

# The Effects of Presynch-10 and Ovsynch on Some Endometrial Toll- and Nod-like Receptor Gene Expressions in Repeat Breeder Cows <sup>[1][2]</sup>

Ali Reha AĞAOĞLU <sup>1,a</sup> Özgecan KORKMAZ AĞAOĞLU <sup>2,b</sup> Selim ASLAN <sup>3,c</sup> Mesih KOCAMÜFTÜOĞLU <sup>1,d</sup>  
Afşin KÖKER <sup>1,e</sup> Yunus ÇETİN <sup>1,f</sup> Örsan GÜNGÖR <sup>1,g</sup> Dilek ÖZTÜRK <sup>4,h</sup> Mustafa SAATCI <sup>5,i</sup>

<sup>[1]</sup> This study was supported by the Scientific and Technological Research Council of Turkey-TUBITAK (project number: 113O590)

<sup>[2]</sup> This study was presented in the Turkish Society of Veterinary Gynaecology VII. National - I. International Congress, 15-18 October 2017, Marmaris, Turkey

<sup>1</sup> Mehmet Akif Ersoy University, Faculty of Veterinary Medicine, Department of Obstetrics and Gynecology, TR-15030 Burdur - TURKEY

<sup>2</sup> Mehmet Akif Ersoy University, Faculty of Veterinary Medicine, Department of Animal Science, TR-15030 Burdur - TURKEY

<sup>3</sup> Near East University, Veterinary Faculty, Department of Obstetrics and Gynecology, Nicosia; North Cyprus, Mersin 10, TURKEY

<sup>4</sup> Mehmet Akif Ersoy University, Faculty of Veterinary Medicine, Department of Microbiology, TR-15030 Burdur - TURKEY

<sup>5</sup> Muğla Sıtkı Koçman University, Fethiye Agriculture Faculty, Department of Animal Science, TR-48000 Muğla - TURKEY

<sup>a</sup> ORCID: 0000-0002-6545-8800; <sup>b</sup> ORCID: 0000-0002-7414-1725; <sup>c</sup> ORCID: 0000-0001-6411-5489; <sup>d</sup> ORCID: 0000-0003-3228-6835

<sup>e</sup> ORCID: 0000-0001-6580-1309; <sup>f</sup> ORCID: 0000-0002-5402-9429; <sup>g</sup> ORCID: 0000-0002-4576-9740; <sup>h</sup> ORCID: 0000-0002-9643-8570

<sup>i</sup> ORCID: 0000-0003-3697-8804

Article ID: KVFD-2019-22428 Received: 07.04.2019 Accepted: 13.08.2019 Published Online: 14.08.2019

## How to Cite This Article

Ağaoğlu AR, Korkmaz Ağaoğlu Ö, Aslan S, Kocamüftüoğlu M, Köker A, Çetin Y, Güngör Ö, Öztürk D, Saatci M: The effects of presynch-10 and ovsynch on some endometrial toll- and nod-like receptor gene expressions in repeat breeder cows. *Kafkas Univ Vet Fak Derg*, 26 (1): 111-120, 2020. DOI: 10.9775/kvfd.2019.22428

## Abstract

Subclinical endometritis (SE) is one cause of repeat breeder syndrome (RBS). When endometrial cells come into contact with antigens during inflammatory events like endometritis, they act like innate immune system cells. Ovsynch-based therapies stimulate the innate immune system, which is how they may be able to cure SE and then RBS. This study aimed to assess the effects of presynch-10 and ovsynch applications on mRNA expressions of some endometrial Toll- and Nod-like receptors (TLRs and NLRs) in cows with RBS. A total of 40 repeat breeder cows were used in the study. The presynch-10 and ovsynch protocols were used in group 1 (G1, n=20), and no protocol was used in group 2 (G2, n=20). Endometrial samples were collected before and after the synchronization protocols in G1. In G2, samples were collected, and after waiting time up to the duration of synchronization protocol in G1, samples were taken again. The expression profiles of the genes being investigated were examined using RT-qPCR. NLR4, NALP3 and TLR4 were basically expressed in all of the samples while NOD2 expression was completely undetectable. There was a statistical difference when NOD1 and TLR2 expressions in the second samples were compared between G1 and G2 (P<0.05). It was concluded that presynch-10 and ovsynch administration in cows may have a positively effect on the innate immune response and so be effective in the treatment of SE.

**Keywords:** Endometritis, Cow, Innate immunity, Pattern recognition receptors

## Repeat Breeder İneklerde Presynch-10 ve Ovsynch Uygulamalarının Bazı Endometrijal Toll ve Nod Benzeri Reseptör Genlerinin Ekspresyonları Üzerine Etkileri

### Öz

Subklinik endometritis (SE), repeat breeder sendromunun (RBS) nedenlerinden biridir. Endometrijal hücreler, endometritis gibi yangısal olaylar sırasında antijenlerle karşılaştıklarında, doğal bağışıklık sistemi hücreleri gibi davranırlar. Ovsynch temelli tedaviler doğal bağışıklık sistemini uyararak SE ve sonra RBS'yi tedavi edebilmektedirler. Bu çalışma presynch-10 ve ovsynch uygulamalarının RBS'li ineklerde bazı endometrijal Toll- ve Nod- benzeri reseptörlerin (TLR'ler ve NLR'ler) mRNA ekspresyonları üzerindeki etkilerini değerlendirmeyi amaçlamıştır. Çalışmada toplam 40 repeat breeder inek kullanılmıştır. Grup 1'de (G1, n=20), presynch-10 ve ovsynch uygulanmış, Grup 2'de herhangi bir uygulama yapılmamıştır (G2, n=20). G1'de senkronizasyon uygulamaları öncesi ve sonrasında endometrijal örnekler alınmıştır. G2'de örnekler alındıktan sonra G1'de uygulanan senkronizasyon protokolü süresi kadar beklenerek örneklemeler tekrarlanmıştır. İncelenen genlerin ekspresyon düzeyleri RT-qPCR ile belirlenmiştir. NLR4, NALP3 ve TLR4'ün temel olarak tüm örneklerde eksprese edildiği, NOD2 ekspresyonunun ise belirlenemeyecek seviyelerde kaldığı saptanmıştır. G1 ve G2'den alınan ikinci endometrijal örnekler arasında NOD1 ve TLR2 ekspresyonları arasında istatistiksel bir fark oluşmuştur (P<0.05). İneklerdeki presynch-10 ve ovsynch uygulamalarının doğal bağışıklık yanıtını olumlu yönde etkileyebileceği ve SE tedavisinde etkili olabileceği sonucuna varılmıştır.

