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ULTRASONOGRAPHY OF THE MAMMARY GLAND IN RUMINANTS: A REVIEW

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Summary

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Fast and accurate diagnostics and prognosis are very important with regard to mammary gland illnesses in ruminants due to the negative economic impact of the loss of milk productivity. This necessitates the usage of modern, accurate and quick methods for mammary gland examination, such as ultrasonography. The main advantage of ultrasonography examination is the method's non-invasiveness and the possibility for visualisation of the structures in all parts of the mammary gland (teat and parenchyma). Possible indications for application could be disruptions in milk secretion, diagnostics of pathological changes (stenosis and obstructions, inflammations, abscesses, haematomas, foreign bodies, etc.), measurements of teat canal length and diameter, teat cistern diameter, and teat wall thickness. The ultrasound examination of the mammary gland parenchyma in ruminants is mainly performed through the direct contact technique (transcutaneous echography) with low-frequency linear, sector or convex transducer (3.5–5 MHz) and horizontal scanning. Examination of the teat is most commonly conducted through the water bath technique and vertical scanning. A high-quality image can be produced if a high-frequency probe is used. The present review aimed to summarise the data related to ultrasound examination of the mammary gland in ruminant animals, with regard to its advantages, clinical applications, indications for performance, scanning techniques, and the interpretation of the echographic image of the udder's different parts.

Key words: ultrasonography, mammary gland, ruminants

INTRODUCTION

Maintaining a healthy mammary gland in ruminants plays a significant role in modern animal husbandry aimed at achieving high-quality milk production (Wendt *et al*., 1994; Kossaibati, 2000). The disturbances causing a drop in milk production are a major problem at dairy farms. Different types of mastitis leading to loss and adverse changes in the quality of the milk, as well as increased costs for treatment and early culling of the animals make up the negative economic effect (Anderson *et al*., 2002; Bergonier *et al*., 2003; Khan & Khan, 2006; Blowey & Edmondson, 2010). For these reasons, the quick and accurate diagnostics and prognosis are exceptionally important in mammary gland disorders. This entails the application of modern, accurate and fast methods for examination, such as ultrasonography.

Ultrasonography is a non-invasive method for the diagnostics of various physiological and pathological conditions of the reproductive organs of ruminants

(Dimitrov *et al*., 2002; Kähn, 2004; Yotov, 2005; Vassilev *et al*., 2005; Yotov *et al*., 2008). Ultrasound examination of the mammary gland in ruminants was performed for the first time by Caruolo & Mochrie (1967), who studied the teats of lactating cows with an A-mode ultrasonic device and a 1 MHz probe. The first report of applying B-mode ultrasonography to a mammary gland was done by Cartee *et al*. (1986). They used a 5 MHz linear and 5 and 10 MHz sector transducers to determine milk secretion distrubances and structural changes in the teat of cows.

During the 1970s and the 1980s, teat radiography was routinely used in the diagnostics of milk secretion anomalies (Kubicek, 1972; Witzig & Hugelshofer, 1984; Witzig *et al*., 1984; Alacam *et al*., 1990). In more recent times, however, this method of visualisation of mammary gland structures has been replaced by ultrasonography. In support of this statement, Stocker & Rüsch (1997) and Hospes & Seeh (1999) pointed out the method's non-invasiveness and the possibility to observe the separate mammary gland structures (teat and parenchyma) without using ionised radiation as its main advantages. Teat endoscopy (theloscopy) permits a direct visualisation of pathological changes (Couture & Mulon, 2005). Unlike ultrasonography, theloscopy only allows the visualisation of the papillary part of the milk cistern and the teat canal, while the anatomical structures located proximally to them are not displayed (Geishauser *et al*., 2005; Vangroenweghe *et al*., 2006; Kiossis *et al*., 2009).

A number of authors have reported about mammary gland ultrasonography in cows (Jenninger, 1989; Stocker *et al*., 1989; Will *et al*., 1990; Bruckmaier & Blum, 1992; Saratsis & Grunert 1993; Seeh *et al*., 1996; Banting, 1998), sheep (Ruberte *et al*., 1994; Nudda *et al*., 2000; Franz *et al*., 2003; Wójtowski *et al*., 2006; Rovai *et al*., 2008; Hiepler *et al*., 2009) and goats (Wójtowski *et al*., 2002; Fasulkov *et al*., 2010; Ślósarz *et al*., 2010). Ruberte *et al*. (1994) and Franz *et al*. (2003) used the method to visualise the parenchymal tissue, the mammary canals, the gland and teat cisterns, and the teat wall in sheep. Using a B-mode ultrasonic device, Bruckmaier & Blum (1992) were able to observe the changes in the volume of the milk cistern of cows, goats and sheep after treatment with oxytocin.

