

1 **Role of staphylococci in mastitis in sheep**

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8 **SUPPLEMENTARY FILE**

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10 **Supplementary Table S1.**

11 List of body sites of healthy sheep, from which staphylococci have been isolated.

Site	References
Skin	Kayalvizhi et al. (2008), Gbolagunte et al. (2010)
Nasal cavity	Queen et al. (1994), Vautor et al. (2009), Tesfaye et al. (2013), Rahimi et al. (2015)
Respiratory tract	Barbour et al. (1997), Glendinning et al. (2017)
Vagina	Manes et al. (2010), Silva et al. (2011)
Teat duct	Fragkou et al. (2007), Vasileiou et al. (2018)
Preputial cavity	Gouletsou et al. (2006)

12 List of disorders of sheep (other than mastitis), in which staphylococci have been implicated.

Disorder	References
Septicaemia	Elidrissi et al. (1992), Jonkam et al. (2007)
Dermatitis / Impetigo	Scott et al. (1980), Fraser (1982), Synge et al. (1985), Hajtos et al. (2000), Koutinas et al. (2007)
Wound infections	Tiwari et al. (2016)
Interdigital dermatitis	Azizi et al. (2011)
Furunculosis	Yeruham et al. (2002)
Necrotic dermatitis	Jubb et al. (1985), Bath et al. (2011)
Abscess disease	de la Fuente (1985, 1997), Moller (2000), Alharbi et al. (2011)
Lymphadenitis	Ribeiro et al. (2011), Chikhaoui et al. (2013)
Granulomas ('botryomycosis')	Jubb et al. (1985).
Vaginal infections	de Paula Vasconcelos et al. (2016), Manes et al. (2018)
Uterine infections	Regassa and Noakes (1999)
Abortion	Lehman and Elze (1997), Edwards et al. (2008)
Orchitis	Gouletsou (2005)
Epididymitis	Jubb et al. (1985), Gouletsou and Fthenakis (2015)
Scrotal pyocele	Lacasta et al. (2009)
Tick pyaemia	Gillespie and Timoney (1981), Anderson (1983), Jubb et al. (1985), Webster and Mitchell (1986)
Experimental rhinosinusitis	Ha et al. (2007)
Respiratory infection	Tibbo et al. (2001), Enkhbaatar et al. (2008)
Lung abscesses	Azizi et al. (2013)
Experimental osteomyelitis	Kaarsemaker et al. (1997)
Neonatal polyarthritis	Jubb et al. (1985)
Keratoconjunctivitis	Eqwu and Faull (1993)

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13 *Supplementary References*