**Anahtar sözcükler:** Endometritis, İnek, Doğal bağışıklık, Kalıp tanıyan reseptörler



### İletişim (Correspondence)



+90 248 2132239 Fax: +90 248 2132001



rehaagaoglu@mehmetakif.edu.tr

## INTRODUCTION

Repeat breeding syndrome (RBS) is one of the most important causes of infertility in dairy herds and prolongs the calving interval, which results in economic losses <sup>[1]</sup>. Repeat breeding syndrome is defined as cows younger than 10 years of age that fail to conceive after 3 consecutive inseminations while exhibiting normal estrus every 18 to 24 days, have no clinical disorders or pathological discharge in the genital organs <sup>[1,2]</sup>. The most common causes of RBS are subclinical endometritis (SE) <sup>[3]</sup>, poor estrus detection <sup>[4]</sup>, delayed increase in LH that delayed a rise in progesterone level <sup>[5]</sup>, embryonic losses <sup>[6]</sup>, environmental factors <sup>[7]</sup> and malnutrition <sup>[8]</sup>. When the microorganisms that play a role in the etiology of SE, which one of the most important causes of RBS, reach the uterus, they come into contact with the endometrium, which is the frontline of the genital tract defense. Endometrial cells have pattern recognition receptors (PRRs) which recognize pathogen-associated molecular patterns (PAMPs) on the surface of microorganisms. This allows them to function like a member of the innate immune system <sup>[9]</sup>. Studies have shown that PRRs are expressed in endometrial cells in humans <sup>[10]</sup> and many animal species <sup>[11]</sup>. TLRs and NLRs are important members of the PRR family. TLR2 is very important receptor involved in the recognition of the cell surface components of Gram-positive bacteria <sup>[12]</sup>. The interaction of TLR2 and its ligand triggers an inflammatory response. Similar to TLR2, activation of TLR4 also leads to an inflammatory response. TLR4 is responsible for recognizing Gram-negative bacteria, such as *Escherichia coli* <sup>[9]</sup>. NLRs are also known as the second line in the natural defense system after TLRs. Responses to microorganisms were generated by NLRs when TLR response was inadequate or microorganisms escaped TLRs <sup>[13]</sup>. NLRs recognize endotoxin, protein or RNA of many microorganisms <sup>[14-18]</sup>, viral agents and fungi <sup>[19]</sup>.

This interaction acts as a signal that initiates inflammatory reactions <sup>[20]</sup>. Luteal function deficiencies are another important factor that causes RBS. In this context, bacteria found in the uterus or inflammation in the endometrium may inhibit the release of luteinizing hormone (LH) and adversely affect follicular development, ovarian functions and the ovulation mechanism <sup>[21]</sup>. Therefore, one approach to resolving RBS related to ovarian dysfunctions or sub-clinical endometrial inflammation is administering ovulation synchronization protocols. In this way, the compromised ovulation mechanism can be made functional by hormonal intervention. Studies revealed that if the first injection of gonadotropin-releasing hormone (GnRH) is given when the diameter of the dominant follicle is 10 mm, the ovsynch protocol will be more successful <sup>[22]</sup>. Therefore, the success of ovsynch can be improved by administering two doses of prostaglandin F2-alpha (PGF2 $\alpha$ ) at an interval of 14 days before starting the ovsynch protocol. As a result, the dominant follicle can be brought to the proper size. It is further hypothesized that PGF2 $\alpha$  administration

is beneficial in the treatment of SE as it induces local immunity of uterus <sup>[23,24]</sup>.

This study aimed to assess the effects of administering presynch-10 and ovsynch to change mRNA expressions of some TLRs and NLRs in the endometrial tissue of cows with RBS. Cytological and bacteriological samples were also investigated.

## MATERIAL and METHODS

All procedures were approved by the Local Ethical Committee of the Experimental Research on Animals (No: 2013/14). Cows were housed in a free stall barn from November 2013 through November 2014 and fed *ad libitum* total mixed ration diet and fresh water.

### Cows

Forty multiparous Holstein-Friesian cows with RBS were enrolled in this study. Cows with RBS were identified by reviewing dairy farm records and gynecological examinations. For this purpose, multiparous cows that had been inseminated three consecutive times but did not get pregnant were selected. Rectal, vaginal and ultrasonographic examinations were performed to determine whether or not there were any pathological conditions in uterus or ovarium. Body condition scores (BCS) were determined using a 5-point scale (1= thin to 5= obese) <sup>[25]</sup>. The BCS's of the cows in the present study were between 3.25 and 3.5 and, were clinically healthy and there was a corpus luteum (CL) in the ovaries.

### Study Design

Cytological, bacteriological and biopsy samples were collected from the endometrium for microbiological identification, polymorph nuclear leucocyte rates and detection of gene expressions from all cows. Blood samples were also collected from the tail vein to identify the blood levels of estradiol and progesterone. The cows were randomly divided into two groups.

In group 1 (G1, n=20), rectal, vaginal and ultrasonographic examinations were performed and then endometrial samples were collected 10 days before synchronization began. Then presynch-10 and ovsynch protocols <sup>[26]</sup> were administered. Blood samples were collected from the tail vein on injection days. Endometrial samplings and clinical examinations were repeated 10 days after the last injection of ovsynch, and blood samples were collected (*Table 1*). The cows in group 2 (G2, n=20) were not given any medications. First, clinical examinations were performed, and endometrial and blood samples were taken. Following the waiting period as long as the synchronization protocol used in G1, estruses were followed-up. Corpora lutea were identified by rectal examination 10 days after estrus, after which clinical examinations were performed and all of the samples were collected again in G2.

**Table 1.** Applications of synchronization, gynecological examination and endometrial sampling in G1

Synchronization Protocols	Days	Applications
Presynch-10	-34	VI, RE, R-USG, ESS-1, EBS-1, ECS-1, BIS
	-24	1 <sup>st</sup> Clo
	-10	2 <sup>nd</sup> Clo
Ovsynch	0	1 <sup>st</sup> Buse, BIS
	7	Clo
	9	2 <sup>nd</sup> Buse, BIS
	10	Ovulation, BIS
	20	VI, RE, R-USG, ESS-1, EBS-1, ECS-1, BIS

VI: vaginal inspection, RE: rectal examination, R-USG: rectal ultrasonography, ESS: endometrial swab sampling, EBS: endometrial biopsy sampling, ECS: endometrial cytology sampling, BIS: blood sampling, Clo: cloprostenol [estrumate, 500 µg, im], Buse: buserelin acetate [receptal, 10 µg, im]

### Bacteriologic and Cytologic Examination

Special swabs (Uterus Culture Swab with AMIES transport medium, Ref. 17214/2951, Minitube, Germany) and endometrial brushes (Cytobrush®, Ref.17214/2960, Minitube, Germany) were used for bacteriological and cytological sampling. The swab and cytobrush were inserted inside a stainless-steel catheter about 50 cm long to reach the uterine lumen without any contamination.

First, cytological samples were collected by rotating the cytobrush while in contact with the uterine wall. Cytological slides were prepared by rolling the cytobrush onto clean microscope glass. Slides were dried for 1-2 min in the air and then placed in special labeled transport containers. Samples were dyed with the May Grünwald Giemsa Method, and 200 cells were counted per slide. Bacteriologic samples were collected by swabs and, immediately placed in the AMIES medium and transported to the laboratory within 24 h. Samples were plated onto blood, Brucella, Campylobacter, SDA and MacConkey agars.

### RNA Extraction and cDNA Synthesis

Endometrial biopsy samples were collected from the dorsal wall and intercaruncular area of the uterus with a bovine biopsy instrument (Kruuse, 63 cm, Kat no: 141700, Denmark). Collected samples were placed into microcentrifuge tubes, and snap-frozen in liquid nitrogen. Samples were transported to the laboratory in a nitrogen tank, transferred to a refrigerator (-86°C) and stored until analysis. Total RNA extracted from endometrial samples was performed using the Trizol method.

Purity and concentration evaluations were assessed with Thermo Scientific NanoDrop 2000®, and integrity was evaluated by electrophoresis in 0.8% agarose gel. DNase I (#EN0521) was used for DNA digestion, and the Thermo Scientific Revert Aid First Strand cDNA Synthesis Kit was

used according to manufacturer recommendations for cDNA synthesis.

### Real Time PCR

Primer sequences were designed using PrimerQuest and primer-BLAST (idt/PrimerQuest and ncbi/tools/primer-blast) software programs (Table 2). Housekeeping genes (HKGs) (B2-GAPDH, Beta-Aktin, HPRT1, YHWAZ, SDHA, SUZ12, TUBA1, 18S) were examined in order to select those that were the most stable and suitable.