Echography of the teat is used for detection and differentiation of stenosis or obstruction of the teat canal, tissue proliferation, foreign bodies, milk stones, and congenital defects (Hospes & Seeh, 1999; Dinç *et al*., 2000; Franz *et al*., 2009). Echography can be used to monitor the recovery process after surgical removal of proliferated tissue or to differentiate a supernumerary teat or fistula (Franz *et al*., 2009). It is also used in the diagnostics of mastitis, haematomas, abscesses and tumours of the mammary gland (Gonzalez de Bulnes *et al*., 1998; Flöck & Winter, 2006; Trasch *et al*., 2007).

Apart from the studies on the application of B-mode echography, reports on the latest methods of ultrasound examination of the mammary gland in ruminants, such as colour Doppler echography (Franz *et al*., 2001; Braun & Hoegger, 2008) and three-dimensional (3D) echography (Franz *et al*., 2004) are also available.

TECHNIQUES OF EXAMINATION AND ULTRASOUND IMAGE INTERPRETATION

Techniques of examination

Using a proper B-mode ultrasonography equipment allows the differentiation of

morphological structures, such as mammary gland parenchyma, gland and teat cisterns, teat wall, rosette of Furstenberg, and teat canal (Franz *et al*., 2001). For this purpose, convex, linear and sector transducers can be used (Cartee *et al*., 1986; Flöck & Winter, 2006; Wójtowski *et al*., 2006).

Ultrasound examination of the mammary gland parenchyma in ruminants and the space between the gland and teat cisterns is done primarily through the direct contact technique (transcutaneous echography, Fig. 1) with a 5 MHz or lower frequency transducer (Cartee *et al*., 1986). After preliminary hair shaving, dipping of the skin with alcohol and contact gel application, the transducer is placed on the lateral and caudal surfaces, directly on the udder skin (Franz *et al*., 2009). During scanning, the probe is placed longitudinally and transversely to the mammary gland, designated as horizontal and vertical position, respectively (Cartee *et al*., 1986; Franz *et al*., 2003; Güngör *et al*., 2005).

Fig. 1. Ultrasonography of a goat's teat through the direct contact technique.

Fig. 2. Ultrasonography of a goat's teat through the water bath technique:
A – horizontal scan; B – vertical scan.

The primary technique used for echography of the teat structures is the "water bath" (Stocker *et al*., 1989; Will *et al*., 1990; Saratsis & Grunert, 1993; Şendağ & Dinç, 1999; Santos *et al*., 2004; Franz *et al*., 2009). It is done by immersion of the teat in a plastic container filled with warm water (30–35°C), with the transducer placed horizontally (Fig. 2A) or vertically (Fig. 2B) in contact with the container (Stocker *et al*., 1989). Seeh *et al*. (1996) obtained an image of satisfactory quality through direct contact with the teat with a 3.5 or 5 MHz probes, whereas Stocker *et al*. (1989), Will *et al*. (1990) and Saratsis & Grunert (1993) achieved better visualisation using the water-bath technique. The

echographic examinations of the mammary glands of lactating goats performed by us showed that transcutaneous teat echography (direct contact) using a linear 5 MHz transducer did not produce satisfactory results (Fasulkov *et al*., 2010). For high quality of the echographic teat image, most authors recommend using a linear probe with a frequency of no less than 7.5 MHz (Gufler *et al*., 1998; Franz *et al*., 2001; Güngör *et al*., 2005; Flöck & Winter, 2006).

Franz *et al*. (2009) believed that the water bath technique allows the operator to use one hand to move the teat in different positions and manipulate the echograph, while at the same time holding the plastic container and moving the probe vertically. The authors consider that using this method for displaying the structures of the teat prevents deformations in its tip, which would impede the visualisation of the papillary canal along its entire length.

Şendağ & Dinç (1999) observed a better image when the teat was full of milk or if neutral solutions were introduced before the examination. In support of this claim, Franz *et al*. (2001) proved that it was not necessary to fill the teat with sterile water or saline solution while examining animals in their lactation period.

Our studies with lactating goats showed that the application of the water bath technique was more effective for examining the teat, whereas the transcutaneous method (direct contact) – in the examination of the structures in the other areas of the mammary gland (Fasulkov *et al*., 2010; Fasulkov *et al.*, 2011; Fasulkov & Koleva, 2011).

Another method for echographic examination of the teat is the "stand off" technique (Fig. 3). Rambadu *et al*. (2008) used this technique in buffaloes by placing the teat in a latex condom filled with contact gel, with the transducer moved vertically or horizontally along the outer surface of the condom.

Fig. 3. Ultrasonography of a goat's teat through the stand off technique.

Ultrasound image of the teat

The ultrasound image of the teat in ruminants has been described by a number of authors (Cartee *et al*., 1986; Stocker *et al*., 1989; Takeda, 1989; Trostle & O'Brien, 1998; Nudda *et al*., 2000; Franz *et al*., 2001; Babkine & Couture, 2002).

B-mode echography of the teat in ruminants is most often performed using the water bath technique and vertical scanning (Stocker *et al*., 1989). The data by Franz *et al*. (2001) on teat canal echography in cows and sheep indicate that a high-quality image of the teat can be produced by using a 8.5 MHz linear transducer and the vertical position, whereas Couture & Mulon (2005) believed that probes with

frequencies of 5 MHz, 7.5 MHz and 10 MHz could also be used for this purpose.

