ASPRA Asociación Peruana de Reproducción Animal

www.spermova.pe

SPERMOVA

Spermova 2021; 11(1): 01- 10

Artículo de revisión – Review article DOI. 10.18548/aspe/0009.01

POST-PARTUM SUB-CLINICAL ENDOMETRITIS IN DAIRY COWS: INCIDENCE AND DIAGNOSIS

Endometritis subclínica posparto en vacas lecheras: incidencia y diagnóstico

Akshay Sharma[1]*; Madhumeet Singh[1]

[1] Department of Veterinary Gynecology and Obstetrics, DGCN College of Veterinary and Animal Sciences, CSKHPKV, Palampur-176062 INDIA.

* Corresponding author: Dr. Akshay Sharma; e-mail: akshays482@gmail.com

Recibido: 23/02/2021

Aceptado: 03/04/2021

Publicado:13/08/2021

ABSTRACT

Post-partum uterine infections such as metritis, clinical endometritis and sub-clinical endometritis, are the most common cause for decreased productivity and fertility in dairy cows. Being the least severe form of endometritis, sub-clinical endometritis (SCE) is defined as the superficial inflammation of endometrium with no signs of systemic illness and characterized by an increase in number of polymorphonuclear cells (PMNCs) inside the uterine lumen. The impact of sub-clinical endometritis on fertility of dairy cows is well known probably due to absence of any clinical signs and thus, difficulty in diagnosis and treatment. Different techniques such as endometrial cytology, uterine biopsy, biochemical analysis of uterine fluid, and measurement of acute phase proteins and inflammatory markers have been employed for the diagnosis of SCE. Doppler and B-mode ultrasonography of middle uterine arteries and uterus have also been used to diagnose the inflammation via assessment of uterine perfusion, respectively. Among all methods, endometrial cytology via cytotape is one of the most advanced and frequently employed methods for diagnosis of cytological endometritis based on the fact that proportion of PMNCs increase during uterine inflammation. The review focuses mainly on current status of incidence and diagnosis of post-partum sub-clinical endometritis in dairy cows.

Keywords: Dairy cows, Diagnosis, Incidence, Post-partum period, Sub-clinical endometritis

RESUMEN

Las infecciones uterinas posparto, como la metritis, la endometritis clínica y la endometritis subclínica, son la causa más común de disminución de la productividad y fertilidad en las vacas lecheras. Al ser la forma menos grave de endometritis, la endometritis subclínica (SCE) se define como la inflamación superficial del endometrio sin signos de enfermedad sistémica y caracterizada por un aumento en el número de células polimorfonucleares (PMNC) dentro de la luz uterina. El impacto de la endometritis subclínica sobre la fertilidad de las vacas lecheras es bien conocido, probablemente debido a la ausencia de signos clínicos y, por lo tanto, a la dificultad en el diagnóstico y tratamiento. Para el diagnóstico de endometritis subclínica se han empleado diferentes técnicas como la citología endometrial, la biopsia uterina, el análisis bioquímico del líquido uterino y la medición de proteínas de fase aguda y marcadores inflamatorios. La ecografía Doppler y modo B de las arterias uterinas medias y el útero también se han utilizado para diagnosticar la inflamación mediante la evaluación de la perfusión uterina, respectivamente. Entre todos los métodos, la citología endometrial a través de cytotape es uno de los métodos más avanzados y empleados con frecuencia para el diagnóstico de endometritis citológica basado en el hecho de que la proporción de PMNC aumenta durante la inflamación uterina. La revisión se centra principalmente en el estado actual de la incidencia y el diagnóstico de la endometritis subclínica posparto en vacas lecheras.

Palabras clave: Vacas lecheras, Diagnóstico, Incidencia, Posparto, Endometritis subclínica.

INTRODUCTION

Uterine infections after parturition are the most common cause for decreased productivity and fertility in dairy cows (Gilbert, 2011). For last 50 years, there has been a constant increase in the incidence of uterine diseases due to post-partum uterine infections which can be broadly classified into three types i.e. metritis, clinical endometritis and sub-clinical endometritis. Sub-clinical endometritis (SCE) is defined as the superficial inflammation of endometrium with no signs of systemic illness and characterized by an increase in number of polymorphonuclear cells (PMNCs) inside the uterine lumen (Kasimanickam et al., 2004; Pascottini and Opsomer, 2016). In cows diagnosed with SCE, scanty exudates often accumulate inside uterus and result in lack of cervical discharge (Gilbert et al., 2005). Sub-clinical endometritis has a detrimental effect on reproductive performance of dairy cows after parturition (Carneiro et al., 2014).

Etio-pathogenesis of sub-clinical endometritis

Etiological agents associated with occurrence of sub-clinical endometritis and other post-partum uterine diseases such as metritis and clinical endometritis are not common (Prunner et al., 2014a). So there is a possibility that SCE occurs as the result of prolonged inflammation of endometrium due to persistence of bacterial contamination after parturition. However, exact mechanism of the prolonged inflammation of endometrium is not well understood yet. Although some researchers have reported an increased endometrial mRNA expression along with tissue remodeling, acute phase response and lipopolysaccharide signaling in cows diagnosed with SCE (Kasimanickam et al., 2014; Gartner et al., 2015; Raliou et al., 2019).

Serum concentrations of pro-inflammatory mediators such as IL-1β, IL-6 and TNF-α, serve as the molecular markers for assessment of sub-clinical endometritis (Kasimanickam et al., 2013; Elsayed et al., 2020). Prolonged inflammation of endometrium persists due to high production of eicosanoids along with inadequate levels of anti-inflammatory substances like IL-10 and TGF-β owing to delayed restoration of homeostasis at tissue level (Fischer et al., 2010; Mattmiller et al., 2013). Some researchers have reported an unbalanced production of pro-inflammatory to anti-inflammatory cytokines leading to delayed clearance of bacterial contamination and subsequent development of sub-clinical endometritis after parturition (Galvao et al., 2011; Ghasemi et al., 2012). In other words, a low ratio of pro-inflammatory to anti-inflammatory cytokines can disrupt the process of uterine inflammation and vice-versa as pro-inflammatory cytokines have been involved actively in uterine immune cascade via their upregulation in the endometrium (Loyi et al., 2013; Brodzki et al., 2015).

INCIDENCE OF SUB-CLINICAL ENDOMETRITIS

Dairy industry has witnessed a constant increase in the incidence of sub-clinical endometritis over the last two decades which can be due to better understanding of the concept related to it. However, usage of advanced diagnostic techniques has also contributed towards the increase in incidence of SCE. Incidence of sub-clinical endometritis in dairy cows at different days after parturition has been reported in Table 1.