### Hormone Analysis

Blood samples were collected on injection days and when the 1<sup>st</sup> and 2<sup>nd</sup> endometrial samples were collected. They were then centrifuged for three min at 3000g to obtain blood serum. Serum samples were stored at -20°C until analysis. Serum estradiol and progesterone assays were performed using the ECLIA® method (Electrochemiluminescence Immunoassay) in an internationally certified laboratory (TURKAK, TS EN ISO/IEC 17025:2005, DUZEN Laboratory Group, Turkey).

### Statistical Analysis

Normality tests were conducted for all of the data obtained from the study. The paired t test was used to compare cytological cell count data. The Chi-square test was used to compare microbiological data among groups. Statistical comparison of serum estradiol and progesterone levels were performed using the paired t test and Wilcoxon test, respectively.

Quantification of the RT-qPCR results was performed using the ROCHE Nano Lightcycler® software. The most stable and suitable gene was identified as YHWAZ and selected as a reference gene. Subsequently, this reference gene was used to normalize qPCR data. The normalization procedure was performed on the mathematical model of  $2^{-\Delta\Delta Ct}$  reported by Livak and Schmittgen [29]. The Wilcoxon test was performed for data from the same cow, and the Mann-Whitney U test was performed to identify differences among the groups. Minitab 16.0® software was used for statistical analysis and box plot graphics.

## RESULTS

The calving-to-first-service interval for cows in G1 and G2 was 85.95±19.79 and 90.05±21.77 respectively. The mean number of days in milk (DIM) was 205.6±55.60 in G1 and 236.25±54.51 in G2 (min: 150, max: 349). Since the mean DIM of the cows is 205.60±55.60 (min: 150, max: 349), >3% polymorphonuclear leukocyte (PMNL) was accepted as a threshold value for SE in the cytological evaluation [30].

There were 38 cows that had SE according to the first endometrial cytology samples (ECS1) taken from 40 cows, and this number constitutes 95% of all cows. On the

Gene	Primer (5'-3') Forward, Reverse	PCR	Gen Accession Number	Reference
TLR2	5'-GGTTTAAAGGCAGAATCGTTTG-3' 5'-AAGGCACTGGGTAAACTGTGT-3'	190bp	NM_174197	[27]
TLR4	5'-CTTGCGTACAGGTTGTCCTAA-3' 5'-CTGGGAAGCTGGAGAAGTTATG-3'	153bp	NM_174198	[27]
NLRC4 (lpaf)	5'-CCAGGAAGTGTGAGAAAGG-3' 5'-CCCTTTACGTTTGTGCCTGT-3'	214bp	NM_001192323.2	Designed using Primer3
NOD-1	5'-GCTTATCCAGAACCAGATCAC-3' 5'-CCTCTTCTCATCTTCAAAGACC-3'	142bp	NM_001256563.1	Design using idt/PrimerQuest and ncbi/tools/primer-blast
NOD-2	5'-GTAGACTTCACTGAATCCCAAC-3' 5'-GCTCTCCACACCATAAATAC-3'	168bp	NM_001002889.1	Design using idt/PrimerQuest and ncbi/tools/primer-blast
NALP3	5'-CAGAATTCACCCACCTTTAC-3' 5'-GTCTAACTCCAACCTGAAG-3'	114bp	NM_001102219.1	Design using idt/PrimerQuest and ncbi/tools/primer-blast
YHWAZ	5'-CTGAGCAAGGAGCTGAATTATC-3' 5'-CTCTGTATTCTCGAGCCATCT-3'	162bp	NM_174814.2	Design using idt/PrimerQuest and ncbi/tools/primer-blast
B2-GAPDH	5'-GGCGTGAACCACGAGAAGTATAA-3' 5'-CCCTCCACGATGCCAAAGT-3'	119bp	NM_001034034.2	[28]
$\beta$ -actin	5'-ATCGGCAATGAGCGTTCC-3' 5'-GTGTTGGCGTAGAGGTCCTTG-3'	143bp	BT030480.1	[27]
HPRT1	5'-GCTACTGTGTGCTTAGGAAAG-3' 5'-CTACCGAAACCTACTGAAACAC-3'	114bp	NM_001034035.2	Design using idt/PrimerQuest and ncbi/tools/primer-blast
SDHA	5'-CGTTGTATGGAAGTCTCTG-3' 5'-GATGGACCCGTTCTTCTATG-3'	126bp	NM_174178.2	Design using idt/PrimerQuest and ncbi/tools/primer-blast
SUZ12	5'-GAACACCTATCACACACATTCTGT-3' 5'-TAGAGGCGGTTGTGCCACT-3'	130bp	XM582605	Designed using Primer3
TUBA1	5'-GCCCTACAACCTCATCCTCA-3' 5'-ATGGCCTCATTGTCTACCA-3'	78bp	NM_001166505.1	Designed using Primer3
S18	5'-ATGCGGCGGCGTTATTCC-3' 5'-GCTATCAATCTGCAATCCTGTCC-3'	204bp	NR_036642.1	Designed using Primer3

**B2-GAPDH:** B2-glyceraldehyde-3-phosphate dehydrogenase,  **$\beta$ -actin:** beta actin, **HPRT1:** hypoxanthine phosphoribosyl transferase-1, **YHWAZ:** tyrosine 3-monooxygenase/tryptophan 5-monooxygenase activation protein zeta, **SDHA:** succinate dehydrogenase complex, subunit A, **SUZ12:** suppressor of zeste 12, **TUBA1:** tubulin alpha 1a, **S18:** ribosomal protein S18, bp: base pairs

Groups	Percentage of PMNL (SE status)	ECS1		ECS2	
		n	%	n	%
G1	>0% - <3% (not SE)	0	0	1	5
	$\geq$ 3% (SE)	20	100	19	95
G2	>0% - <3% (not SE)	2	10	0	0
	$\geq$ 3% (SE)	18	90	20	100

**PMNL:** polymorphonuclear leukocyte; **ECS:** endometrial cytology sample; **SE:** subclinical endometritis

other hand, all of the cows in G1 had SE, and this number decreased to 19 after administering the presynch-10 + ovsynch protocol.

Eighteen cows had SE according to the evaluation of ECS1, and all cows had SE when the second endometrial cytology samples (ECS2) were evaluated in G2 (Table 3). There was no statistical difference between the PMNL cell numbers in the ECS1 taken from G1 and G2 ( $P>0.05$ ). Also, there were no statistical differences between the PMNL counts of ECS1 and ECS2 in both G1 and G2 ( $P>0.05$ ) (Table 4).