Our results on the echography of goat teats using different techniques indicated that the water bath technique provided the best option for observation of the goat's teat structures (Fig. 4), while using a 10 MHz probe provided a high-quality image (Fasulkov *et al*., 2011). The direct contact and stand off techniques allowed the visualisation of the proximal papillary part, yet observation of the structures within the distal part of the teat was considerably limited (Fasulkov *et al*., 2011).

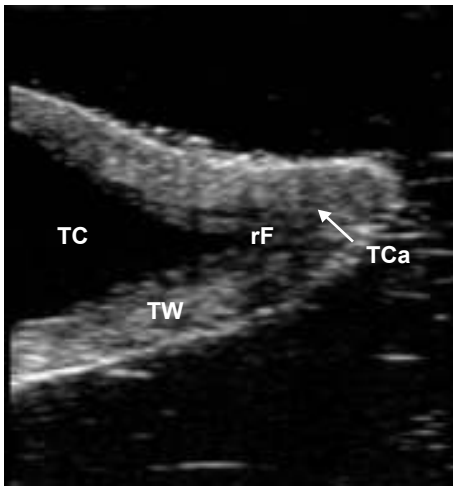

Fig. 4. Visualisation of the structures of the goat's teat (water bath technique, vertical scan, 10 MHz linear probe): TCa – teat canal; rF – rosette of Furstenberg; TW – teat wall; TC – teat cistern.

Cartee *et al*. (1986) observed the papillary orifice as a small anechoic formation located at the tip of the teat, whereas Şendağ & Dinç (1999) and Couture & Mulon (2005) established it as a hyperechoic structure.

Using a 3.5 MHz linear transducer, Stocker *et al*. (1989) visualised the teat canal as a single hypoechoic zone. Unlike them, Will *et al*. (1990) and Saratsis & Grunert (1993), using a 5 MHz linear probe, visualised the teat canal as one or two hyperechoic areas, whereas Franz *et al*. (2001) observed it via an 8.5 MHz linear probe as a centrally located hyperechoic line, bordered by two parallel hypoechoic zones.

The transition between the teat canal and the teat cistern is designated as the rosette of Furstenberg (Riedl *et al*., 2004). During echographic examination, it is visualised as a homogenous hyperechoic structure located directly above the teat canal (Franz *et al*., 2009).

By ultrasonography, Cartee *et al*. (1986), Şendağ & Dinç (1999) and Franz *et al*. (2003), differentiated three distinct layers of the teat wall in cows and sheep. The outer layer (teat skin) appears as a lucent hyperechoic line. The middle layer (musculature and connective tissue) is homogenous, thick, and of moderate echogenicity (hypoechoic layer), while the innermost layer (the mucosa) is hyperechoic. Our echographic studies on lactating goats also proved three different layers of the teat wall (Fasulkov *et al*., 2010). Couture & Mulon (2005) differentiated 5 papillary wall layers depending on the echogenicity – skin, hyperechoic musculature, connective tissue and submucosa with average echogenicity, and hyperechoic mucosa.

The teat cistern is anechoic, surrounded by a hyperechoic line (mucosa) (Takeda, 1989; Şendağ & Dinç, 1999; Santos *et al*., 2004), yet it could not be visualised if not filled with milk (Franz *et al*., 2001). The boundary between the gland and teat cisterns (Fig. 5) is visualised as round anechoic structures, which correspond to the veins of the venous ring of Furstenberg (Franz *et al*., 2009).

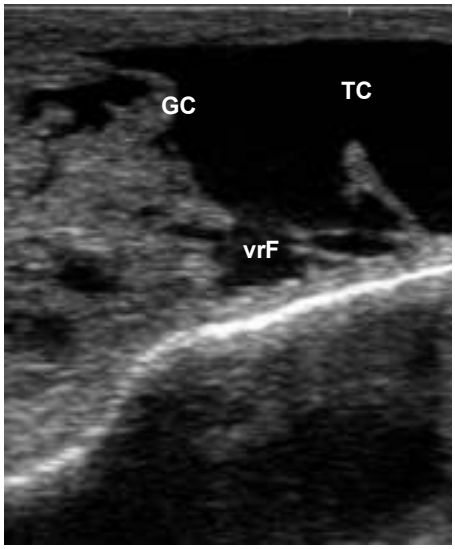

Fig. 5. Sonogramme of the transition between the teat and gland cisterns of a goat (direct contact technique, vertical scan, 5 MHz linear probe): TC – teat cistern; GC – gland cistern; vrF – venous ring of Furstenberg.

Ultrasound image of the mammary parenchyma

The echographic examination of the mammary gland parenchyma in ruminant animals is performed primarily via the direct contact technique (transcutaneous echography). For this purpose, a linear, convex or sector transducer can be used, with a frequency of 3.5 and 5 MHz (Cartee *et al*., 1986; Trostle & O'Brien, 1998; Flöck & Winter, 2006).