Table 1. Incidence of sub-clinical endometritis in dairy cows at different days post-partum.

#	Incidence (%)	Days post-partum (d)	Author and year of research
1	38.00	18-38 d	Plontzke et al. (2010)
	19.00	32-52 d	
2	25.90	38-49 d	Cheong et al. (2011)
3	35.00	26-34 d	Lopdell et al. (2011)
	7.00	35-49 d	
4	29.00	29 d	McDougall et al. (2011)
	23.00	43 d	
5	14.00	35-49 d	Senosy et al. (2012)
6	18.90-75.40	21-28 d	Baranski et al. (2012)
7	13.50	32-35 d	Heidarpour et al. (2012)
8	13.40	21-27 d	Sens and Heuweiser (2013)
9	13.40	46-52 d	Ribeiro et al. (2013)
10	21.50	28-35 d	Madoz et al. (2013)
	16.00	≥49 d	
11	27.59	30-39 d	Carneiro et al. (2014)
	28.00	40-49 d	
	27.66	50-59 d	
	19.05	≥60 d	
12	27.80	≥49 d in cows	Pascottini (2016)
	7.86	≥49 d in heifers	
13	33.33	43 d	Sharma (2017)
14	11.30	28 d	Salah and Yimer (2017)
	9.40	35 d	
15	15.70-64.10	28 d	Lee et al. (2018)
16	19.27	30 d	Vallejo et al. (2018)
17	18.75	42 d	Rana (2019)
18	56.00	43 d	Sharma and Singh (2019)
19	50.00	35 d	Escandon et al. (2020)

DIAGNOSIS OF SUB-CLINICAL ENDOMETRITIS

Cows suffering from sub-clinical endometritis do not show any clinical signs for diagnostic purpose but continues to affect the economics of dairy industry in a substantial way for the last decade. Different techniques such as endometrial cytology, uterine biopsy, biochemical analysis of uterine fluid, uterine lavage sample optical density test (ULSOD), bacterial culture, white side test, leucocyte esterase test and measurement of acute phase proteins and inflammatory markers have been employed for the diagnosis of SCE (Pascottini et al., 2016a; Vinita et al., 2018; Nehru et al., 2019). Doppler and B-mode ultrasonography of middle uterine arteries and uterus have also been used to diagnose sub-clinical endometritis, respectively (Dourey et al., 2011; Debertolis et al., 2016). All the methods have been discussed in the literature below.

Endometrial cytology

Endometrial cytology is one of the most accurate and frequently employed methods for diagnosis of sub-clinical endometritis based on the fact that proportion of polymorphonuclear cells (PMNCs) increase during uterine inflammation (Dubuc et al., 2010; Pascottini and Opsomer, 2016). Being semi-invasive and not much costly, it is very much preferred and can be done by different technique such as Cytobrush (CB), Cytotape (CT) and Low volume uterine lavage (LVUL). All the techniques used for endometrial cytology have different sets of advantages and disadvantages, thus, drawing a comparison can be helpful in selection of the most reliable, accurate and practically feasible method for diagnosis of sub-clinical endometritis. Some of the comparative aspects of these techniques have been mentioned in Table 2.

Table 2. Comparison between different techniques of endometrial cytology used for diagnosis of sub-clinical endometritis

Parameters for comparison	Techniques		
	Cytobrush (CB)	**Cytotape (CT)**	**Low volume uterine lavage (LVUL)**
Red blood cells contamination	High (Due to laceration caused by brush bristles)	Low	Low
Representative sample percentage	Low (1.5-2.5 cm^2 area)	Low (1.5-2.5 cm^2 area)	High
Amount of PMNCs collected	Low	Low	High
Cellular details	Moderate	High	Low
Distortion of cells	Moderate (During smear formation due to brush bristles)	Low	High (Due to centrifugation)
Accuracy level	Good	Good	Very good
Time consumption	Less	Less	More
Practically feasible	Yes	Yes	Yes
Monitoring purpose	Yes	Yes	Yes
Cow side test	No	No	No
Sensitivity	Low (Test is limited to a specific area)	Low (Test is limited to a specific area)	High (Test involves a larger area)
Specificity	High	High	High
Common constraint	Skilled personnel is required	Skilled personnel is required	Skilled personnel is required

Source: Kasimanickam et al. (2004); Barlund et al. (2008); LeBlanc et al. (2011); Dini et al. (2015); Pascottini et al. (2015); Wagener et al. (2017)

Polymorphonuclear cells threshold values (%) to diagnose sub-clinical endometritis

Diagnosis of sub-clinical endometritis is based on the threshold level of PMNCs at different days post-partum, however, the cut-off value for diagnosis of SCE is still under discussion due to different level of immune response and PMNCs population to uterine contamination occurred during the process of parturition (Wagener et al., 2017; Rana, 2019). Threshold values for PMNCs used for the diagnosis of SCE at different days post-partum have been discussed in Table 3.

Endometrial histopathology

Endometrial histopathology is considered the gold standard test as it allows visualizing the changes in endometrial epithetlium, stratum compactum, endometrial glands and blood vessels directly during acute and chronic inflammation (Bonnett et al., 1991; Ahmadi et al., 2005). High specificity (92%) and not very low sensitivity (44%) associated with endometrial histopathology has made it reliable for use in understanding the uterine pathology (Meira Jr et al., 2012). Histopathology also allows the examination of examination of endometrial epithelium along with stratum compactum, therefore, helps in collection of more PMNCs as they are present more in deeper stratum compactum (Pascottini et al., 2016a). Histologically, disruption of surface epithelium, leucocytic infiltration, cystic dilatation of endometrial glands, varying degree of glandular degeneration and endometrial fibrosis provides clear details about the stage of inflammation (Hartmann et al., 2016; Fuentes et al., 2017). This method has been an integral part of breeding soundness evaluation in mares (Snider et al., 2011), however, its use in cows is questionable due to time consumption, invasive nature and potential threat to future fertility (Pascottini et al., 2016a; Coto and Lucy, 2018).

Table 3. Threshold values for polymorphonuclear cells (%) with different techniques to diagnose sub-clinical endometritis at different days post-partum.