Groups	PMNL ( $\bar{X}\pm S$ )		
	ECS1	ECS2	P
G1	21.85 $\pm$ 9.50	18.70 $\pm$ 8.08	>0.05
G2	13.85 $\pm$ 8.54	16.15 $\pm$ 7.13	>0.05
P	>0.05	>0.05	

**X:** mean; **S:** standard deviation; **P:** significance value; **ECS:** Endometrial cytology sample

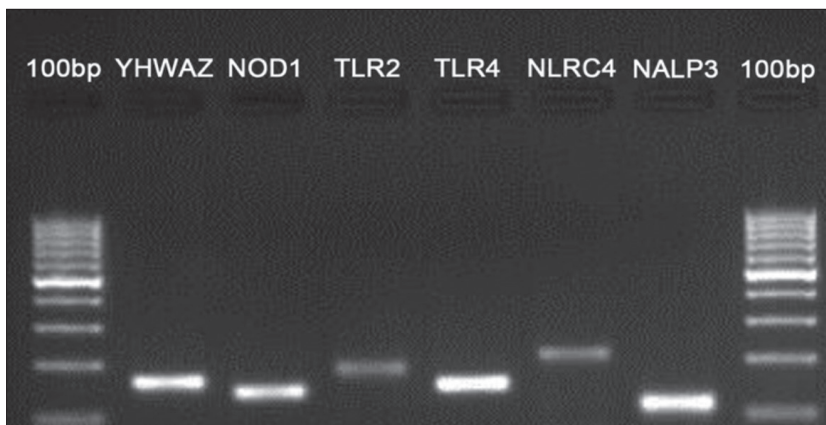
When the first endometrial swabs (ESS1) taken from all cows were evaluated, no pathogenic microorganisms were identified in 30 of 40 samples. According to the microbiological analyses, no pathogens were identified in 18 samples while *Citrobacter* sp. was identified in the other 2 samples in G1. In the second endometrial swabs (ESS2) taken after the synchronization protocol, there was no pathogen in 17 endometrial swabs while *Citrobacter* sp. and *E. coli* were isolated in the other 3 samples. In G2, no pathogenic agent was isolated in 12 of the ESS1 while *E. coli*, *Streptococcus* sp., *Candida* sp., *Klebsiella* sp. and *Aspergillus* sp. were isolated in the other samples.



**Table 5.** Isolated microorganism rates of G1 in and G2

Isolated Microorganism	G1 (n=20)				G2 (n=20)			
	ESS1		ESS2		ESS1		ESS2	
	n	%	n	%	n	%	n	%
NPI	18	90	17	85	12	60	10	50
<i>Citrobacter</i> sp.	2	10	2	10	-	-	-	-
<i>E. coli</i>	-	-	1	5	4	20	7	35
CNS	-	-	-	-	-	-	1	5
<i>Streptococcus</i> sp.	-	-	-	-	1	5	1	5
<i>Candida</i> sp.	-	-	-	-	1	5	-	-
<i>Klebsiella</i> sp.	-	-	-	-	1	5	1	5
<i>Aspergillus</i> sp.	-	-	-	-	1	5	-	-

NPI: no pathogen was isolated; CNS: coagulase negative staphylococci; ESS: endometrial swab sample



**Fig 1.** Agarose gel electrophoresis of RT-qPCR products from endometrial tissues. YHWAZ: tyrosine 3-monooxygenase/tryptophan 5-monooxygenase activation protein, zeta polypeptide, NOD1: nod like receptor 1, TLR2: toll like receptor 2, TLR4: toll like receptor 4, NLRC4: NLR family CARD domain-containing protein 4, NALP3: NACHT-, LRR-, and pyrin domain-containing protein 3, bp: base pair

When ESS2 were examined, no pathogen was isolated in 10 samples. However, *E. coli*, *Streptococcus* sp., *Coagulase negative staphylococci* (CNS) and *Klebsiella* sp. were isolated in the other 10 samples in G2 (Table 5).

The resulting PCR products from YHWAZ, NOD1, NOD2, TLR2, TLR4, NLRC4 (IpaF) and NALP3 were separated with electrophoresis on 2% agarose gel (Fig. 1). The qPCR test results, melting curve analyzes and agarose gel images were evaluated together.

The geNorm®, NormFinder® and BestKeeper® programs were used to select the reference gene. YHWAZ was identified as the most suitable and stable reference gene. Expression levels of the genes being examined were determined based on statistical evaluations.

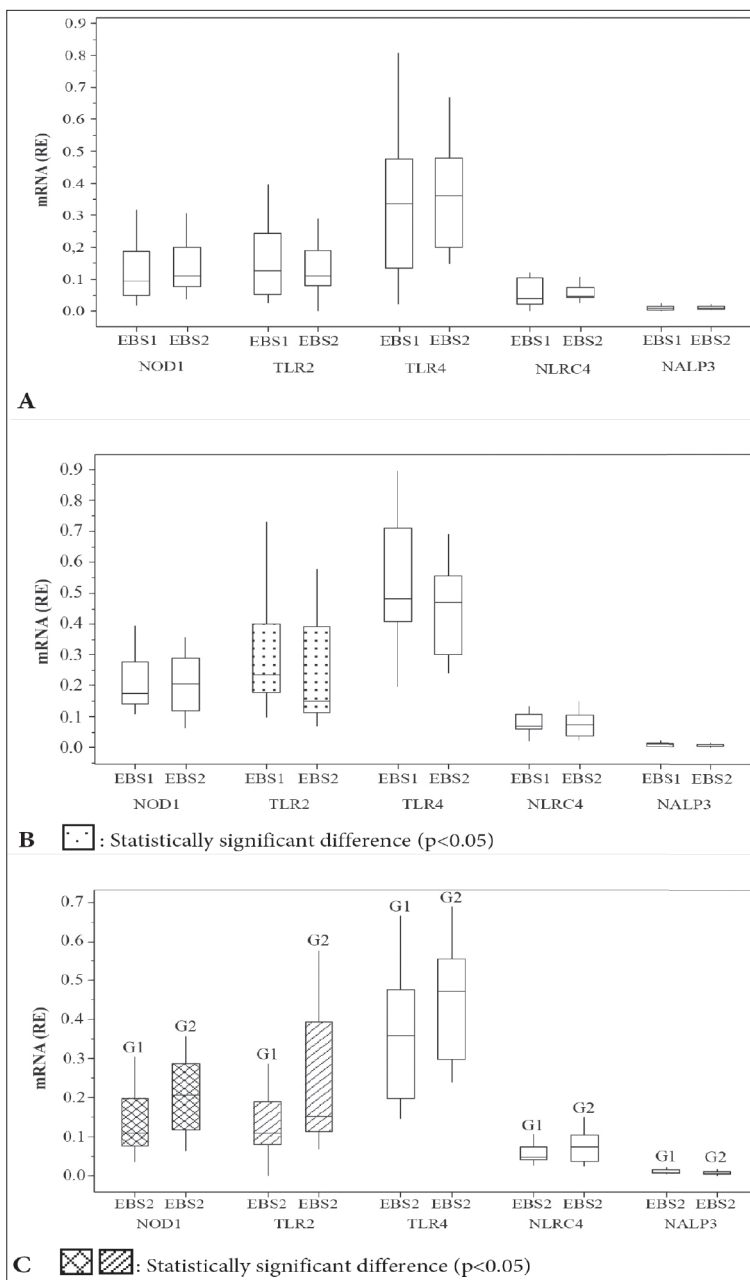
Data show that NLRC4, NALP3 and TLR4 were basically expressed in all samples while NOD2 expression was undetectable. There was a significant statistical difference when NOD1 expressions of EBS2s were compared between G1 and G2 ( $P < 0.05$ ). Similarly, there were differences in TLR2 expression between EBS1 and EBS2 in G2 ( $P < 0.05$ ) and between EBS2s in G1 and G2 ( $P < 0.05$ ) (Fig. 2).

Serum progesterone levels were  $8.52 \pm 3.83$  ng/mL in G1

and  $6.26 \pm 2.20$  ng/mL in G2 in the first samples ( $P > 0.05$ ). In addition, progesterone and estradiol levels were identified in G1 on the days indicated in Fig. 3 and Fig. 4. No statistical difference was observed between the estradiol levels while progesterone levels showed significant differences between the first ( $6.56 \pm 1.67$ ) and second ( $3.20 \pm 0.03$ ) samplings ( $P < 0.05$ ).