- 14 Alharbi KB 2011 Bacterial isolates from visceral abscesses of sheep at Qassim, Saudi Arabia. *African*
15 *Journal of Microbiology Research* **31** 5622-5627.
- 16 Anderson JC 1983 Veterinary aspects of staphylococci. In: Easmon CSF, Adlam C (eds) *Staphylococci*
17 *and Staphylococcal Infections*, vol. 1. Academic Press, London, pp. 193-241.
- 18 Azizi S, Tehrani, A.A., Dalir-Naghadeh B., Hemmati M 2011. The effects of farming system and season
19 on the prevalence of lameness in sheep in northwest Iran. *New Zealand Veterinary Journal* **59** 311-
20 319.
- 21 Azizi S, Korani FS, Oryan A 2013 Pneumonia in slaughtered sheep in south-western Iran: pathological
22 characteristics and aerobic bacterial aetiology. *Veterinaria Italiana* **49** 109-118.
- 23 Barbour EK, Nabbut NH, Hamadeh SK, Al Nakhli HM 1997 Bacterial identity and characteristics in
24 healthy and unhealthy respiratory tracts of sheep and calves. *Veterinary Research Communications*
25 **21** 421-430.
- 26 Bath GF, van Rensburg AJ, Pettey KP, van Vuuren M, Kidanemariam A 2011 A literature review and
27 investigation of staphylococcal necrotic dermatitis in sheep. *Journal of the South African Veterinary*
28 *Association* **82** 227-231.
- 29 Chikhaoui M, Khoudja FB 2013 Clinicopathological investigation on caseous lymphadenitis in local
30 breed sheep in Algeria. *Tropical Animal Health and Production* **45** 1641-1643.
- 31 de la Fuente R, Cid D, Sanz R, Ruiz-Santa-Quiteria JA 1997 An outbreak of abscess disease associated
32 with shearing. *Small Ruminant Research* **26** 283-286.
- 33 de la Fuente R, Suarez JG, Schleifer KH 1985 *Staphylococcus aureus* subsp. *anaerobius* subsp. nov.,
34 the causal agent of abscess disease of sheep. *International Journal of Systematic Bacteriology* **35**
35 99-102.
- 36 de Paula Vasconcelos CO, Brandao FZ, Martins G, Penna B, Goncalves de Souza-Fabjan JM, Lilenbaum
37 W 2016 Qualitative and quantitative analysis of bacteria from vaginitis associated with intravaginal
38 implants in ewes following estrus synchronization. *Ciencia Rural* **46** 632-636.
- 39 Edwards JF, Lassala AL, Spencer TE 2008 *Staphylococcus*-associated abortions in ewes with long-term
40 central venous catheterization. *Veterinary Pathology* **45** 881-888.
- 41 Elidrissi AH, Ward GE, Johnson DW, Benkirane A, Fassifehri MM 1992 bacteriological investigation of
42 sudden sheep mortality in Morocco. *Preventive Veterinary Medicine* **12** 35-46.
- 43 Enkhbaatar P, Joncam C, Traber L, Nakano Y, Wang J, Lange M, Connelly R, Kulp G, Saunders F, Huda
44 R, Cox R, Schmalstieg F, Herndon D, Traber D 2008 Novel ovine model of methicillin-resistant
45 staphylococcus aureus-induced pneumonia and sepsis. *Shock* **29** 642-649.
- 46 Egwu GO, Faull WB 1993 Clinico-serological studies of ovine infectious keratoconjunctivitis in adult
47 ewes experimentally infected with mycoplasma-conjunctivae and or *Staphylococcus aureus*. *Small*
48 *Ruminant Research* **12** 171-183.
- 49 Fragkou IA, Mavrogianni VS, Cripps PJ, Gougoulis DA, Fthenakis GC 2007 The bacterial flora in the
50 teat duct of ewes can protect against and can cause mastitis. *Veterinary Research* **38** 525-545.
- 51 Fraser J, Scott FMM, Angus KW, Martin WB 1982 Experimental reinfection of the skin of sheep with
52 *Staphylococcus aureus*. *Veterinary Record* **111** 485-48
- 53 Gbolagunte GD, Hambolu JO 2010 Types and frequency of isolation of bacteria affecting leather surfaces
54 from small Nigerian ruminant dermatoses. *Journal of the Society of Leather Technologists and*
55 *Chemists* **94** 102-105.
- 56 Gillespie JH, Timoney JF 1981 *Hagan and Bruner's Infectious Diseases of Domestic Animals*, 7th edn.
57 Cornell University Press,
- 58 Glendinning L, Collie D, Wright S, Rutherford KMD, McLachlan G 2017 Comparing microbiotas in the
59 upper aerodigestive and lower respiratory tracts of lambs. *Microbiome* **5** 145.
- 60 Gouletsou (2005). *The Role of Arcanobacterium pyogenes in Ram Orchitis and Reproductive Performance*.
61 PhD thesis, University of Thessaly.
- 62 Gouletsou PG, Fthenakis GC 2015 Microbial diseases of the genital system of rams or bucks. *Veterinary*
63 *Microbiology* **181** 130-135.
- 64 Gouletsou PG, Fthenakis GC, Tzora A, Cripps PJ, Saratsis P 2006 Isolation of *Arcanobacterium pyogenes*
65 from the scrotal skin and the prepuce of healthy rams or from rams with testicular abnormalities.
66 *Small Ruminant Research* **63** 177-182.
- 67 Ha KR, Psaltis AJ, Tan L, Wormald PJ 2007 A sheep model for the study of biofilms in rhinosinusitis.
68 *American Journal of Rhinology* **21** 339-345.