#	PMNCs threshold (%)	Technique used for diagnosis	Days post-partum (d)	Author and year of research
1	≥5.00	Cytobrush	18-38 d	Plontzke et al. (2010)
			32-52 d	
2	≥10.00	Uterine lavage	38-49 d	Cheong et al. (2011)
3	≥18.00	Cytobrush	26-34 d	Lopdell et al. (2011)
			35-49 d	
4	≥9.00	Cytobrush	29 d	McDougall et al. (2011)
	≥7.00		43 d	
5	≥10.00	Cytobrush	21-28 d	Baranski et al. (2012)
6	≥18.00	Cytobrush	32-35 d	Heidarpour et al. (2012)
7	≥5.00	Cytobrush	35-49 d	Senosy et al. (2012)
8	≥18.00	Cytobrush	21-27 d	Sens and Heuweiser (2013)
9	≥5.00	Cytobrush	46-52 d	Ribeiro et al. (2013)
10	≥8.00	Cytobrush	21-35 d	Madoz et al. (2013)
	≥6.00		35-49 d	
	≥4.00		≥49 d	
11	≥18.00	Cytobrush	21-35 d	Barrio et al. (2014)
12	≥5.00	Cytobrush	30-39 d	Carneiro et al. (2014)
			40-49 d	
			50-59 d	
			≥60 d	
13	≥5.00	Cytobrush	35-49 d	Barrio et al. (2015)
14	≥1.00	Cytotape	≥49 d in cows	Pascottini (2016)
	≥1.00	Cytotape	≥49 d in heifers	
15	≥6.00	Cytobrush	35 d	Singh et al. (2016)
	≥4.00		56 d	
16	≥8.00	Cytobrush	28 d	Salah and Yimer (2017)
	≥8.00		35 d	
17	≥14.00	Cytobrush	28 d	Lee et al. (2018)
18	≥5.00	Cytobrush	30 d	Vallejo et al. (2018)
19	≥5.00	Cytobrush	29-35 d	Van Schyndel et al. (2018)
20	≥10.00	Cytobrush	42 d	Rana (2019)
		Cytotape		
		Uterine lavage		
21	≥10.00	Cytobrush	43 d	Sharma and Singh (2019)
22	≥10.00	Cytobrush	35 d	Escandon et al. (2020)

Trans-rectal ultrasonography

Trans-rectal ultrasonography has been an indispensable part of routine examination of reproductive tract of dairy cows for diagnosis of various physiological and pathological changes in uterus and ovaries (Ribeiro et al., 2019). Considering the importance of post-partum period, an early diagnosis based on a non-invasive technique is very helpful in determining the future fertility of dairy cows (Vinita et al., 2018). Various important events such as uterine involution, endometrial regeneration and resumption of ovarian activity occur during post-partum period and their occurrence is mainly affected by persistent uterine infections (Coto and Lucy, 2018; Sharma and Singh, 2019). The B-mode of trans-rectal ultrasonography detects the amount of fluid inside uterine lumen (Meira Jr et al., 2012), thickened endometrial wall (Purohit et al., 2013), cervical measurement (≥5.0 cm; Salah and Yimer, 2017) and alterations in the endometrial echotexture, i.e. contrast change based on cellular density and homogeneity for ascertaining the uterine inflammation in absence of any clinical signs of illness after 4-5 weeks of parturition (Silper et al., 2016). Many researchers have validated a correlation between the amount of intra-luminal uterine fluid (ILUF) and proportion of PMNCs diagnosed through trans-rectal ultrasonography and cytology, thus, making ILUF a potential diagnostic marker for sub-clinical endometritis (Dourey et al., 2011; Marino et al., 2017)., has also been used as an important marker for diagnosis of sub-clinical endometritis (Polat et al., 2015).

Doppler mode of ultrasonography still remains an unexplored tool for diagnosis of endometritis in dairy cows (Arias et al., 2018) although some latest research have focused mainly on assessment of uterine inflammation based on various haemodynamic indices such as Pulsatility index (PI), Resistance index RI), Timed average mean and maximum velocity (TAMEAN and TAMAX, respectively), volume of blood flow to the uterus and diameter of middle uterine artery (Bollwein et al., 2002; Sharma et al., 2019). Reduced PI, RI and increased TAMEAN, TAMAX and volume of blood flow to the uterus along with diameter of middle uterine artery has been considered as an important indicator for assessment of uterine inflammation and subsequent reproductive performance in dairy cows post-partum (Heppelmann et al., 2013; Rawy et al., 2018). However, lack of standardization and less knowledge of Doppler ultrasonography among practitioners makes it less popular for diagnosis of uterine inflammation in dairy cows

(Debertolis et al., 2016; Sharma, 2020). Therefore, a comparison must be drawn between endometrial histopathology, cytology and ultrasonography to decide the suitability of methods used for diagnosis of sub-clinical endometritis (Table 4).

Table 4. Comparison between endometrial histopathology, cytology and trans-rectal ultrasonography techniques used for the diagnosis of sub-clinical endometritis

Parameters for comparison	Techniques		
	Endometrial histopathology	**Endometrial cytology**	**Trans-rectal ultrasonography**
Diagnostic criteria	Endometrial changes (Disruption of uterine epithelium and glandular changes)	PMNCs proportion (%)	Cervical measurement, intra-luminal uterine fluid, endometrial thickness and echotexture
Nature of test	Invasive	Semi-invasive	Non-invasive
Endometrial layers sampled	Epithelium+ *stratum compactum* (superficial and deeper)	Epithelium only	Not applicable
Distribution pattern of PMNCs	Uneven (Depends on the layer sampled)	Uniform	Not applicable
Accuracy level	Very good (Detects low degree of inflammation)	Good (Detects moderate to high degree of inflammation)	Need to be investigated
Time consumption	More	Less	Less
Monitoring purpose	No (Associated with high risk)	Yes	Yes
Cow side test	No	No	Yes
Sensitivity (%)	44.00-85.00	60.00-78.00	30.80-57.00
Specificity (%)	87.00-96.00	80.00-93.80	66.00-93.80
Negative effect on future fertility	High	Low	Low
Disadvantage(s)	Injury to endometrium	Observer bias and vast variety of cut-off values available	Interpretation and validation of results is difficult

Source: Kasimanickam et al. (2004); Nielsen (2005); Barlund et al. (2008); Meira Jr et al. (2012); Madoz et al. (2014); Moscuzza et al. (2015); Pascottini et al. (2016a,b); Salah and Yimer (2017); Lee et al. (2018); Van Schyndel et al. (2018).

