tests were performed after collections of milk samples from selected animals on the basis of the above-mentioned criteria for the diagnosis of mastitis. Screening of mastitis cow was done by California Mastitis Test (CMT)), strip cup test and modified white side test. Out of the milk samples of selected animals, four random samples were taken for PCR-based analysis and sequencing. This was a part of M.V.Sc. work in the Department of Veterinary Medicine, CoVSc. & A.H on the topic “Therapeutic efficacy of Psidium guajava and Punica granatum against coliform mastitis in cattle”. The current research article is based on the molecular analysis part of the research. The purpose of PCR-based assay was to emphasize on molecular diagnostic techniques and to be able to decipher the holistic phylogenetic detail of the causative organism of the mastitis in current experimental units. The following work was done by outsourcing in Akriti Biotech Research & Development Centre, Kathal More, Ranchi, Jharkahnd.

Four milk samples were received and labeled as LF, RF, RH1 and LH1 (Figure1). After serial dilution they were inoculated (Figure 2a, 2b, 2c and 2d). Milk samples were serially diluted and the highest dilution was spread on EMB agar plates and incubated at 37°C overnight. No bacterial growth was observed in sample RF and RH1. Single colony obtained on the EMB agar plates of samples LF1 and LH (Figure 3a, 3b, 3c and 3d) was inoculated in Lysogeny Broth (LB) and incubated at 37°C for overnight. Genomic DNA was isolated from the respective bacteria culture (Figure 4a and 4b) using Hi Media bacterial DNA isolation kit (Figure 5). Universal 16S rRNA gene primer set was used to amplify the 16S rRNA gene and sent for sequencing. Two PCR reactions failed for unknown reasons, so our internal primer set was used (Figure 6).

The composition of the PCR Mix was as follows-

**PCR Composition (for 50 l reaction):**

Master Mix (Promega)– 25µl

Forward Primer– 2.5 µl

Reverse Primer– 2.5µl

Template DNA– 2 µl

Nuclease-free water for final volume – 18ul

**PCR programme was run in the following steps-**

Initial denaturation 94 0C for 5minutes

Denaturation 940C for 40seconds

Annealing 450C for 45seconds

Extension 720C for 1minute

Final Extension 720C for 10minutes

Sequencing of the PCR amplicon thus obtained was performed on the Applied Biosystems platform. Sequence analysis was done online on the NCBI Database.

**Results**

**Result and Discussion**

**Fig 2 : Serial dilution technique**

Out of Four milk samples were received and labeled as LF, RF, RH1 and LH1. The milk samples LH1 and LF were found to be contaminated with bacteria as evidenced by the growth on EMB agar plates, however sample LH1 being highly infected as shown in Fig 3c and 3d. Milk samples RH1 and RF had no bacterial contamination as no growth of bacteria was observed on the plate (Fig. 3a and b).

**Genomic DNA yield**: The genomic DNA yield from the respective pure bacterial cultures (Fig. 4a and 4b) was found to be 10 µg (Fig. 5) as analyzed by spectrophotometry analysis.

**PCR Amplification:** The PCR reaction of 16S rRNA gene gave an amplification of 1.5 kb (Fig.6)

**Sequencing**: The DNA sequence obtained after sequencing, when analyzed using the NCBI Database, revealed that both the milk samples were infected with Enterobacter hormaechei, a common pathogen that is a recognized contaminant of raw milk and dairy products.