The echogenicity of the lactating mammary gland depends on its volume (Cartee *et al*., 1986; Flöck & Winter, 2006). According to Franz *et al*. (2009), the cow's mammary gland parenchyma is a homogenous structure and the visualisation of anechoic zones within it is usually related to a blood vessel or a lactiferous duct. The milk in the gland cistern is an anechoic formation (Fig. 6) with the presence of echoic particles.

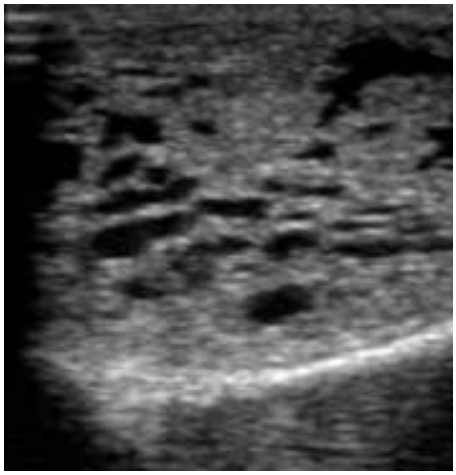

Fig. 6. Sonogramme of goat's mammary gland parenchyma (direct contact technique, horizontal scan, 5 MHz linear probe).

Cartee *et al*. (1986) established the gland cistern in cows as a large anechoic zone, whereas the parenchyma was hypoechoic. Our results during the echographic examination of lactating goats were similar. We proved that the lack of milk secretion makes the visualisation of the udder structures more difficult. This necessitates the separation of the offspring in goats kept together with the newborn, at least two hours before the examination. For other animals, a better visualisation can be achieved when the examination is performed at least 2 hours after the last milking (Fasulkov *et al*., 2010).

Flöck & Winter (2006) established the parenchyma of a healthy mammary gland as a homogenous structure of average echogenicity and presence of anechoic blood vessels and lactiferous ducts. The authors observed an abscess within the mammary parenchyma as a round clearly distinguished structure with a different size, a visible capsule and hypoechoic content. Haematomas were displayed as large septated areas within the gland parenchyma, filled with anechoic to hypo-

echoic fluid (Flöck & Winter, 2006; Franz *et al*., 2009).

INDICATIONS AND CLINICAL APPLICATION OF THE METHOD

Milk secretion disturbances are the main indication for ultrasound examination of the mammary gland in ruminants (Franz *et al*., 2009). Teat injuries and the milking technique are the main reasons for disturbed milk secretion (Bleul *et al*., 2002; Geishauser *et al*., 2005; Condino *et al*., 2010).

Echographic scanning of the teat is used primarily on cows and sheep for the diagnostics of stenoses, obstructions and fibrous changes in the area of the teat canal, the rosette of Furstenberg or the boundary between the teat and gland cisterns (Saratsis, 1991; Trostle & O'Brien, 1998; Dinç *et al*., 2000; Flöck *et al*., 2004; Mavrogianni *et al*., 2004; Couture & Mulon, 2005).

Echography is used for examination of the mammary gland parenchyma in cases of inflammatory processes (mastitis), oedema of the udder without mastitis symptoms, pathological formations localised deep within the parenchyma (abscesses, haematomas, tumours, foreign bodies, connective tissue buildups), which cannot be detected through clinical examination (Flöck & Winter, 2006; Franz *et al*., 2009). Banting (1998) used the echostructure of the mammary gland in cows with induced staphylococcal mastitis (*Staphylococcus aureus*), in order to determine the prognosis and the choice of treatment. Flöck & Winter (2006) found out the characteristic echographic image in cows' mammary glands inflammation caused by *Arcanobacterium pyogenes* and some Gram-negative bacteria of the Enterobacteriaceae family. They described the changes in the udder parenchyma in cases of abscesses and haematomas. Franz *et al*. (2009) observed a penetrating foreign body in the parenchyma as a hyperechoic linear structure causing a strong acoustic window. O'Brien *et al*. (2002) found gases during the echographic examination of an oedematous mammary gland in cows.

Our echographic studies on the mammary gland in goats suffering from acute mastitis, revealed a non-homogenous and hypo- to hyperechoic mammary gland parenchyma structure, with a lack of clear visualisation of the mammary canals and the blood vessels (Fasulkov & Koleva, 2011). The echography of the teat in these animals exhibited a thickened hyperechoic teat wall, as well as numerous hyperechoic structures in the teat cistern, representing milk coagula. Because of the more severe clinical expression and the major change in the echogenicity of the udder of goats with acute mastitis caused by *Staphylococcus aureus*, we believe that the severity of the inflammation and the type of the etiological agent possibly affected the echographic image for these animals (Fasulkov & Koleva, 2011).