Uterine lavage sample optical density test (ULSOD)

Several diagnostic techniques have been used for diagnosis for sub-clinical endometritis, however, some degree of invasiveness is associated with each one of them. Therefore, Machado et al. (2012) have developed a completely non-invasive test which measures the optical density of uterine lavage sample. Measurement of optical density provides an objective and numerical value of the light absorbed based on the concentration of cells and proteins in uterine fluid collected after lavage (Metris et al., 2006). The ULSOD is basically influenced by the high concentration of PMNCs and presence of bacteria inside uterine lumen during endometrial inflammation (Bondurant, 1999; Miller et al., 2007). 620 nm wavelengths with a sensitivity and specificity of 85.70 and 73.80 per cent, respectively, has been reported to be a cut-off value for diagnosis of sub-clinical endometritis (Nehru et al., 2019) and the higher value of wavelength corresponds to presence of bacteria, exudation of protein and PMNCs level within the uterine lumen (Machado et al., 2012). Therefore, ULSOD method, despite not being a cow side test, offers to be a non-invasive option for diagnosis of sub-clinical endometritis (Nehru et al., 2019).

Bacterial culture

Study of microflora associated with occurrence of sub-clinical endometritis has been well established in the last two decades (Coto and Lucy, 2018). The common pathogens isolated from the reproductive tract of cows diagnosed with SCE are mainly Escherichia coli, Trueperella pyogenes, Streptococcus spp., Staphylococcus spp., Corynebacterium spp. and Bacillus spp. (Prunner et al., 2014b). Brodzki et al., (2014) also found the same pathogens while comparing them in early and late post-partum stage samples. However, the presence of T. pyogenes in uterine discharge samples of all the cows with SCE has been rejected (Duvel et al., 2014). Bacterial culture has been used as a diagnostic method for SCE but split results have been reported by many researchers on its comparison with other diagnostic methods (Madoz et al., 2014). This happens generally during sterile or non-infectious inflammation where the prolongation of exaggerated immune response remains the cause of SCE (Coto and Lucy, 2018). Therefore, time consumption, false negative results and requirement of laboratory facilities are some of the limitations for this method (Madoz et al., 2014).

Biochemical analysis of uterine fluid

Uterine fluid composition tends to differ in its composition during estrus and inflammatory changes of uterus in cows (Alavi-Shoushtari et al., 2008). Different biochemical parameters such as urea, urea nitrogen, creatinine, total protein, albumin, glucose, cholesterol, triglycerides have altered concentrations during sub-clinical endometritis (Gahlot et al., 2017). Of all these, a negative relationship between urea concentrations and

expression of genes associated with innate immunity and inflammation in the uterus has been reported (Cheng et al., 2015). High cholesterol concentration leads to its accumulation in macrophages, promotes inflammatory responses via inducing Toll-like receptor signalling and thus, results in clearing the infection from the uterus (Tall and Yvan-Charvet, 2015). However, creatinine, triglycerides, total albumin and alkaline phosphatase levels have not been the suitable indicators for diagnosis of sub-clinical endometritis (Gahlot et al., 2017). This method of diagnosis is useful for assessment of uterine inflammation but high cost and infra-structure facilities limit its use for monitoring purpose (Patbandha et al., 2016).

Inflammatory markers and acute phase proteins

Any process that leads to tissue damage results in activation of the defence system and generates an acute phase response (Mossallam et al., 2015) for re-establishing the homeostasis and promoting the healing process (Boby et al., 2017). Acute phase response is generally characterized by release of a number of inflammatory mediators (pro-inflammatory cytokines) such as interleukin-1 (IL-1), interleukin-6 (IL-6), interleukin-8 (IL-8) and tumour necrosis factor-α (Ajevar et al., 2014; Wang et al., 2018). The generation of pro-inflammatory cytokines is mediated by activation of Toll like receptors (TLRs) and recognition of infectious agents in the endometrium (Kim et al., 2014). The pro-inflammatory cytokines play a fundamental role in intracellular communication among uterine cells and ovarian steroidogenesis as their overproduction impairs these processes including low concentrations of estradiol, slow growth of dominant follicle, anovulation and delayed resumption of ovarian activity (Stassi et al., 2017). IL-6, IL-8 and TNF-α are directly involved in the recruitment of T-lymphocytes and polymorphonuclear cells for eliminating the uterine pathogens and thus, play an important role in uterine immune cascade via their upregulation in the endometrium (Elsayed et al., 2020).

During inflammation, special group blood proteins known as acute phase proteins (APPs) have altered concentrations and thus, play an important role in diagnosis (Kaya et al., 2016). Haptoglobin (Hp) and serum amyloid-A (SAA) are the main acute phase proteins in cattle and help in initiating a response against pathological damage of uterus induced by post-partum bacterial contamination (Eckersall and Bell, 2010). Therefore, the elevated concentrations of Hp and SAA i.e. 0.80 g/L and 85 mg/L, respectively, during first 3 weeks after parturition have been used as the risk factors or early predictors of post-partum endometritis (Chan et al., 2010; Dubuc et al., 2010). Moreover, another important component of innate immune system is C-reactive protein (C-RP), a non-glycosylated protein (Du Clos and Mold, 2001), which also helps in tissue regeneration and repair by protecting the tissues from damage caused by pathogens (Krakowski and Zdzisinska, 2007; Kaya et al., 2016). Serum C-RP and PMNCs have been reported to share a significantly positive correlation in cows and buffaloes diagnosed with sub-clinical endometritis during 5-7 weeks post-partum (Li et al., 2010; Elsayed et al., 2020).

POST-PARTUM SUB-CLINICAL ENDOMETRITIS AND REPRODUCTIVE PERFORMANCE OF DAIRY COWS

Post-partum sub-clinical endometritis occurs mainly due to alteration in inflammation regulatory mechanism (Arias et al., 2018). As SCE is a chronic condition, it affects the reproductive performance of cows and results in economic losses to dairy farmers (Barrio et al., 2015). Various researchers have reported a negative impact on reproductive parameters such as first insemination conception rate (Gilbert et al., 2005; Barlund et al., 2008), days to first insemination and calving to conception interval (Barrio et al., 2015; Ricci et al., 2015; Rinaudo et al., 2017; Sharma et al., 2018) and number of inseminations per conception (Bacha and Regassa, 2010; El-Rheem et al., 2019), thus, significantly affects the economy of dairy farmers.

CONCLUSIONS

In peroration, the unavoidable contamination of uterus during the process of parturition and suppression of immune system often leads to persistence of infection/inflammation for longer duration. Lack of any visible signs with SCE makes it difficult for diagnosis and thus, requires the standardization of different techniques such as Doppler ultrasonography of uterus and estimation of serum inflammatory markers. However, endometrial cytology still remains one of the confirmatory methods for diagnosis of SCE. Therefore, this review will help to make the better understanding about the current status of incidence and an array of diagnostic methods employed for sub-clinical endometritis in dairy cows after parturition.