Sequencing Result

**Sample:** LF bacteria **Identity**:Enterobacter*hormaechei*

# Sequence:

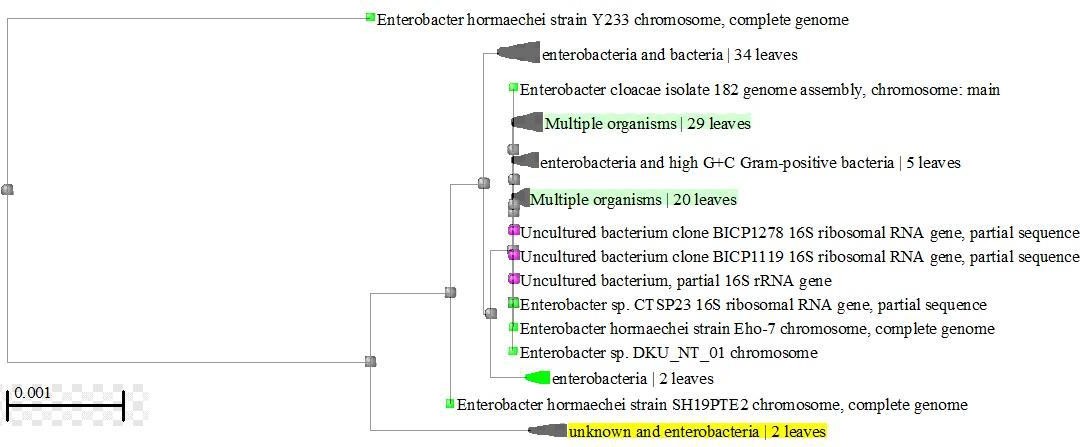
GCTGAGGCGGCTACACATGCAGTCGAACGGTAACAGGAAGCAGCTATGCTAGCTATTGCTAGACGAGTGGCGGACGGGTGAGTAATGTCTGGGAAACTCGCCTGATGGAGGGGGATAACTACTGGAAACGGTAGCTAATACCGCATAACGTCGCAAGACCAAAGAGGGGGACCTTCGGGCCTCTTGCCATCGGATGTGCCCAGATGGGATTAGCTAGTAGGTGGGGTAACGGCTCACCTAGGCGACGATCCCTAGCTGGTCTGAGAGGATGACCAGCCACACTGGAACTGAGACACGGTCCAGACTCCTACGGGAGGCAGCAGTGGGGAATATTGCACAATGGGCGCAAGCCTGATGCAGCCATGCCGCGTGTATGAAGAAGGCCTTCGGGTTGTAAAGTACTTTCAGCGGGGAGGAAGGTGTTGAGGTTAATAACCTCAGCAATTGACGTTACCCGCAGAAGAAGCACCGGCTAACTCCGTGCCAGCAGCCGCGGTAATACGGAGGGTGCAAGCGTTAATCGGAATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCC CCGGGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGGCGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAGAACTTACCAGAGATGCTTTGGTGCCTTCGGGAACTCTGAAACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAAATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTATCATTTGTTGCCGGGGGTCGGCCGGGAACTCAAAGGAGACTGCCAGTGATAACTGGAGGAAGGGGGGGATGACGTCAAGTCATCAGGCCCTTACGAGTAGGGCTCCCCCCTGCTAAATGGCGCTTCAAGAAAAAGCGACCT

**Sample:** LH bacteria **Identity: *Enterobacter hormaechei*** Sequence:

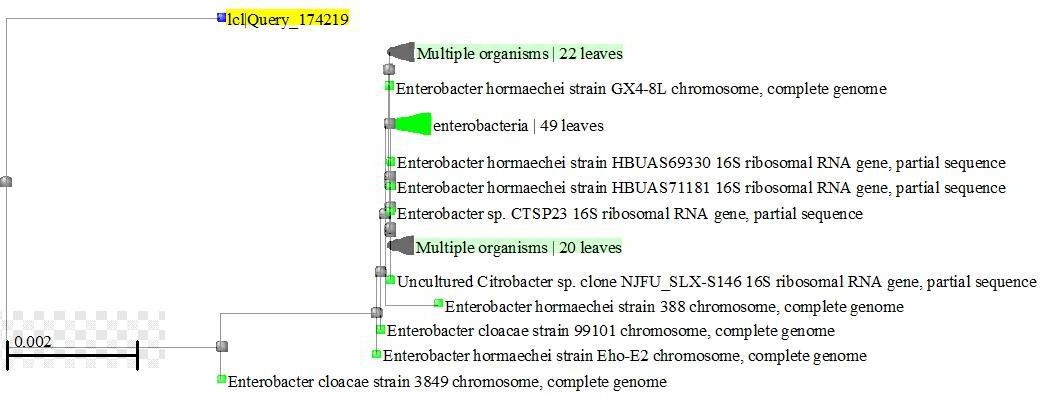
CCGGGGCGGGCAGGCCTAACACATGCAAGTCGAACGGTAACAGGAAGCAGCTTGCTGCTTTGCTGACGAGTGGCGGACGGGTGAGTAATGTCTGGGAAACTGCCTGATGGAGGGGGATAACTACTGGAAACGGTAGCTAATACCGCATAACGTCGCAAGACCAAAGAGGGGGACCTTCGGGCCTCTTGCCATCGGATGTGCCCAGATGGGATTAGCTAGTAGGTGGGGTAACGGCTCACCTAGGCGACGATCCCTAGCTGGTCTGAGAGGATGACCAGCCACACTGGAACTGAGACACGGTCCAGACTCCTACGGGAGGCAGCAGTGG GGAATATTGCACAATGGGCGCAAGCCTGATGCAGCCATGCCGCGTGTATGAAGAAGGCCTTCGGGTTGTAAAGTACTTTCAGCGGGGAGGAAGGTGTTGAGGTTAATAACCTCAGCAATTGACGTTACCCGCAGAAGAAGCACCGGCTAACTCCGTGCCAGCAGCCGCGGTAATACGGAGGGTGCAAGCGTTAATCGGAATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGGCTCAACCTGGGAACTGCATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGGTGTAGCGGTGAAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCGTGGGGAGCAAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTGAGGCGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGGCCCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTGACATCCAGAGAACTTACCAGAGATG CTTTGGTGCCTTCGGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAAATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTATCTTTGTTGCCAGCGGTTCGGCCGGGAACTCAAGGGAAACTGCCAGTGATAAACTGGAGGAAGGTGGGGATGACGTCAAGTCATCATGGCCCTTACGAGTAGGGCTACCACCTGCTACATGGGCCATACAAGAAGAAGCGACTTCGCGA AAACAAGCGGACCTCATAAAATGCTTCCAATCCGAATGAAAT