Another indication for the echographic examination of the mammary gland is the determination of the dimensions of structures within the area of the teat. It allows for detailed measurements of the length and diameter of the teat canal, cistern, and the thickness of the teat wall (Gleeson *et al*., 2002; Ślósarz *et al*., 2010). Spencer *et al.* (1996), Gleeson & O'Callaghan (1998) and Neijenhuis (1999) used echography to detect changes in the teat tissues of cows. A number of authors established a connection between mastitis in cows, the stage of lactation, the characteristics of the teat, and the visualisation of the teat canal (McDonald, 1975; Seykora & McDaniel, 1985; Grindal *et al*., 1991; Seyfried, 1992; Scherzer, 1992; Celik *et al*., 2008). Some

studies have pointed out that echography can be useful in reviewing breed differences in the number of lactations, the teat canal elongation as a consequence of mechanical milking, and determining the influence of the teat parameters on the development of mastitis (Neijenhuis *et al*., 2001; Ayadi *et al*., 2003; Klein *et al*., 2005; Khol *et al*., 2006; Wójtowski *et al*., 2006; Rovai *et al*., 2008; Olechnowicz & Jaśkowski, 2009).

CONCLUSIONS

In conclusion, it could be summarised that ultrasound imaging of the mammary gland in ruminants is a non-invasive method, allowing the visualisation of the separate structures of the mammary gland (teat and parenchyma).

The main indications for application of this method inlcude milk secretion disorders, diagnostics of pathological changes (stenosis and obstructions, inflammations, abscesses, haematomas, foreign bodies, etc.), measurements of teat canal length and diameter, teat cistern diameter, and teat wall thickness.

Echography of the mammary gland parenchyma in ruminants is performed primarily through the direct contact technique (transcutaneous echography) with a low-frequency linear, sector or convex transducer (3.5–5 MHz) and horizontal scanning.

Examination of the teat is done primarily through the water bath technique and vertical scanning. A high quality image can be achieved by using a high frequency probe (at least 7.5 MHz).

The application of ultrasonography for the diagnostics of physiological and pathological conditions of the mammary gland has been commonly reported for cows and sheep, whereas data about goats are scarce. This is a rationale for future echographic studies on various pathological conditions of the mammary gland in goats, aimed at correct diagnostics and monitoring of goat mammary gland pathology.

REFERENCES

Alacam, D., A. Dinc, M. Güler & E. Elma, 1990. Incidence and radiographic examination of different pathological findings in the teat of dairy cows. *Deutsche Tierärztliche Wochenschrift*, **97**, 523–525.

Anderson, D., B. Hill & D. Pugh, 2002. Diseases of the mammary gland. In: *Sheep and Goat Medicine*, W. B. Saunders, Philadelphia, pp. 341–357.

Ayadi, M., G. Caja, X. Such & C. H. Knight, 2003. Use of ultrasonography to estimate cistern size and milk storage at different milking intervals in the udder of dairy cows. *Journal of Dairy Research*, **70**, 1–7.

Babkine, M. & Y. Couture, 2002. L'échographie du trayon est un outil diagnostique non invasif. *Point Vétérinaire*, **33**, 16–17.

Banting, A., 1998. Ultrasonographical examination of the mammary gland in cows with induced *S. aureus* mastitis: A criteria for prognosis and evaluation of therapy. *Cattle Practice*, **6**, 121–124.

Bergonier, D., R. Crémoux, R. Rupp, G. Lagriffoul & X. Berthelot, 2003. Mastitis of dairy small ruminants. *Journal of Veterinary Research*, **34**, 689–716.

Bleul, U. T., S. C. Schwantag, C. Bachofner, M. R. Hässig & W. K. Kähn, 2005. Milk flow and udder health in cows after treatment of covered teat injuries via theloresectoscopy: 52 cases (2000–2002). *Journal of American Veterinary Medical Association*, **226**, 1119–1123.

Blowey, R. & P. Edmondson, 2010. Mastitis Control in Dairy Herds, 2nd edn, CAB International, Oxfordshire, pp. 1–4.

Braun, U. & R. Hoegger, 2008. B-mode and colour Doppler ultrasonography of the

milk vein in 29 healthy Swiss braunvieh cows. *Veterinary Record*, **163**, 47–49.

Bruckmaier, R. M. & J. W. Blum, 1992. B-mode ultrasonography of mammary glands of cows, goats and sheep during alpha- and beta-adrenergic agonist and oxytocin administration. *Journal of Dairy Research*, **59**, 151–159.

Cartee, R. E., A. K. Ibrahim & D. McLeary, 1986. B-mode ultrasonography of the bovine udder and teat. *Journal of American Veterinary Medical Association*, **188**, 1284–1287.

Caruolo, E. V. & R. D. Mochrie, 1967. Ultrasonograms of lactating mammary gland. *Journal of Dairy Science*, **50**, 225–230.

Celik, H. A., I. Aydin, M. Colak, S. Sendag & D. A. Dinc, 2008. Ultrasonographic evaluation of age related influence on the teat canal and the effect of this influence on milk yield in Brown Swiss cows. *Bulletin of the Veterinary Institute in Pulawy*, **52**, 245–249.