CONFLICT OF INTEREST
Authors' declare no conflict of interest.

AUTHOR CONTRIBUTIONS
Dr. Madhumeet Singh gave approval to the final version of manuscript submitted to journal.

REFERENCES

1. Ahmadi MR, Khodakaram Tafti A, Nazifi S, Ghaisari HR. The comparative evaluation of uterine and cervical mucosa cytology with endometrial histopathology in cows. Comparative Clinical Pathology. 2005; 14:90-4.
2. Ajevar G, Muthu S, Sarkar M, Kumar H, Das GK, Krishnaswamy N. Transcriptional profile of endometrial TLR4 and 5 genes during the estrous cycle and uterine infection in the buffalo (Bubalus bubalis). Veterinary Research Communications. 2014; 38(2):171-76.
3. Alavi-Shoushtari SM, Asri-Rezai S, Abshenas J. A study of the uterine protein variations during the estrous cycle in the cow: Molecular weights determination. Animal Reproduction Science. 2008; 105:302-10.
4. Arias LAQ, Fernandez MV, Gonzalez JJB, Lopez MB, Herradon PG, Martinez AIP. Subclinical endometritis in dairy cattle. In: New Insights into Theriogenology. InTechOpen, London. 2018; 80-81pp.
5. Bacha B, Regassa FB. Subclinical endometritis in Zebu x Friesian crossbred dairy cows: its risk factors, association with subclinical mastitis and effect on reproductive performance. Tropical Animal Health and Production.2010; 42:397-403.
6. Baranski W, Podhalicz-Dzigielewska M, Zdunczyk S, Janowski T. The diagnosis and prevalence of subclinical endometritis in cows evaluated by different cytologic thresholds. Theriogenology. 2012; 78:1939-47.

7. Barlund TD, Carruthers TD, Waldner CL, Palmer CW. A comparison of diagnostic techniques for postpartum endometritis in dairy cows. Theriogenology. 2008; 69: 714-23.
8. Barrio M, Becerra JJ, Herradon PG, Sebastian F, Fernandez M, Quintela LA. Fertility in cows with endometritis diagnosed by cytology at day 30 postpartum. Proceedings of 12th Cong AERA. Abstract. 2014.
9. Barrio M, Vigo M, Quintela LA, Becerra JJ, Garcia-Herradon PJ, Martinez-Bello D. Influence of subclinical endometritis on the reproductive performance of dairy cows. Spanish Journal of Agricultural Research. 2015; 13(4): 5-12.
10. Bell MJ, Roberts DJ. The impact of uterine infections on dairy cow's performance. Theriogenology. 2007; 68: 1074-79.
11. Boby J, Kumar H, Gupta HP, Jan MH, Singh SK, Patra MK, Nandi S, Abraham A, Krishnaswamy N. Endometritis increases pro-inflammatory cytokines in follicular fluid and cervico-vaginal mucus in the buffalo cow. Animal Biotechnology. 2017; 28(3): 163-67.
12. Bollwein H, Baumgartner U, Stolla R. Transrectal Doppler sonography of uterine blood flow in cows during pregnancy. Theriogenology. 2002; 57: 2053-61.
13. Bondurant RH. Inflammation in the bovine female reproductive tract. Journal of Animal Science. 1999; 77(2): 101-10.
14. Bonnett BN, Miller RB, Etherington WG, Martin SW, Johnson WH. Endometrial biopsy in Holstein-Friesian dairy cows. I. Technique, histological criteria and results. Canadian Journal of Veterinary Research. 1991; 55: 155.
15. Brodzki P, Kostro K, Brodzki A, Lisiecka U. Determination of selected parameters for non-specific and specific immunity in cows with subclinical endometritis. Animal Reproduction Science. 2014; 148: 109-14.
16. Brodzki P, Kostro K, Brodzki A, Wawron W, Marczuk J, Kurek L. Inflammatory cytokines and acute-phase proteins concentrations in the peripheral blood and uterus of cows that developed endometritis during early postpartum. Theriogenology. 2015; 84: 11-18.
17. Carneiro LC, Ferreira AF, Paduo M, Saut JP, Ferraudo AS, dos Santos RM. Incidence of subclinical endometritis and its effects on reproductive performance of crossbred dairy cows. Tropical Animal Health and Production. 2014; 46: 1435-39.
18. Chan JPW, Chang CC, Hsu WI, Liu WB, Chen TH. Association of increased serum acute-phase protein concentrations with reproductive performance in dairy cows with postpartum metritis. Veterinary Clinical Pathology. 2010; 39(1): 72-78.
19. Cheng Z, Chike F, Uthai TS, Carr S, Wathes DC. Relationships between circulating urea concentrations endometrial function in postpartum dairy cows. Animals. 2015; 5: 748-73.
20. Cheong SH, Nydam DV, Galvao KN, Croiser BM, Ricci A, Caixeta LS. Cow-level and herd-level risk factors for subclinical endometritis in lactating Holstein cows. Journal of Dairy Science. 2011; 94: 762-70.
21. Coto RM, Lucy MC. Uterine inflammation affects the reproductive performance of dairy cows: A review. Agronomia Mesoamericana. 2018; 29(2): 449-68.
22. Debertolis L, Mari G, Merlo B, Merbach S, Schoon HA, Iacono E, Bollwein H. Effects of induced endometritis on uterine blood flow in cows as evaluated by transrectal Doppler sonography. Journal of Veterinary Science. 2016; 17(2): 189-97.
23. Dini P, Farhoodi M, Hostens M, Eetvelde MV, Pascottini OB, Fazeli MH, Opsomer G. Effect of uterine lavage on neutrophil counts in postpartum dairy cows. Animal Reproduction Science. 2015; 158: 25-30.
24. Dourey A, Colazo MG, Barajas PP, Ambrose DJ. Relationships between endometrial cytology and interval to first ovulation, and pregnancy in postpartum dairy cows in a single herd. Research in Veterinary Science. 2011; 91: 149-53.
25. Du Clos TW, Mold C. The role of C-reactive protein in the resolution of bacterial infection. Current Opinion in Infectious Diseases. 2001; 14(3): 289-93.
26. Dubuc J, Duffield TF, Leslie KE, Walton JS, LeBlanc SJ. Definitions and diagnosis of postpartum endometritis in dairy cows. Journal of Dairy Science. 2010; 93: 5225-34.
27. Duffy P, Crowe MA, Boland MP, Roche JF. Effect of exogenous LH pulses on the fate of the first dominant follicle in postpartum beef cows nursing calves. Journal of Reproduction and Fertility. 2000; 118(1): 9-17.
28. Duvel A, Maass J, Heppelmann M, Hussen J, Koy M, Piechotta M, Sandra O, Smith DG, Sheldon IM, Dieuzy-Labaye I, Zieger P, Schuberth HJ. Peripheral blood leukocytes of cows with subclinical endometritis show an altered cellular composition and gene expression. Theriogenology. 2014; 81: 906-17.
29. Eckersall PD, Bell R. Acute phase proteins: Biomarkers of infection and inflammation in veterinary medicine. The Veterinary Journal. 2010; 185: 23-27.
30. El-Rheem SMA, Ghallab RS, El-Sharkawy S. SAT, a New Approach in Understanding and Treatment of Subclinical Endometritis in Dairy Cows. Open Journal of Veterinary Medicine. 2019; 9: 109-19.
31. Elsayed DH, El-Azzazi FE, Mahmoud YK, Dessouki SM, Ahmed EA. Subclinical endometritis and postpartum ovarian resumption in respect to TNF-α, IL-8 and CRP in Egyptian buffaloes. Animal Reproduction. 2020; 17(1): 1-13.
32. Escandon BM, Espinoza JS, Perea FP, Quito F, Ochoa R, Lopez, GE, Galarza DA, Garzon JP. Intrauterine therapy with ozone reduces subclinical endometritis and improves reproductive performance in postpartum dairy cows managed in pasture based systems. Tropical Animal Health and Production. 2020. https://doi.org/10.1007/s11250-020-02298-3.
33. Fischer C, Drillich M, Odau M, Heuwieser W, Einspanier R, Gabler C. Selected proinflammatory factor transcripts in bovine endometrial epithelial cells are regulated during the estrus cycle and elevated in case of subclinical or clinical endometritis. Reproduction, Fertility and Development. 2010; 22: 818-29.