**Phylogenetic Analysis:**

Bacteria from milk sample LF clearly depicts that the bacteria found in the milk sample is closest to *Enterobacter hormaechei* in terms of evolutionary tree or distance. Whereas, bacteria from milk sample LH1 was closest to *Enterobacter cloacae.* On the contrary, the sequence alignment presented *Enterobacter hormaechei* in the first match.

The 16S rRNA gene based DNA Barcoding of the bacteria found in milk revealed the cattle is infected with *Enterobacter hormaechei* bacteria. The 16S rRNA gene sequence of bacteria isolated from LF milk sample, on sequence alignment analysis matched 97.95% with *Enterobacter hormaechei* and in accordance with the phylogenetic tree of distance tree. In case of bacteria from milk sample LH1 the sequence alignment analysis shows 98.73% identity with *Enterobacter hormaechei.* However, in the phylogenetic tree the query sequence shows closest relation to *Enterobacter cloacae*. But, since the query sequence matches first with *Enterobacter hormaechei*, we consider it to be the correct identity.

**Figure 7- Phylogenetic tree of bacteria isolated from LH1 milk sample**



**Figure 8- Phylogenetic tree of bacteria isolated from LF milk sample**

**Discussion**

*Enterobacter* is an oxidase-negative, gram-negative bacterium that belongs to the family *Enterobacteriaceae* formerly known as Enteric group 75 (O'hara *et al.,* 1989). *Enterobacter hormaechei* is a common pathogen that infects both cattle and humans (O'hara *et al.,* 1989). *Enterobacter hormaechei* infection can cause mastitis in cattle as reported earlier in a number of cases (Aslantaş *et al.,* 2022; Mokgaotsi, 2019; Rodrigues *et al.,* 2017; Zhong *et al.,* 2023) as observed in present study also. Enterobacter sp. exists in a broad range of environments like soil, water, food processing factories, plantations etc. They are also widely considered as potential human pathogens. Several clinical cases of *Enterobacter hormaechei* milk infection have been reported in almost every region of the world. The case of *Enterobacter hormaechei* infection was first reported in a 2-months old severely ill calf (Wang *et al.,* 2020). It also infects the buffalos as reported by Fagiolo and Lai (2007). *Enterobacter hormaechei* has also been isolated from animals suffering from polymicrobial bovine pneumonia (Choudhary *et al.,* 2019). In recent times, *E. hormaechei* has evolved as an emerging pathogenic bacteria due to its potential to cause bloodstream infection in livestock linked with morbidity, mortality and financial cost (Qian *et al.,* 2020).

Incidence of multidrug resistant strains of *Enterobacter hormaechei* being isolated from cow with reproductive system infection (Zaitsev *et al.,* 2022). It belongs to the Cluster VI of *Enterobacter cloacae* complex (ECC) that is a group of common nosocomial pathogens that are capable of cause a wide variety of infections (Annavajhala *et al.,* 2019). One of the primary reasons for Multidrrug Resistance or Antimicrobial Resistance among pathogens is due to the ability of pathogens to produce biofilm that prevents the drug to reach the bacteria cell (Liu *et al.,* 2022). Since, *Enterobacter hormaechei* belongs to the biofilm-forming group of pathogens, the reason for its drug resistance is its ability of formation of biofilm (Edris *et al.,* 2023).

**Conclusion**

The finding of the present revealed that milk samples were found to contain *Enterobacter hormechei* bacteria hitherto not very common causative agent for bovine mastitis with zoonotic importance, so it raises alarming public health concerns in the wake of milk being global source of food. Further and future research is needed with more number of samples to ascertain and confirm *Enetrobacter hormechei* as well as to find other causative agent in mastitic milk using PCR method.

**References**

Abebe, R., Hatiya, H., Abera, M., Megersa, B., & Asmare, K. (2016). Bovine mastitis: prevalence, risk factors and isolation of Staphylococcus aureus in dairy herds at Hawassa milk shed, South Ethiopia. BMC Vet. Res., 12, 1-11.

Adkins, P. R., & Middleton, J. R. 2018. Methods for diagnosing mastitis. Vet. Clin: Food Anim. Pract., 34(3): 479-491.