Condino, M. P., K. Suzuki, K. Sato, K. Hyakutake & K. Taguchi, 2010. Evaluation of a milk-flow assessment technique in dairy cows with normal teat canals or stenotic teat canals. *American Journal of Veterinary Research*, **71**, 1123–1126.

Couture, Y. & P. Y. Mulon, 2005. Procedures and surgeries of the teat. *Veterinary Clinic of North America, Food Animal Practice*, **21**, 173–204.

Dimitrov, M., N. Vassilev, P. Georgiev, I. Ivanov & S. Yotov, 2002. Ultrasonographic assessment of early pregnancy in animals. *Bulgarian Journal of Veterinary Medicine*, **5**, 167–178.

Dinç, D. A., S. Şendağ & I. Aydin, 2000. Diagnosis of teat stenosis in dairy cattle by real-time ultrasonography. *Veterinary Record*, **147**, 270–272.

Fasulkov, I. & M. Koleva, 2011. Ultrasound imaging findings in acute mammary gland inflammations in goats. *Journal of Mountain Agriculture on the Balkans*, **14**, 210–221.

Fasulkov, I. R., P. I. Georgiev, A. L. Antonov & A. S. Atanasov, 2010. B-mode ultrasonography of mammary glands in goats during the lactation period. *Bulgarian Journal of Veterinary Medicine*, **13**, 245–251.

Fasulkov, I., S. Yotov, A. Atanasov & A. Antonov, 2011. Evaluation of different techniques of teat ultrasonography in goats. *Journal of The Faculty of Veterinary Medicine – Istanbul University* (in press).

Flöck, M., D. Klein & M. Hofmann-Parisot, 2004. Ultrasonographic findings of pathological teat changes in cattle. *Wiener Tierärztliche Monatsschrift*, **91**, 184–195.

Flöck, M. & P. Winter, 2006. Diagnostic ultrasonography in cattle with disease of the mammary gland. *The Veterinary Journal*, **171**, 314–321.

Franz, S., M. Floek & M. Hofmann-Parisot, 2009. Ultrasonography of the bovine udder and teat. *Veterinary Clinic of North America, Food Animal Practice*, **25**, 669–685.

Franz, S., M. Hofmann-Parisot, S. Gütler & W. Baumgartner, 2003. Clinical and ultrasonographic findings in the mammary gland of sheep. *New Zealand Veterinary Journal*, **51,** 238–243.

Franz, S., M. Hofmann-Parisot & W. Baumgartner, G. Windischbauer, A. Suchy & B. Bauder, 2001. Ultrasonography of the teat canal in cows and sheep. *Veterinary Record*, **149**, 109–112.

Franz, S., M. Hofmann-Parisot & W. Baumgartner, 2004. Evaluation of three-dimensional ultrasonography of the bovine mammary gland. *American Journal of Veterinary Research*, **65**, 1159–1163.

Geishauser, T., K. Querengässer & J. Querengässer, 2005. Teat endoscopy (theloscopy) for diagnosis and therapy of milk flow disorders in dairy cows. *Veterinary Clinics of North America: Food Animal Practice*, **21**, 205–225.

Gleeson, D. E. & E. O'Callaghan, 1998. The effect of machine milking on teat tissue reaction using ultrasonic analysis. In: *Proceedings of the 37th Annual Meeting of the*

National Mastitis Council Inc, St. Louis, Missouri, USA, pp. 254–255.

Gleeson, D. E., E. J. O'Callaghan & M. V. Rath, 2002. Effect of milking on bovine teat tissue as measured by ultrasonography. *Irish Veterinary Journal*, **55**, 628–632.

Gonzalez de Bulnes, A., P. Garcia Fernandez, A. M. Mayenco Aquirre & M. Sanchez de la Muela, 1998. Ultrasonographic imaging of canine mammary tumours. *Veterinary Record*, **143**, 687–689.

Grindal, R. J., A. W. Walton & J. E. Hillerton, 1991. Influence of milk flow rate and streak canal length on new intramammary infection in dairy cows. *Journal of Dairy Research*, **58**, 383–388.

Gufler, H., S. Franz & W. Baumgartner, 1998. Ultraschalldiagnostik beim Wiederkauer. In: *Proceedings of the 10th Middle European Buiatrics Congress*, Siofok, May 21 to 23 1998, Hungary, pp. 239–241.

Güngör, Ö., Ş. M. Pancarci & A. Karabacak, 2005. Examination of equine udder and teat by B-mode ultrasonography. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi*, **11**, 107–111.

Hiepler, T., A. Schönfelder & A. Wehrend, 2009. Sonographische Untersuchung des ovinen Euters. *Tierärztliche Praxis*, **37**, 157–163.

Hospes, R. & C. Seeh, 1999. Sonographie. In: *Sonographie und Endoskopie an der Aitze des Rindes,* Schattauer, Stuttgart, pp. 29–48.

Jenninger, S., 1989. Ultraschalluntersuchungen an der Milchdrüse des Rindes – physiologische and pathologische Befunde. Dr. med. vet. thesis, Veterinärmedizinische Fakultät München, Munich.