## DISCUSSION

RBS is one of the most important problems affecting fertility, causing economic loss in dairy farming [31,32]. SE is one of the major etiologic factors of RBS in high milk-yielding cows, and it causes infertility, delayed onset of postpartum ovarian activity, prolongation of the luteal phase and a decline in the rate of conception [33]. The most commonly used technique to diagnosis SE is endometrial cytology using the cytobrush method [34]. Diagnosis is made by counting the PMNLs in the slides prepared from samples taken from the endometrium. But, the threshold number of cells required to diagnose SE is still a matter of debate. Various studies have been conducted on this subject, and different PMNL cells ratios have been accepted as a threshold based on DIM values [23,35,36]. Salasel et al. [30] defined a threshold of 3% PMNL for samples

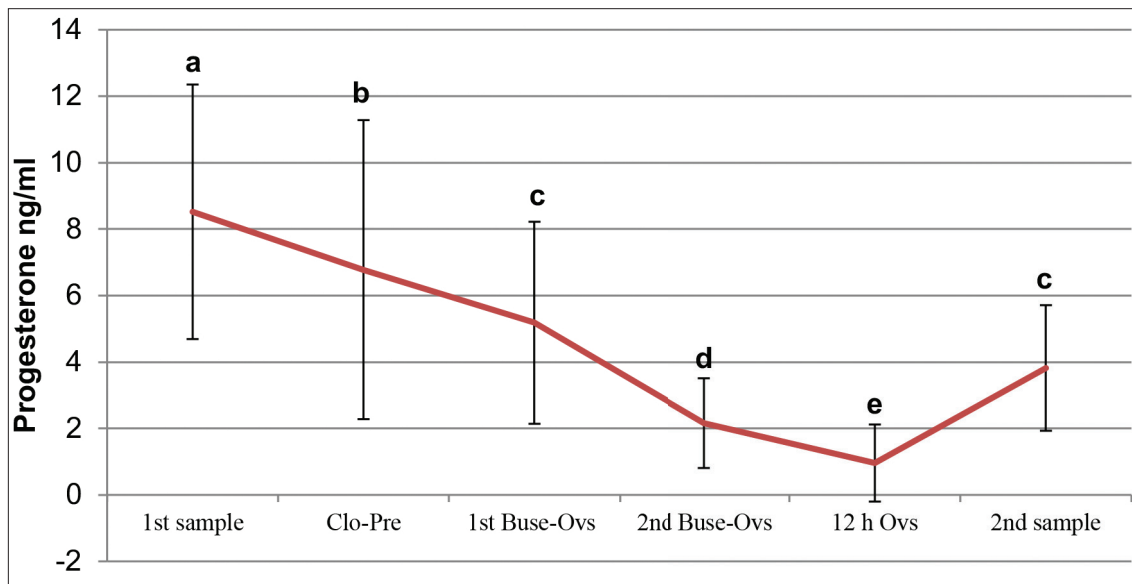


**Fig 2.** Box plot graphics of gene expressions. **A-** Transcription levels of NOD1, TLR2, TLR4, NLRC4 and NALP3 between EBS1 and EBS2 in G1, **B-** Transcription levels of NOD1, TLR2, TLR4, NLRC4 and NALP3 between EBS1 and EBS2 in G2, **C-** Transcription levels of NOD1, TLR2, TLR4, NLRC4 and NALP3 between EBS2 in G1 and EBS2 in G2

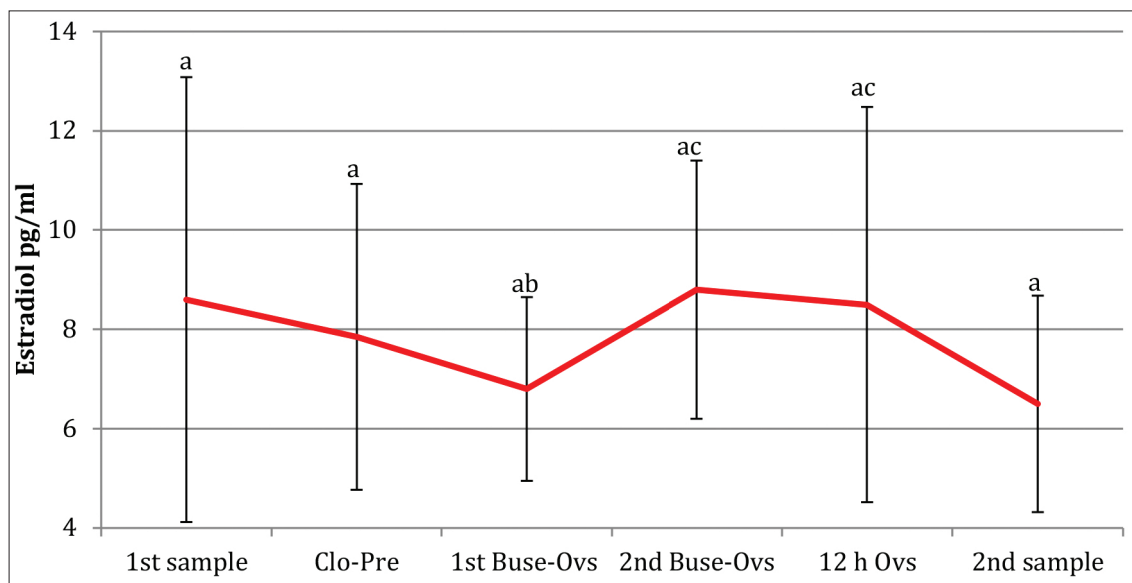
collected from cows at 190 DIM based on the results of the ROC analysis. The 3% PMNL threshold for diagnosis of SE was used in this study since the mean value of DIM was  $205.6 \pm 55.6$ . Many studies have shown that the incidence of SE varies between 12-94% in the etiology of RBS [34,35]. The 95% SE rate calculated in this study is consistent with these studies.

One of the treatments of RBS caused by SE is the administration of presynch-10 and ovsynch. However, the use of PGF2 $\alpha$  or GnRH in the treatment of endometritis on cytological recovery is controversial. For example, it has been reported in various studies that PGF2 $\alpha$  stimulates the release of proinflammatory cytokines from the endometrium, induces local immunity and for these reasons can be used for SE treatment [37]. Nevertheless,

there are also some studies which indicate that PGF2 $\alpha$  administration has no statistically significant effect on the treatment of cytological SE [23,38,39]. Similarly, cows with active CL cytologically diagnosed with SE were administered PGF2 $\alpha$  for treatment, the cytological examination was performed again after treatment and there was no decrease in the prevalence of cytological SE [23]. In another study, GnRH administration was performed to stimulate ovulation in 128 cows at postpartum days  $17 \pm 3$ . No significant differences were found between the control and the SE group based on the cytological examination on postpartum day  $35 \pm 3$  [39]. Histological studies have shown that leukocytes and neutrophils accumulate in the deep layers of the endometrium, such as stratum compactum [40]. Therefore, PMNL cells may not be found in the cytological samples taken from endometrium in



**Fig 3.** Progesterone levels by administration days in G1. a:b:c:d:e,  $P < 0.05$ , **Clo-Pre:** 1<sup>st</sup> cloprostenol injection of presynch-10; 1<sup>st</sup> **Buse-Ovs:** 1<sup>st</sup> buserelin acetate injection of ovsynch; 2<sup>nd</sup> **Buse-Ovs:** 2<sup>nd</sup> buserelin acetate injection of ovsynch; 12 h Ovs: 12 h after ovsynch