- 69 Hajtos J, Glavits R, Kovacs T, Palfi V, Makrai L 2000 Enzootic (staphylococcal) dermatitis in a Hungarian
70 sheep flock. *Magyar Allatorvosok Lapja* **122** 649-654.
- 71 Jonkam C, Enkhbaatar P, Hamahata A, Lange M, Traber L, Herndon D, Traber D 2007 Nitric oxide and
72 methicilin resistant *Staphylococcus aureus*-induced septic shock in sheep. *Shock* **27** 65-65.
- 73 Jubb KVF, Kennedy PC, Palmer N 1985 Pathology of Domestic Animals, 3rd edn. Academic Press,
74 London.
- 75 Kaarsemaker S, Walenkamp GHM, van der Bogaard AEJ 1997 New model for chronic osteomyelitis with
76 *Staphylococcus aureus* in sheep. *Clinical Orthopaedics and Related Research* **339** 246-252.
- 77 Kayalvizhi N, Anthony T, Gunasekaran P 2008 Characterization of the predominant bacteria associated
78 with sheep and goat skin. *Journal of the American Leather Chemists Association* **103** 182-187.
- 79 Koutinas AF, Saridomichelakis MN, Argyroudis S, Koutinas CK, Karatzanos P, Giadinis N 2007 Clinical,
80 histopathological and therapeutic considerations in a flock of sheep with facial staphylococcal-
81 associated dermatitis. *Veterinary Dermatology* **18** 211-216.
- 82 Lacasta D, Ferrer LM, Ramos JJ, Ortin A, Vela AI, Latre MV 2009 Unilateral scrotal pyocele in ram
83 caused by *Staphylococcus capitis*. *Australian Veterinary Journal*. **87** 484-486.
- 84 Lehman C, Elze K 1997 Results of microbiological investigations of abortions in horses, cattle, pigs and
85 sheep in Germany. *Tierarztliche Umschau* **52** 495-498.
- 86 Manes J, Fiorentino MA, Kaiser G, Hozbor F, Alberio R, Sanchez E, Paolicchi F 2010 Changes in the
87 aerobic vaginal flora after treatment with different intravaginal devices in ewes. *Small Ruminant*
88 *Research* **94** 201-204.
- 89 Manes J, Fiorentino MA, San Martino S, Ungerfeld R 2018 Changes in the vaginal microbiota in ewes
90 after insertion of intravaginal sponges at different stages of the oestrous cycle. *Livestock Science*
91 **208** 55-59.
- 92 Moller K, Agerholm JS, Ahrens P, Jensen NE, Nielsen TK 2000 Abscess disease, caseous lymphadenitis,
93 and pulmonary adenomatosis in imported sheep. *Journal of Veterinary Medicine Series B* **47** 55-62.
- 94 Queen C, Ward ACS, Hunter DL 1994 Bacteria isolated from nasal and tonsillar samples of clinically
95 healthy rocky-mountain bighorn and domestic sheep. *Journal of Wildlife Diseases* **30** 1-7.
- 96 Rahimi H, Saei HD, Ahmadi M 2015 Nasal carriage of *Staphylococcus aureus*: frequency and antibiotic
97 resistance in healthy ruminants. *Jundishapur Journal of Microbiology* **8** e22413.
- 98 Regassa F, Noakes DE 1999 Acute phase protein response of ewes and the release of PGFM in relation
99 to uterine involution and the presence of intrauterine bacteria. *Veterinary Record* **144** 502-506.
- 100 Ribeiro MG, Belotta AF, Fernandes MC, Guena R, de Nardi G, Lara GHB, Giuffrida R, Zamprogna TD
101 2011 Fine needle aspiration in diagnosis of lymphadenitis in sheep. *Pesquisa Veterinaria Brasileira*
102 **31** 839-843.
- 103 Scott FMM, Fraser J, Martin WB 1980 Staphylococcal dermatitis of sheep. *Veterinary Record* **107** 572-
104 574.
- 105 Silva VF, Damasceno TEF, Souza NJD, Franco I, Costa MM 2011 Cervical-vaginal microbiota of
106 crossbred sheep in Petrolina/PE, Brazil, and its susceptibility to antibiotics. *Pesquisa Veterinaria*
107 *Brasileira* **31** 586-590.
- 108 Syngé BA, Scott FMM, MacDougall DC 1985 Dermatitis of the legs of sheep associated with
109 *Staphylococcus aureus*. *Veterinary Record* **116** 459-460.
- 110 Tesfaye B, Tessema TS, Tefera G 2013 Diversity of bacterial species in the nasal cavity of sheep in the
111 highlands of Ethiopia and first report of *Histophilus somni* in the country. *Tropical Animal Health*
112 *and Production* **45** 1243-1249.
- 113 Tibbo M, Woldemeskel M, Gopilo A 2001 An outbreak of respiratory disease complex in sheep in central
114 Ethiopia. *Tropical Animal Health and Production* **33** 355-365.
- 115 Tiwari R, Yadav SK, Singh S 2016 Methicillin resistant *Staphylococcus aureus* isolated from wounds of
116 livestock and companion animals of Uttar Pradesh India: a preliminary study. *International Journal*
117 *of Pharmacology* **12** 821-829.
- 118 Vasileiou NGC, Cripps PJ, Ioannidi KS, Chatzopoulos DC, Gougoulis DA, Sarrou S, Orfanou DC, Politis
119 A, Calvo Gonzalez-Valerio T, Argyros S, Mavrogianni VS, Petinaki E, Fthenakis GC 2018 Extensive
120 countrywide field investigation of subclinical mastitis in sheep in Greece. *Journal of Dairy Science*
121 **101** 7297-7310.
- 122 Vautor E, Magnone V, Rios G, Le Brigand K, Bergonier D, Lina G, Meugnier H, Barbry P, Thiery R, Pepin
123 M 2009 Genetic differences among *Staphylococcus aureus* isolates from dairy ruminant species: a
124 single-dye DNA microarray approach. *Veterinary Microbiology* **133** 105-114.

125 Webster KA, Mitchell GBB 1986 Experimental production of tick pyaemia. *Veterinary Record* **119** 186-
126 187.
127 Yeruham I, Hadani A, Elad D, Perl S, Samir Y 2002 Staphylococcal furunculosis in sheep severely
128 infested by psoroptic mange. *Australian Veterinary Journal* **80** 349-349.
129
130
131