34. Fuentes BM, Arias LAQ, Gonzalez JJB, del Sol LDB, Feijoo JEM, Punal JLG, Lopez MB, Lago AP, Cao JMD, Gonzalez GF, Herradon PJG, Martinez AIP. Agreement between postmortem endometrial cytology, biopsy and bacteriology in culled dairy cows. Animal Reproduction. 2017; 14(4): 1024-33.
35. Gahlot SC, Kumar S, Kumaresan A, Vairamuthu S, Saraf KK, Sreela L, Baithalu RK, Lathwal SS, Mohanty TK. Biochemical analysis of uterine fluid for identification of indicators for subclinical endometritis in the water buffalo (Bubalus bubalis). Reproduction in Domestic Animals. 2017; 1-6pp. https://doi.org/10.1111/rda.13051.
36. Galvao KN, Santos NR, Galvao JS, Gilbert RO. Association between endometritis and endometrial cytokine expression in postpartum Holstein cows. Theriogenology. 2011; 76: 290-99.
37. Gartner MA, Peter S, Jung M, Drillich M, Einspanier R, Gabler C. Increased mRNA expression of selected pro-inflammatory factors in inflamed bovine endometrium in vivo as well as in endometrial epithelial cells exposed to Bacillus pumilus in vitro. Reproduction, Fertility and Development. 2015; 28: 982-94.
38. Ghasemi F, Gonzalez-Cano P, Griebel PJ, Palmer C. Proinflammatory cytokine gene expression in endometrial cytobrush samples harvested from cows with and without subclinical endometritis. Theriogenology. 2012; 78: 1538-47.
39. Gilbert RO. The effect of endometritis on the establishment of pregnancy in cattle. Reproduction Fertility and Development. 2011; 24: 252-57.
40. Gilbert RO, Shin ST, Guard CL, Erb HN, Frajblat M. Prevalence of endometritis and its effect on reproductive performance in dairy cows. Theriogenology. 2005; 64: 1879-88.
41. Hartmann D, Rohkohl J, Merbach S, Heilkenbrinker T, Klindworth HP, Schoon HA, Hoedemaker M. Prevalence of cervicitis in dairy cows and its effect on reproduction. Theriogenology. 2016; 85: 247-53.
42. Heidarpour M, Mohri M, Fallah Rad AH, Shahreza FD, Mohammadi M. Acute-phase protein concentration and metabolic status affect the outcome of treatment in cows with clinical and subclinical endometritis. The Veterinary Record. 2012; 171: 1-5.
43. Heppelmann M, Weinert M, Brommling A, Piechotta M, Hoedemaker M, Bollwein H. The effect of puerperal uterine disease on uterine involution in cows assessed by Doppler sonography of the uterine arteries. Animal Reproduction Science. 2013; 143(1-4): 1-7.
44. Kasimanickam TF, Duffield RA, Foster CL, Gartley KE, Leslie JS, Johnson WH. Endometrial cytology and ultrasonography for the detection of subclinical endometritis in postpartum dairy cows. Theriogenology. 2004; 62: 9-23.
45. Kasimanickam R, Kasimanickam V, Kastelic JP. Mucin 1 and cytokines mRNA in endometrium of dairy cows with postpartum uterine disease or repeat breeding. Theriogenology. 2014; 81: 952-58.
46. Kasimanickam RK, Kasimanickam VR, Olsen JR, Jeffress EJ, Moore DA, Kastelic JP. Associations among serum pro- and anti-inflammatory cytokines, metabolic mediators, body condition, and uterine disease in postpartum dairy cows. Reproductive Biology and Endocrinology. 2013; 11(1): 103.
47. Kaya S, Kacar C, Ogun M, Kuru MN, Ozen HC, Demir M, Sahin L, Zonturlu AK. Evaluation of serum C-reactive protein and natural antibodies in cows with endometritis. Kafkas University Vet Fak Derg. 2016; 22: 709-15.
48. Kim IH, Kang HG, Jeong JK, Hur TY, Jung YH. Inflammatory cytokine concentrations in uterine flush and serum samples from dairy cows with clinical or subclinical endometritis. Theriogenology. 2014; 82(3): 427-32.
49. Krakowski L, Zdzisinska B. Selected cytokines and acute phase proteins in heifers during the ovarian cycle course and in different pregnancy periods. Bulletin of the Veterinary Institute Pulawy. 2007; 51: 31-36.
50. LeBlanc SJ, Osawab T, Dubuc J. Reproductive tract defense and disease in postpartum dairy cows. Theriogenology. 2011; 76: 1610-18.
51. Lee SC, Jeong JK, Choi Is, Kang HG, Jung YH, Park SB, Kim IH. Cytological endometritis in dairy cows: diagnostic threshold, risk factors, and impact on reproductive performance. Journal of Veterinary Science. 2018; 19(2): 301-08.
52. Li D, Liu Y, Pei X, Guo D. Research on change of acute phase protein and IL-6 in cows with endometritis. Acta Veterinaria Zootechnica Sinica. 2010; 41: 1333-36.
53. Lopdell T, Berg MC, Green MP, Back PJ. Effect of sub-clinical uterine infection on plasma amino acid concentrations in early lactation dairy cows. Proceedings of New Zealand Society of Animal Production. 2011; 71: 291-295
54. Loyi T, Kumar H, Nandi S, Mathapati BS, Patra M and Pattnaik B. Differential expression of pro-inflammatory cytokines in endometrial tissue of buffaloes with clinical and sub-clinical endometritis. Research in Veterinary Science. 2013; 294(2): 336-40.
55. Machado VS, Knauer WA, Bicalho MLS, Oikonomou G, Gilbert RO, Bicalho RC. A novel diagnostic technique to determine uterine health of Holstein cows at 35 days postpartum. Journal of Dairy Science. 2012; 95(3): 1349-57.
56. Madoz LV, Giuliodori MJ, Plontzke J, Drillich M, de la Sota RL. The relationship between endometrial cytology during estrus cycle and cutoff points for the diagnosis of subclinical endometritis in grazing dairy cows. Journal of Dairy Science. 2013; 96(7): 4333-37.
57. Madoz LV, Giuliodori MJ, Migliorisi AL, Jaureguiberry M and de-la-Sota RL. Endometrial cytology, biopsy, and bacteriology for the diagnosis of subclinical endometritis in grazing dairy cows. Journal of Dairy Science. 2014; 97: 195-201.
58. Marino B, Quintela LA, Becerra JJ, Barrio L, Mocinos JE and Guillin JL. Agreement between postmortem endometrial cytology, biopsy and bacteriology in culled dairy cows. Animal Reproduction. 2017; 14(4): 1024-33.
59. Mattmiller SA, Carlson BA, Sordillo LM. Regulation of inflammation by selenium and selenoproteins: Impact on eicosanoid biosynthesis. Journal of Nutritional Science. 2013; 2(28): 1-13.