**Fig 4.** Estradiol levels by administration days in G1. b:c,  $P < 0.05$ , **Clo-Pre:** 1<sup>st</sup> cloprostenol injection of presynch-10; 1<sup>st</sup> **Buse-Ovs:** 1<sup>st</sup> buserelin acetate injection of ovsynch; 2<sup>nd</sup> **Buse-Ovs:** 2<sup>nd</sup> buserelin acetate injection of ovsynch; 12 h Ovs: 12 h after ovsynch

chronic SEs [41]. The reason that there is no cytological difference in the samples before and after presynch-10 and ovsynch administration in G1, or between the two samples in G2 may be that the cells are located in the deep layers of the endometrium. In addition to cytology, bacteriological examination is also important to evaluation of SE. Many different bacterial strains can be identified in clinical or subclinical endometritis in cows. For example, *Trueperella pyogenes* is the most prevalent microorganism in clinical endometritis [42] and is less common in SE [43]. In addition, it has been shown that the increase in the PMNL count is associated more with *T. pyogenes* than other

pathogens [44]. *T. pyogenes* was not be identified in any microbiological cultures made from the 40 endometrial samples. However, *Coagulase negative staphylococci*, which is considered an opportunistic microorganism of the genital tract, and *E. coli*, *Bacillus* sp. and *Citrobacter* sp. which are classified as uterine pathogens in cows, and fungi, such as *Aspergillus* sp. were identified at various concentrations. The microbiological results indicate that there was no microbiological improvement in the samples whether taken before or after presynch-10 and ovsynch. In this context, it can be assumed that the synchronization protocols have no microbiological healing effect in

cows with RBS. However, the statistical difference found between the first and second samples in G2 may be coincidental. The results of microbiological analyses have revealed that a wide variety of microorganisms are isolated in cows with RBS and SE. This situation suggests that endometrial microbiological findings are coincidental in RBS with SE [3]. Moreover, serum estradiol and progesterone levels were also monitored to determine whether the presynch-10 and ovsynch administrations were effective or not. And, as a result of the statistical analysis; hormone levels in the first serum samples of all cows in G1 and G2 were revealed to be consistent with progesterone and estradiol levels in the late diestrus of cows [45]. This also shows that they were in the same stage of the estrus cycle. In addition, the hormone levels in the other blood samples collected from G1 were compatible with the measured hormone levels with applications similar synchronization protocols in a different study [46]. On the other hand, progesterone levels measured during ovsynch were found to be different from our findings in another study. When the study examined, it was determined that as presynch, PGF2 $\alpha$  was administered 2 days before ovsynch and the CLs were lysed [47]. Therefore, the measured progesterone levels were less than our findings. Because the last PGF2 $\alpha$  injection was administered to 10 days before starting ovsynch. Namely, it was an active CL when ovsynch started. These results suggest that there was no abnormality in the ovarian functions of these cows and, administered synchronization protocols were effective.

After all these evaluations, the effects of synchronization methods administered on expression levels of some TLR and NLR genes were assessed. TLR2 and 4 are members of the TLR family that contribute to the innate immune response by stimulating the release of proinflammatory cytokines, and it has been determined that they were expressed in the endometrial cells of cows. In addition, the expression profiles of these receptors reportedly do not change according to the region where the samples are taken from in the uterus [27]. Recent studies revealed that TLR4 expression was higher in healthy and fertile cows than infertile ones with chronic endometritis at approximately 200 days postpartum [48]. Lower TLR4 expression in chronic endometritis has been associated with repeated or prolonged antigen stimulation [49]. There was no difference in TLR4 gene expression levels between or within groups, which is probably due to the fact that subclinical infections were chronic at that time. When the NLR expression profile was examined; it was concluded that the level of NLRC4 expressions did not change in all biopsy samples because the *Salmonella* could not be isolated from any endometrial swab. The activation of NLRC4 occurs when Salmonella flagellin bind to NLRC4 [20]. The NOD2 and NALP3 are other members of NLRs and they are intracellular receptors. Muramyl dipeptide (MDP), which is a minimal structure of the bacteria's peptidoglycan cell wall, is a ligand that

activates NOD2 and NALP3. MDP must be in cytosol to activate NOD2 and NALP3 [50]. NALP3 expression levels were low, and there were no differences between the samples. Similarly, NOD2 expression remained at undetectable levels. The low and undetectable expression levels of these genes may be due to the absence of activators in the cytosol. Likewise, this may be due to these receptors not being affected by prolonged inflammatory stimulus or synchronization protocols.

Tissue stress or malfunction could induce the innate immune response, which is referred to as para-inflammation. In this context, the reason for higher TLR2 and NOD1 expressions in EBS1 than EBS2 in G2, may be due to immune system stimulators, such as poor environmental conditions or malnutrition of the endometrial cells due to their malfunction and prolonged inflammation [51]. The increases seen in both TLR2 and NOD1 in the EBS2s of G1 supported the hypothesis that synchronization protocols may have immunomodulatory effects. These findings may be due to decreased progesterone level in EBS2 than EBS1 or administered PGF2 $\alpha$  injections during presynch-10 and ovsynch. Because it is known that progesterone suppresses local immunity of uterus and, the synthesis of prostaglandins. PGF2 $\alpha$  administered during synchronization caused luteolysis and, decreased progesterone concentration. Besides, PGF2 $\alpha$  has also immunomodulatory effects independent of progesterone concentration [52]. However, these administrations did not affect the expression profiles of other receptor genes. These data showed that the mechanisms linking the steroids to immunity are yet to be fully elucidated and many studies need to be done in reproductive immunity.

Our data show that except for NOD2 all of the receptor genes examined were expressed in the endometrial cells of cows with SE. All of the other gene expressions were identified in all groups. These gene expressions could indicate that the mucosal innate immune system of endometrium plays various roles in RBS caused by SE. Furthermore, this study revealed that expressions of TLR-2 and NOD1 genes could be affected by ovulation synchronization methods related to GnRH and PGF2 $\alpha$ .

Hence, a potential reason for the low success rate of implantation is subclinical endometritis in cows that may damage tissues. This damage could induce an inflammatory process by releasing some cytokines that are also stimulated by the activation of TLR and NLRs, thus initiating an inflammatory process and leading to embryo implantation failure, which is one of the causes of RBS. In this context, it was concluded that presynch-10 and ovsynch administration in cows positively affected the innate immune response and may be effective in the treatment of subclinical endometritis. Finally, the future potential scope of our research is to investigate the effects of TLR2 and/or NOD1 on the etiology of RBS.