Kähn, W., 2004. Ultrasonography in sheep and goats. In: *Veterinary Reproductive Ultrasonography*, Schlütersche Verlagsgesellschaft GmbH & Co., Hannover, pp. 187–210.

Khan, M. Z. & A. Khan, 2006. Basic facts of mastitis in dairy animals: A review. *Pakistan Veterinary Journal*, **26**, 204–208.

Khol, J. L., S. Franz, D. Klein, D. Lexer, S. Waiblinger, K. Luger & W. Baumgartner, 2006. Influence of milking technique and lactation on the bovine teat by means of ultrasonographic examination. *Berliner und Münchener Tierärztliche Wochenschrift*, **119**, 68–73.

Kiossis, E., C. N. Brozos, N. Papaioannou, N. Tzanidakis & C. Boscos, 2009. Endoscopic and histopathological findings of teats in dairy ewes. *Small Ruminant Research*, **87**, 70–75.

Klein, D., M. Flöck, J. L. Khol, S. Franz, H. P. Stüger & W. Baumgartner, 2005. Ultrasonographic measurement of the bovine teat: breed differences, and the significance of the measurements for udder health. *Journal of Dairy Research*, **72**, 296–302.

Kossaibati, M. A., 2000. The costs of clinical mastitis in UK dairy herds. *Cattle Practice*, **8**, 323–327.

Kubicek, J., 1972. The radiographical view of the bovine teat. Attribution to physical findings in the teat of dairy cows. *Tierärztliche Umschau*, **27**, 119–124.

Mavrogianni, V. S., G. C. Fthenakis, A. R. Burriel, P. Gouletsou, N. Papaioannou & I. A. Taitzoglou, 2004. Experimentally induced teat stenosis in dairy ewes: Clinical, pathological and ultrasonographic features. *Journal of Comparative Pathology*, **130**, 70–74.

McDonald, J. S., 1975. Radiographic method for anatomic study of the teat canal: Characteristics related to resistance to new intramammary infection during lactation and the early dry period. *The Cornell Veterinarian*, **65**, 492–499.

Neijenhuis, F., 1999. Recovery of cow teats after milking: Ultrasonic scanning. In: *Proceedings of International Conference on Mastitis and Machine Milking*. Silver Springs Hotel, Cork, pp. 39–41.

Neijenhuis, F., G. H. Klungel & H. Hogeveen, 2001. Recovery of teats after milking as determined by ultrasonographic scanning. *Journal of Dairy Science*, **84**, 2599–2606.

Nudda, A., G. Pulina, R. Vallebella, R. Bencini & G. Enne, 2000. Ultrasound technique for measuring mammary cistern size of dairy ewes. *Journal of Dairy Science*, **67**, 101–106.

O'Brein, R. T., K. R. Waller III & J. S. Matheson, 2002. Ultrasonographic appearance of edema caused by injections in the mammary gland attachments of dairy cows. *Journal of American Veterinary Medical Association*, **221**, 408–410.

Olechnowicz, M. & J. M. Jaśkowski, 2009. Ultrasound examination of mammary glands in ruminants. *Medycyna Weterynaryjna*, **65**, 147–150.

Rambadu, K., M. Sreenu, R. V. Suresh Kumar & T. S. C. Rao, 2008. Ultrasonography of the udder and teat in buffaloes: A comparision of four methods. *Buffalo Bulletin*, **27**, 269–273.

Riedl, J., E. Kiossis, M. Müller, S. Seidl, R. Stolla & W. Hermanns, 2004. Endoscopic, pathologic-anatomic and histologic findings in the bovine teat. 2. Changes in the area of Fürstenberg's rosette. *Deutsche Tierärztliche Wochenschrift,* **111**, 423–429.

Rovai, M., G. Caja & X. Such, 2008. Evaluation of udder cisterns and effects on milk yield of dairy ewes. *Journal of Dairy Science*, **91**, 4622–4629.

Ruberte, J., A. Carretero, M. Fernández, M. Navarro, G. Caja, F. Kirchner & X. Such, 1994. Ultrasound mammography in the lactating ewe and its correspondence to anatomical section. *Small Ruminant Research*, **13**, 199–204.

Santos, D., W. Vicente, J. Canola & E. Léga, 2004. B-mode ultrasonography in cows during lactation to evaluate the teat anatomy using four different techniques. *Brazilian Journal of Veterinary Research and Animal Science*, **41**, 349–354.

Saratsis, P., 1991. Zur diagnostik von Zitzenstenosen des Rindes mit Hilfe der Ultraschalltomographie (Literaturübersicht). *Deutsche Tierärztliche Wochenschrift*, **98**, 441–476.

Saratsis, P. & E. Grunert, 1993. Ultraschalluntersuchungen zur Abgrenzung der räumlichen Ausdehnung von Zitzenstenosen and anderen Zitzenveränderungen beim Rind. *Deutsche Tierärztliche Wochenschrift*, **100**, 159–163.