60. McDougall S, Hussein H, Aberdein D, Buckle K, Roche J, Burke C, Mitchell M, Meier S. Relationships between cytology, bacteriology and vaginal discharge scores and reproductive performance in dairy cattle. Theriogenology. 2011; 76: 229-40.
61. Meira Jr EBS, Henriques LCS, Sa LRM, Gregory L. Comparison of ultrasonography and histopathology for the diagnosis of endometritis in Holstein-Friesian cows. Journal of Dairy Science. 2012; 95: 6969-73.
62. Metris A, George SM, Baranyi J. Use of optical density detection times to assess the effect of acetic acid on single cell kinetics. Applied Environmental Microbiology. 2006; 72: 6674-79.
63. Miller AN, Williams EJ, Sibley K, Herath S, Lane EA, Fishwick J, Nash DM, Rycroft AN, Dobson H, Bryant CE, Sheldon IM. The effect of Arcanobacterium pyogenes on endometrial function in vitro, and on uterine and ovarian function in vivo. Theriogenology. 2007; 68: 972-80.
64. Moscuzza C, Gaudalupe A, Betiana G, Marcelo Z, Marcelo T, Roberto P. Endometrial cytology as a diagnostic tool for subclinical endometritis in beef heifers. Turkish Journal of Veterinary and Animal Sciences. 2015; 39: 34-41.
65. Mossallam AAA, El Nahas SM, Mahfouz ER, Osman NM. Characterization of buffalo interleukin 8 (IL-8) and its expression in endometritis. Journal of Genetics Engineering and Biotechnology. 2015; 13(1): 71-77.
66. Nehru DA, Dhaliwal GS, Jan MH, Cheema RS, Kumar S. A non-invasive diagnostic test for subclinical endometritis in buffaloes. Indian Journal of Animal Sciences. 2019; 89(2): 140-44.
67. Nielsen JM. Endometritis in the mare: A diagnostic study comparing cultures from swab and biopsy. Theriogenology. 2005; 6(4): 510-18.
68. Pascottini OB. Subclinical Endometritis in Dairy Cattle: A Practical Approach. PhD Thesis, Department of Reproduction, Obstetrics and Herd Health, Faculty of Veterinary Medicine, Ghent University. 2016.
69. Pascottini OB, Opsomer G. Postpartum uterine diseases in dairy cows: a review with emphasis on subclinical endometritis. Vlaams Diergeneeskundig Tijdschrift. 2016; 85: 378-85.
70. Pascottini OB, Dini P, Hostens M, Ducatelle R, Opsomer G. A novel cytologic sampling technique to diagnose subclinical endometritis and comparison of staining methods for endometrial cytology samples in dairy cows. Theriogenology. 2015; 84: 1438-46.
71. Pascottini OB, Hostens M, Dini P, Vandepitte J, Ducatelle R, Opsomer G. Comparison between cytology and histopathology to evaluate subclinical endometritis in dairy cows. Theriogenology. 2016a; 86(6): 1550-56.
72. Pascottini OB, Hostens M, Sys P, Vercauteren P, Opsomer G. Cytological endometritis at artificial insemination in dairy cows: Prevalence and effect on pregnancy outcome. Journal of Dairy Science. 2016b; 100: 588-97.
73. Patbandha TK, Mohanty TK, Layek SS, Kumaresan A, Behera K, Chand S. Association of peri-partum blood energy metabolites with post-partum puerperal metritis in crossbred cows. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. 2016; 1-7. https://doi.org/10.1007/s40011-016-0737-8.
74. Plontzke J, Madoz LV, De la Sota RL, Drillich M, Heuwieser W. Subclinical endometritis and its impact on reproductive performance in grazing dairy cattle in Argentina. Animal Reproduction Science. 2010; 122: 52-57.
75. Polat B, Cengiz M, Cannazik O, Colak A, Oruc E, Altun S, Salar S, Bastan A. Endometrial echotexture variables in postpartum cows with sub-clinical endometritis. Animal Reproduction Science. 2015; 155: 50-55.
76. Prunner I, Pothmann H, Wagener K, Giuliodori M, Huber J, Ehling-Schulz M. Dynamics of bacteriologic and cytologic changes in the uterus of postpartum dairy cows. Theriogenology. 2014a; 82: 1316-22.
77. Prunner I, Wagener K, Pothmann H, Ehling-Schulz M, Drillich M. Risk factors for uterine diseases on small- and medium-sized dairy farms determined by clinical, bacteriological, and cytological examinations. Theriogenology. 2014b; 82: 857-65.
78. Purohit GN, Dholpuria S, Yadav S, Barolia Y, Kumar P. Diagnosis and treatment of clinical and sub-clinical endometritis- A clinical study in 30 cows. Intas Polivet. 2013; 14(1): 31-33.
79. Raliou M, Dembele D, Duvel A, Bolifraud P, Aubert J, Mary-Huard T, Rocha D, Piumi F, Mockly S, Heppelmann M, Dieuzy-Labaye I, Zieger P, Smith DGE, Schuberth HJ, Sheldon IM, Sandra O. Subclinical endometritis in dairy cattle is associated with distinct mRNA expression patterns in blood and endometrium. PLoS ONE. 2019; 14(8): e0220244. https://doi.org/10.1371/journal.pone.0220244.
80. Rana A. Sub-clinical endometritis- diagnosis and its impact on subsequent reproductive performance in postpartum dairy cows. MVSc Thesis, Chaudhary Sarwan Kumar Himachal Pradesh Agriculture University, Palampur. 2019.
81. Rawy M, Mido S, Ali HES, Derar DE, Meghaded GE, Kitahara G, Osawa T. Effect of exogenous estradiol benzoate on uterine blood flow in postpartum dairy cows. Animal Reproduction Science. 2018; 192: 136-45.
82. Ribeiro BLM, Junior EBSM, Reyes MAA, Marques EC, Nassar AFC, Gregory L. Assessment of the bovine uterus with endometritis using Doppler ultrasound. BioRxiv. 2019. doi: https://doi.org/10.1101/826065.
83. Ribeiro ES, Lima FS, Greco LF, Bisinotto RS, Monteiro AP, Favoreto M. Prevalence of periparturient diseases and effects on fertility of seasonally calving grazing dairy cows supplemented with concentrates. Journal of Dairy Science. 2013; 96: 5682-97.
84. Ricci A, Gallo S, Moilnaro F, Dondo A, Zoppi S, Vincenti L. Evaluation of subclinical endometritis and consequences on fertility in Piedmontese beef cows. Reproduction in Domestic Animals. 2015; 50:142-48.
85. Rinaudo A, Bernardi SF, Marini PR. Relation between subclinical endometritis and reproductive efficiency in dairy cows in Argentina. Journal of Veterinary Science and Technology. 2017; 8(6):1-4.