## REFERENCES

1. **Gustafsson H, Emanuelson U:** Characterisation of the repeat breeding syndrome in Swedish dairy cattle. *Acta Vet Scand*, 43 (2): 115-125, 2002. DOI: 10.1186/1751-0147-43-115
2. **Zemjanis R:** Repeat breeding or conception failure in cattle. In: Morrow DA (Ed): *Current Therapy in Theriogenology*. Philadelphia: W.B. Saunders; 1980.
3. **Pothmann H, Prunner I, Waganer K, Jaureguiberry M, de la Sota RL, Erber R, Aurich C, Ehling-Schulz M, Drillich M:** The prevalence of subclinical endometritis and intrauterine infections in repeat breeder cows. *Theriogenology*, 83, 1249-1253, 2015. DOI: 10.1016/j.theriogenology.2015.01.013
4. **Heuwieser W, Oltenacu PA, Lednor AJ, Foote RH:** Evaluation of different protocols for prostaglandin synchronization to improve reproductive performance in dairy herds with low estrus detection efficiency. *J Dairy Sci*, 80, 2766-2774, 1997. DOI: 10.3168/jds.S0022-0302(97)76239-8
5. **Duchens M, Gustafsson H, Rodriguez-Martinez H, Forsberg M, Edqvist LE:** Effect of induced suprabasal progesterone concentrations on follicular dynamics in heifers. *Reprod Domest Anim*, 29, 315-325, 1994. DOI: 10.1016/0093-691X(94)90864-8
6. **Wodaje HB, Mekuria TA:** Risk factors of repeat breeding in dairy cattle. *Adv Biol Res*, 10 (4): 213-221, 2016.
7. **Ferreira RM, Ayres H, Chiaratti MR, Ferraz ML, Araújo AB, Rodrigues CA, Watanabe YF, Vireque AA, Joaquim DC, Smith LC, Meirelles FV, Baruselli PS:** The low fertility of repeat-breeder cows during summer heat stress is related to a low oocyte competence to develop into blastocysts. *J Dairy Sci*, 94 (5): 2383-2392, 2011. DOI: 10.3168/jds.2010-3904
8. **O'Callaghan D, Boland MP:** Nutritional effects on ovulation, embryo development and the establishment of pregnancy in ruminants. *Anim Sci*, 68, 299-314, 1999. DOI: 10.1017/S1357729800050311
9. **Turner ML, Cronin JG, Healey GD, Sheldon IM:** Epithelial and stromal cells of bovine endometrium have roles in innate immunity and initiate inflammatory responses to bacterial lipopeptides *in vitro* via toll-like receptors TLR2, TLR1, and TLR6. *Endocrinology*, 155 (4): 1453-1465, 2014. DOI: 10.1210/en.2013-1822
10. **Sheldon IM, Bromfield JJ:** Innate immunity in the human endometrium and ovary. *Am J Reprod Immunol*, 66, 63-71, 2011. DOI: 10.1111/j.1600-0897.2011.01034.x
11. **Turner ML, Healey GD, Sheldon IM:** Immunity and inflammation in the uterus. *Reprod Domest Anim*, 47, 402-409, 2012. DOI: 10.1111/j.1439-0531.2012.02104.x
12. **Akira S, Uematsu S, Takeuchi O:** Pathogen recognition and innate immunity. *Cell*, 124, 783-801, 2006. DOI: 10.1016/j.cell.2006.02.015
13. **Abrahams VM:** The role of the Nod-like receptor family in trophoblast innate immune responses. *J Reprod Immunol*, 88, 112-117, 2011. DOI: 10.1016/j.jri.2010.12.003
14. **Zou Y, Lei W, He Z, Li Z:** The role of NOD1 and NOD2 in host defense against chlamydial infection. *FEMS Microbiol Lett*, 363 (17): 1-6, 2016. DOI: 10.1093/femsle/fnw170
15. **Girardin SE, Tournebise R, Mavris M, Page AL, Li X, Stark GR, Bertin J, DiStefano PS, Yaniv M, Sansonetti PJ, Philpott DJ:** CARD4/Nod1 mediates NF-kappaB and JNK activation by invasive *Shigella flexneri*. *EMBO Rep*, 2, 736-742, 2001. DOI: 10.1093/embo-reports/kve155
16. **Cañas MA, Fábrega MJ, Giménez R, Badia J, Baldomà L:** Outer membrane vesicles from probiotic and commensal *Escherichia coli* activate NOD1-mediated immune responses in intestinal epithelial cells. *Front Microbiol*, 9, 498, 2018. DOI: 10.3389/fmicb.2018.00498
17. **Zilbauer M, Dorrell N, Elmi A, Lindley KJ, Schuller S, Jones HE, Klein NJ, Nunez G, Wren BW, Bajaj-Elliott M:** A major role for intestinal epithelial nucleotide oligomerization domain 1 (NOD1) in eliciting host bactericidal immune responses to *Campylobacter jejuni*. *Cell Microbiol*, 9, 2404-2416, 2007. DOI: 10.1111/j.1462-5822.2007.00969.x
18. **Girardin SE, Boneca IG, Viala J, Chamaillard M, Labigne A, Thomas G, Philpott DJ, Sansonetti PJ:** Nod2 is a general sensor of peptidoglycan through muramyl dipeptide (mdp) detection. *J Biol Chem*, 278, 8869-8872, 2003. DOI: 10.1074/jbc.C200651200
19. **Jin C, Flavell RA:** Molecular mechanism of NLRP3 inflammasome activation. *J Clin Immunol*, 30 (5): 628-631, 2010. DOI: 10.1007/s10875-010-9440-3
20. **Matusiak M, Opendbosch NV, Walle LV, Sirard JC, Kanneganti TD, Lamkanfi M:** Flagellin-induced NLR4 phosphorylation primes the inflammasome for activation by NAIP5. *Proc Natl Acad Sci USA*, 112 (5): 1541-1546, 2015. DOI: 10.1073/pnas.1417945112
21. **Sheldon IM, Noakes DE, Rycroft AN, Pfeiffer DU, Dobson H:** Influence of uterine bacterial contamination after parturition on ovarian dominant follicle selection and follicle growth and function in cattle. *Reproduction*, 123, 837-845, 2002. DOI: 10.1530/rep.0.1230837
22. **Nowicki A, Baranski W, Baryczka A, Janowski T:** OvSynch protocol and its modifications in the reproduction management of dairy cattle herds - An update. *J Vet Res*, 61 (3): 329-336, 2017. DOI: 10.1515/jvetres-2017-0043
23. **Galvão KN, Frajblat M, Brittin SB, Butler WR, Guard CL, Gilbert RO:** Effect of prostaglandin F<sub>2α</sub> on subclinical endometritis and fertility in dairy cows. *J Dairy Sci*, 92, 4906-4913, 2009. DOI: 10.3168/jds.2008-1984
24. **Keith BR, Leisle KE, Johnson WH, Walton JS:** Effect of pre-synchronization using PGF<sub>2α</sub> and a milk ejection test on pregnancy rate after the timed artificial insemination protocol, ovsynch. *Theriogenology*, 63 (3): 722-738, 2005. DOI: 10.1016/j.theriogenology.2004.03.023
25. **Wildman EE, Jones GM, Wagner PE, Bowman RL:** A dairy cow body condition scoring system and its relationship to selected production characteristics. *J Dairy Sci*, 65, 495-501, 1982. DOI: 10.3168/jds.S0022-0302(82)82223-6
26. **Stevenson JS:** Alternative programs to presynchronize estrous cycles in dairy cattle before a timed artificial insemination program. *J Dairy Sci*, 94, 205-217, 2011. DOI: 10.3168/jds.2010-3375
27. **Davies D, Meade KG, Hreth S, Eckersall PD, Gonzalez D, White JO, Conlan RS, Q'Farrelly C, Sheldon IM:** Toll-like receptor and antimicrobial peptide expression in the bovine endometrium. *Reprod Biol Endocrinol*, 6:53, 2008. DOI: 10.1186/1477-7827-6-53
28. **Donofrio G, Capocéfalo A, Franceschi V, Price S, Cavirani S, Sheldon IM:** The chemokine IL8 is up-regulated in bovine endometrial stromal cells by the BoHV-4 IE2 gene product, ORF50/Rta: A step ahead toward a mechanism for BoHV-4 induced endometritis. *Biol Reprod*, 83 (6): 919-928, 2010. DOI: 10.1095/biolreprod.110.086074
29. **Livak KJ, Schmittgen TD:** Analysis of relative gene expression data using real-time quantitative PCR and the 2<sup>-ΔΔT</sup> method. *Methods*, 25, 402-408, 2001. DOI: 10.1006/meth.2001.1262
30. **Salasel B, Mokhtari A, Taktaz T:** Prevalence, risk factors for and impact of subclinical endometritis in repeat breeder dairy cows. *Theriogenology*, 74, 1271-1278, 2010. DOI: 10.1016/j.theriogenology.2010.05.033
31. **Yusuf M, Nakao T, Ranasinghe RBK, Gautam G, Long ST, Yoshida C, Koike K, Hayashi A:** Reproductive performance of repeat breeders in dairy herds. *Theriogenology*, 73 (9): 1220-1229, 2010. DOI: 10.1016/j.theriogenology.2010.01.016
32. **Bartlett PC, Kirk JH, Mather EC:** Repeated insemination in Michigan Holstein-Friesian cattle: Incidence, descriptive epidemiology and estimated economic impact. *Theriogenology*, 26, 309-322, 1986. DOI: 10.1016/0093-691X(86)90150-0
33. **Adnane M, Kaidi R, Hanzen C, England GCW:** Risk factors of clinical and subclinical endometritis in cattle: A review. *Turk J Vet Anim Sci*, 41, 1-11, 2017. DOI: 10.3906/vet-1603-63
34. **Waganer K, Gabler C, Drillich M:** A review of the ongoing discussion about definition, diagnosis and pathomechanism of subclinical endometritis in dairy cows. *Theriogenology*, 94, 21-30, 2017. DOI: 10.1016/j.theriogenology.2017.02.005
35. **Barlund CS, Carruthers TD, Waaldner CL, Palmer CW:** A comparison of diagnostic techniques for postpartum endometritis in dairy cattle. *Theriogenology*, 69, 714-723, 2008. DOI: 10.1016/j.theriogenology.2007.12.005
36. **Kaufmann TB, Drillich M, Tenhagen B, Forderung D, Heuwieser W:** Prevalence of bovine subclinical endometritis 4 h after insemination and