Scherzer, J., 1992. Ultrasound examination of the bovine teat – influence of teat canal length and other factors on the udder health. Thesis, University of Veterinary Medicine, Vienna, Austria.

Seeh, C., R. Hospes & H. Bostedt, 1996. Use of visual methods (sonography/endoscopy) for the diagnosis of a webbed teat in cattle – a case report. *Tierärztliche Praxis*, **24**, 438–442.

Şendağ, S. & D. Dinç, 1999. Ultrasonography of the bovine udder. *Turkish Journal of Veterinary and Animal Sciences*, **23**, 545–552.

Seyfried, G., 1992. The sonographic measurement of teat structures and the significance for udder health of "Braun-and-Fleckvieh" cows. Thesis, University of Veterinary Medicine Vienna, Austria.

Seykora, A. J. & B. T. McDaniel, 1985. Udder and teat morphology related to mastitis resistance: A review. *Journal of Dairy Science*, **68**, 2087–2093.

Ślósarz, P., J. Wójtowski, S. Bielińska, A. Frąckowiak, A. Ludwiczak, J. Krzyżewski, E. Bagnicka & N. Strzalkowska, 2010. Machine induced changes of caprine teats diagnosed by ultrasonography. *African Journal of Biotechnology*, **9**, 8698–8703.

Spencer, S. B., L. C. Griel & J. J. Goldberg, 1996. Bovine teat congestion as measured by ultrasonography. *Journal of Dairy Science*, **79**, 257.

Stocker, H. & P. Rüsch, 1997. Euter und Zitzen. In: *Textbook of Ultrasonography in Cattle*, 1st edn, Parey, Berlin, pp. 163–175.

Stocker, H., U. Battig, M. Duss, M. Zahner, M. Flückinger, R. Eicher & P. Rüsch, 1989. Die abklarung von Zitzenstenosen beim Rind mittels Ultraschall. *Tierarztliche Praxis*, **17**, 251–256.

Takeda, T., 1989. Diagnostic ultrasonography of the bovine udder. *Japanese Journal of Veterinary Research*, **37**, 133.

Trasch, K., A. Wehrend & H. Bostedt, 2007. Ultrasonographic description of canine mastitis. *Veterinary Radiology & Ultrasound*, **48**, 580–584.

Trostle, S. S. & R. T. O'Brien, 1998. Ultrasonography of the bovine mammary gland. *Compendium on Continuing Education for the Practicing Veterinarian*, **20**, 64–71.

Vangroenweghe, F., W. Van Den Broeck, A. De Ketelaere, H. van Bree, L. Duchateau & C. Burvenich, 2006. Endoscopic examination and tissue sampling of the bovine teat and udder cistern. *Journal of Dairy Science*, **89**, 1516–1524.

Vassilev, N., S. Yotov & F. Dimitrov, 2005. Incidence of early embryonic death in dairy cows. *Trakia Journal of Sciences*, **3**, 62–64.

Wendt, K., H. Bostedt, H. Mielke & H. W. Fuchs, 1994. Euter- und Gesaugekrankheiten. Fischer, Jena-Stuttgart., pp. 229-231.

Will, S., S. T. Würgau, J. Fraunholz, C. Bouabid & W. Leidl, 1990. Sonographische befunde an der Papilla mammae des Rindes. *Deutsche Tierärztliche Wochenschrift*, **97**, 403–406.

Witzig, P. & J. Hugelshofer, 1984. Clarification of teat stenoses using radiography double contrast staining. *Schweizer Archiv für Tierheilkunde*, **126**, 155–163.

Witzig, P., P. Rusch & M. Berchtold, 1984. Diagnosis and treatment of the teat stenoses in dairy cattle with special reference to radiography and thelotomy. *Veterinary Medical Review*, **2**, 123–132.

Wójtowski, J., P. Ślósarz, A. Junkuszew, M. Milerski, A. Szymanowska & M. Szymanowski, 2006. Application of ultrasound technique for cistern size measurement in dairy goats. *Archiv für Tierzucht Dummerstorf,* **49**, 382–388.

Wójtowski, J., P. Ślósarz, S. Bielińska, S. Nowicki, A. Gut & R. Danków, 2006. Ultrasound image of morphological changes of teat end in sheep caused by machine milking. *Archiv für Tierzucht Dummerstorf,* **49**, Special Issue, 231–237.

Wójtowski, J., P. Ślósarz, W. Malecha & R. Danków, 2002. Ultrasound measurements of goat's mammary gland cisterns during lactation. *Medycyna Weterynaryjna*, **58**, 977–980.

Yotov, S., 2005. Diagnostics of early pregnancy in Stara Zagora dairy sheep breed. *Bulgarian Journal of Veterinary Medicine*, **8**, 41–45.

Yotov, S., A. Wehrend, N. Vassilev, P. Georgiev, S. Lottner, A. Antonov & A. Atanasov, 2008. Ultrasonographic fetal sex determination in sheep depending on gestational age and fetal position (Abstract). *Reproduction in Domestic Animals*, **43**, Suppl. 1, p. 35.

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