86. Salah N, Yimer N. Cytological endometritis and its agreement with ultrasound examination in postpartum beef cows. Veterinary World. 2017; 10(6): 605-09.
87. Senosy W, Izaike Y, Osawa T. Influences of metabolic traits on subclinical endometritis at different intervals postpartum in high milking cows. Reproduction in Domestic Animals. 2012; 47: 666-74.
88. Sharma A. Uterine infections of puerperal transition phase in cattle of Himachal Pradesh- diagnosis and therapeutic management. MVSc Thesis, Chaudhary Sarwan Kumar Himachal Pradesh Agriculture University, Palampur. 2017.
89. Sharma A, Singh M. Establishing a relationship between endometrial cytology and uterine fluid, followed by evaluation of their association with fertility parameters in post-partum dairy cows. Veterinarski Arhiv. 2019; 89(4): 435-46.
90. Sharma A, Singh M, Abrol A, Soni T. Doppler sonography of uterine blood flow at mid-oestrus during different degree of clinical endometritis in dairy cows. Reproduction in Domestic Animals. 2019; 54(9): 1274-78.
91. Sharma A, Singh M, Sharma A, Kumar P. Diagnosis and assessment of reproductive performance in dairy cows with sub-clinical endometritis. Intas Polivet. 2018; 19(1):42-43.
92. Silper BF, Madureira AM, Burnett TA, Fernandes AC, Abreu FM, Veira DM, Vasconcelos JL, Cerri RL. Diagnosis of uterine and vaginal disorders by different methodologies is affected by concentration of estradiol in plasma from lactating Holstein cows. Journal of Dairy Science. 2016; 99: 4795-807.
93. Singh J, Honparkhe M, Chandra M, Kumar A, Ghuman SPS and Dhindsa SS. Diagnostic efficacy of uterine cytobrush technique for subclinical endometritis in crossbred dairy cattle. Indian Veterinary Journal. 2016; 93(02): 11-13.
94. Snider TA, Sepoy C, Holyoak GR. Equine endometrial biopsy reviewed: observation, interpretation, and application of histopathologic data. Theriogenology. 2011; 75: 1567-81.
95. Stassi AF, Baravalle ME, Belotti EM, Rey F, Gareis NC, Diaz PU, Rodríguez FM, Leiva C, Ortega HH, Salvetti NR. Altered expression of cytokines IL-1α, IL-6, IL-8 and TNF-α in bovine follicular persistence. Theriogenology. 2017; 97: 104-12.
96. Tall AR, Yvan-Charvet L. Cholesterol, inflammation innate immunity. Nature reviews: Immunology. 2015; 15: 104-16.
97. Vallejo C, Chaves C, Benavides C, Astaiza J, Zambrano W. Occurrence of Subclinical Endometritis in Dairy Cattle and Effect on Reproductive Efficiency. Acta Scientiae Veterinariae. 2018; 46: 1540.
98. Van Schyndel, Pascottini OB, LeBlanc SJ. Comparison of cow-side diagnostic techniques for sub-clinical endometritis in dairy cows. Theriogenology. 2018; 120: 117-22.
99. Vinita, Shivhare M, Singh S, Tayeng K and Chakravarti S. Endometrial cytology to diagnose subclinical endometritis in cows. International Journal of Agriculture, Environment and Technology. 2018; 11(4): 623-31.
100. Wagener K, Gabler C, Drillich M. A review on the ongoing discussion about definition, diagnosis and pathomechanism of subclinical endometritis in dairy cows. Theriogenology. 2017; 94: 21-30.
101. Wang X, Yuan T, Yin N, Ma X, Zhang Z, Zhu Z, Shaukat A, Deng G. Luteoloside protects the uterus from Staphylococcus aureus-induced inflammation, apoptosis, and injury. Inflammation. 2018; 41(5): 1702-16.