its effects on first service conception rate. *Theriogenology*, 71 (2): 385-391, 2009. DOI: 10.1016/j.theriogenology.2008.08.005

**37. Hendricks KEM, Bartolome JA, Melendez P, Risco C, Archbald LF:** Effect of repeated administration of PGF<sub>2α</sub> in the early post partum period on the prevalence of clinical endometritis and probability of pregnancy at first insemination in lactating dairy cows. *Theriogenology*, 65, 1454-1464, 2006. DOI: 10.1016/j.theriogenology.2005.08.018

**38. Lima FS, Bisinotto RS, Ribeiro ES, Greco LF, Ayres H, Favoreto MG, Carvalho MR, Galvao KN, Santos JEP:** Effects of 1 or 2 treatments with prostaglandin F<sub>2α</sub> on subclinical endometritis and fertility in lactating dairy cows inseminated by timed artificial insemination. *J Dairy Sci*, 96 (10): 6480-6488, 2013. DOI: 10.3168/jds.2013-6850

**39. Bittar JH, Pinedo P, Hencken KE, Barbosa CC, Gobikrushanth M, Croyle S, Risco CA, Vieira-Neto A, Santos JE, Galvao KN:** Effect of induction of ovulation, early in lactation, on uterine health and fertility in dairy cows. *J Dairy Sci*, 96 (E-Suppl):118, 2013.

**40. Heppelmann M, Weinert M, Ulbrich SE, Brömming A, Piechotta M, Merbach S, Schoon H-A, Hoedemaker M, Bollwein H:** The effect of puerperal uterine disease on histopathologic findings and mRNA expression of proinflammatory cytokines of the endometrium in dairy cows. *Theriogenology*, 85 (7): 1348-1356, 2016.

**41. Duvel A, Maaß J, Heppelmann M, Hussen J, Koy M, Piechotta M, Sandra O, Smith DGE, Sheldon IM, Diezy-Labaye I, Zieger P, Schuberth HJ:** Peripheral blood leukocytes of cows with subclinical endometritis show an altered cellular composition and gene expression. *Theriogenology*, 81, 906-917, 2014. DOI: 10.1016/j.theriogenology.2014.01.007

**42. Bicalho MLS, Lima FS, Machado VS, Meira EB, Ganda EK, Foditsch C, Bicalho RC, Gilbert RO:** Associations among *Trueperella pyogenes*, endometritis diagnosis, and pregnancy outcomes in dairy cows. *Theriogenology*, 85 (2): 267-274, 2016. DOI: 10.1016/j.theriogenology.2015.09.043

**43. Prunner I, Pothmann H, Wagener K, Giuliodori M, Huber J, Ehling-Schulz M, Drillich M:** Dynamics of bacteriologic and cytologic changes in the uterus of postpartum dairy cows. *Theriogenology*, 82, 1316-1322, 2014. DOI: 10.1016/j.theriogenology.2014.08.018

**44. Westermann S, Drillich M, Kaufmann TB, Madoz LV, Heuwieser**

**WA:** A clinical approach to determine false positive findings of clinical endometritis by vaginoscopy by the use of uterine bacteriology and cytology in dairy cows. *Theriogenology*, 74, 1248-1255, 2010. DOI: 10.1016/j.theriogenology.2010.05.028

**45. Díaz T, Manzo M, Trocóniz, Benacchio N, Verde O:** Plasma progesterone levels during the estrous cycle of Holstein and Brahman cows, Carora type and cross-bred heifers. *Theriogenology*, 26 (4): 419-432, 1986. DOI: 10.1016/0093-691X(86)90034-8

**46. Vokovic D, Bozic A, Relic R, Stancic B, Gvozdic D, Kucevic D:** Progesterone concentration in milk and blood serum and reproductive efficiency of cows after Ovsynh treatment. *Turk J Vet Anim Sci*, 40, 75-80, 2016. DOI: 10.3906/vet-1505-17

**47. Špoljarić B, Vince S, Grizelj J, Štibrić G, Samardžija M, Unić A, Romić Ž, Dobranić T, Gereš D:** Progesterone concentration and conception rates after three different synchronization protocols in dairy cows. *Vet Arhiv*, 87 (4): 397-408, 2017. DOI: 10.24099/vet.arhiv.160413

**48. Herath S, Lilly ST, Santos NR, Gilbert RO, Goetze L, Bryant CE, White JO, Cronin J, Sheldon IM:** Expression of genes associated with immunity in the endometrium of cattle with disparate postpartum uterine disease and fertility. *Reprod Biol Endocrinol*, 7:55, 2009. DOI: 10.1186/1477-7827-7-55

**49. Yunhe F, Bo L, Xiaosheng F, Zhicheng L, Dejie L, Fengyang L, Depeng L, Yongguo C, Shuang F, Xichen Z, Naisheng Z, Zhengtao Y:** Lipopolysaccharide increases toll-like receptor-4 and downstream toll-like receptor signaling molecules expression in bovine endometrial epithelial cells. *Vet Immunol Immunopathol*, 151, 20-27, 2013. DOI: 10.1016/j.vetimm.2012.09.039

**50. Sahoo BR, Maharana J, Bhoi GK, Lenka SK, Patra MC, Dikhit MR, Dubey PK, Pradhan SK, Behera BK:** A Conformational analysis of mouse Nalp3 domain structures by molecular dynamics simulation, and binding sites analysis. *Mol BioSyst*, 10 (5): 1104-1116, 2014. DOI: 10.1039/c3mb70600a

**51. Medzhitov R:** Origin and physiological roles of inflammation. *Nature*, 454, 428-435, 2008. DOI: 10.1038/nature07201

**52. Lewis GS:** Steroidal regulation of uterine immune defenses. *Anim Reprod Sci*, 82-83, 281-294, 2004. DOI: 10.1016/j.anireprosci.2004.04.026