Annavajhala, M. K., Gomez-Simmonds, A., & Uhlemann, A. C. (2019). Multidrug-resistant Enterobacter cloacae complex emerging as a global, diversifying threat. Front. Micro., 10, 44.

Aslantaş, Ö., Yılmaz, E. Ş., Büyükaltay, K., & Kocabağ, H. D. (2022). Whole‐genome sequencing of extended‐spectrum β‐lactamase (ESBL)‐producing Enterobacteriaceae from retail raw milk. Int. J. Dairy Tech., 75(1), 77-82.

Cheng, W. N. & Han, S. G. (2020). Bovine mastitis: risk factors, therapeutic strategies, and alternative treatments - A review. Asian-Aus. J. Anim. Sci., 33(11), 1699–1713. <https://doi.org/10.5713/ajas.20.0156>

Choudhary, M., Choudhary, B. K., Ghosh, R. C., Bhoyar, S., Chaudhari, S., and Barbuddhe, S. B. (2019). Cultivable microbiota and pulmonary lesions in polymicrobial bovine pneumonia. Microbiol. Path., 134, 103577.

Edris, S. N., Hamad, A., Awad, D. A. B., and Sabeq, I. I. (2023). Prevalence, antibiotic resistance patterns, and biofilm formation ability of *Enterobacterales* recovered from food of animal origin in Egypt. Vet. World, 16(2),403–413.

Fagiolo, A., & Lai, O. (2007). Mastitis in buffalo. Italian J Anim Sci 6(sup2), 200-206.

Khan, M. Z., & Khan, A., 2006. Basic facts of mastitis in dairy animals: A review. Pakistan Vet. J., 26(4): 204.

Kumari, T., Bhakat, C., & Choudhary, R. K. 2018. A review on subclinical mastitis in dairy cattle. Int. J. Pure Appl. Biosci. 6(2): 1291-1299.

Liu, S., Chen, L., Wang, L., Zhou, B., Ye, D., Zheng, X., ... & Ye, J. 2022. Cluster differences in antibiotic resistance, biofilm formation, mobility, and virulence of clinical Enterobacter cloacae complex. Front. Microbiol., 13, 814831.

Mokgaotsi, G. F. 2019. Assessment of bacteriological quality and handling of bovine raw milk collected from communal areas in Mahikeng, South Africa(Doctoral dissertation, North-West University (South Africa).

Murphy J. M. and Hanson J. J. (1941). A Modified Whiteside Test for the Detection of Chronic Bovine Mastitis.Cornell Vet.,31, 47

O'hara, C. M., Steigerwalt, A. G., Hill, B. C., Farmer 3rd, J. J., Fanning, G. R. and Brenner, D. J. 1989. Enterobacter hormaechei, a new species of the family Enterobacteriaceae formerly known as enteric group 75. J Clin. Microbiol., 27(9), 2046-2049.

Qian, W., Yang, M., Wang, T., Sun, Z., Liu, M., Zhang, J., ... & Li, Y. (2020). Antibacterial mechanism of vanillic acid on physiological, morphological, and biofilm properties of carbapenem-resistant Enterobacter hormaechei. J. Food Prot. 83(4): 576-583.

Rodrigues, N. M. B., Bronzato, G. F., Santiago, G. S., Botelho, L. A. B., Moreira, B. M., Coelho, I. D. S., & Coelho, S. D. M. D. O. (2017). The Matrix-Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry (MALDI-TOF MS) identification versus biochemical tests: a study with enterobacteria from a dairy cattle environment. Brazilian J. of Microbiol., 48, 132-138.

Schalm, O. W., Carroll, E. J., & Jain, N. C. (1971). Bovine Mastitis. Lea and Febiger, Inc., Philadelphia, U.S.A. Google Scholar.

Singh, D., Kumar, S., Singh, B., & Bardhan, D. (2014). Economic losses due to important diseases of bovines in central India. Vet. World, 7(8).

Wang, Z., Duan, L., Liu, F., Hu, Y., Leng, C., Kan, Y., Yao L. a& Shi, H. (2020). First report of Enterobacter hormaechei with respiratory disease in calves. BMC Vet. Res.,16, 1-4.

Zaitsev, S. S., Khizhnyakova, M. A., and Feodorova, V. A. (2022). First Case Report of Detection of Multidrug-Resistant Enterobacter hormaechei in Clinical Sample from an Aborted Ruminant. Microorganism, 10(5), 036.

Zhong, H., Zheng, N., Wang, J., & Zhao, S. (2023). Isolation and pan-genome analysis of Enterobacter hormaechei Z129, a ureolytic bacterium, from the rumen of dairy cow. Front. Microbiol., 14, 1169973.