Readability of visual and electronic leg tags versus rumen boluses and electronic ear tags for the permanent identification of dairy goats

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ABSTRACT

Murciano-Granadina dairy goats ($n = 220$) were used to assess the performance of visual and electronic identification devices: 1) leg tags (LT) on the shank of the right hind leg (metatarsus) consisting of plastic bands (181×39 mm, 21 g; $n = 220$) printed with a 3-digit code and closed with 2 types of electronic button tags (ET1, 3.9 g, 26 mm o.d., $n = 90$; ET2, 5.5 g, 25 mm o.d., $n = 130$); 2) electronic rumen boluses (RB, 75 g, 68×21 mm, $n = 220$) containing 32×3.8 mm transponders; 3) electronic ear tags (EE, button-button, 4.8 g, 24 mm, $n = 47$); and 4) visual plastic ear tags (VE, flag-button, 4.2 g, 40×38 mm, $n = 220$). The shank circumference of 47 replacement kids (5 to 6 mo of age) and 103 adult goats was measured to evaluate the proper circumference for fastened LT. Goats were identified with RB and VE before the experiment. Time for leg tagging, reading, and data recording with a handheld transceiver was measured. Readability [(read/readable) $\times 100$] was monitored for 1 yr with goats restrained in the milking parlor. Reading time and errors of RB and ET2 in the milking parlor using the handheld transceiver were recorded. Shank circumference of kids (70 ± 1 mm) was 79.5% of that in adult goats (88 ± 1 mm), thus LT (107 ± 1 mm inner circumference) were only applied to adult goats as they were inadequate for 6-mo-old kids. Time for leg tagging and data recording was 53 ± 3 s. At 1 yr, readability of RB was 96.5%. No LT losses occurred and all were visually readable, although 3 (1.5%) had to be removed due to limping, leading to a final LT retention of 98.5%. Moreover, 7 (3.6%) LT were found open and electronically unreadable. Readability of button transponders, excluding removed LT, was 93.6% (3 lost and 2 unreadable) for ET1, and 98.3% (2 lost) for ET2. Readability was 95.7 and 97.0% in EE and VE ear tags, respectively. Only LT and ET1 readabilities differed. Reading time and reading errors (0.3 vs. 0%)

in the milking parlor were greater for RB (61.2 s) than for ET2 (45.9 s). In conclusion, LT were not adequate for the identification of goat kids under 6 mo of age. Only LT with ET2 transponders met International Committee for Animal Recording requirements for official identification of adult goats (readability $>98\%$) under the conditions of this experiment.

Key words: electronic identification, goat, leg tag, transponder

INTRODUCTION

The European regulation EC 21/2004 on the identification (ID) and registration of sheep and goats sets out a double-ID system that includes the use of passive radio frequency ID (RFID) devices in member states where total sheep and goat populations surpass 600,000 animals, or where the total number of goats is greater than 160,000. According to this regulation, RFID has been official since 2005, although its compulsory implementation was not adopted until January 2010 (EC 1560/2007). Regulation EC 21/2004 has been enforced in Spain, where RFID rumen boluses have been in use since 2006 (Real Decreto 947/2005).

Deployment of RFID boluses in the Spanish national sheep and goat breeding stock was cost-effective (Saa et al., 2005), and advantages of using RFID boluses vs. visual ear tags for milk recording in dairy goats were reported by Ait-Saidi et al. (2008).

Nevertheless, bolus retention in goats is highly variable (Caja et al., 1999; Pinna et al., 2006; Carné et al., 2009b). As a consequence, the use of small s.c. transponders (i.e., 10 to 15 mm) in the fore (metacarpus) or hind legs (metatarsus) of goats was approved for goat herds with poor bolus retention. However, transponders injected in the leg of kids have been lost and the reading performance of small transponders is low (MAPA, 2007; Carné et al., 2009a). Moreover, injection in the hind leg of dairy goats was more difficult than in the fore-leg (MAPA, 2007).

Recently, European regulation EC 21/2004 was amended by regulation EC 933/2008, which specified

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the mandatory use of 1 visual and 1 electronic ID device simultaneously. Rumen boluses and ear tags have been the authorized RFID devices whenever RFID is compulsory; visual ear tags and visual pastern tags are accepted as the second ID device. Additionally, ID in the pastern with electronic marks (electronic leg tags) and injectable transponders has been accepted in sheep and goats whose first means of ID is a visual ear tag, but only when the animals do not leave the member state of origin (EC 933/2008). Visual tags on the metatarsus are common for goat ID in the milking parlor (Balvay, 2007), but to our knowledge, no long-term reports on visual and electronic leg tag readability have been published. Thus, this work aimed to evaluate the visual and electronic performance of leg tags placed on the metatarsus of dairy goats; rumen boluses and visual and electronic ear tags were also evaluated to allow for comparison.

MATERIALS AND METHODS

Animal care conditions and management practices followed procedures stated by the Ethical Committee of Animal and Human Experimentation of the Universitat Autònoma de Barcelona (CEEAH 606/06), as well as the guidelines of the ICAR (2009) and the Spanish Committee on Animal Electronic Identification (MAPA, 2007).

Animals, Management, and ID Devices

A total of 220 adult Murciana-Granadina dairy goats from a commercial farm (Ramaderia Huguet, Girona, Spain; $n = 170$) and from the experimental farm of the Universitat Autònoma de Barcelona (S1GCE, Barcelona, Spain; $n = 50$) were used. All goats were born before 2005 and were not subject to the new European regulation (EC 21/2004) on goat ID.

Goats were fed indoors with dehydrated ryegrass hay *ad libitum* (12% CP; as fed), 0.5 kg of alfalfa pellets/d (17% CP; as fed), and 0.5 to 1.0 kg of commercial concentrate/d (1.53 Mcal of NE_L /kg and 16% CP; as fed) according to the physiological stage of the animal. Additionally, goats from the experimental farm grazed on cultivated Italian ryegrass pasture for 5 h daily (1000 to 1500 h). Milking was done once daily in double-parallel milking parlors (2×24 and 2×12 stalls, for the commercial and experimental farms, respectively). Milking routine included machine milking (cluster attachment without udder preparation), machine stripping, cluster removal, and teat disinfection by dipping (P3-cide plus, Henkel Hygiene, Barcelona, Spain).

All goats were visually identified on the left hind shank with a leg tag (**LT**) consisting of a yellow plastic

band (weight, 21 g; length and width, 181×39 mm; thickness, 2.2 mm; Animalcomfort, Jumilla, Murcia, Spain; Figure 1) with an adjustable buckle-like closure system with 6 holes. The suitable buckle hole for the goats (third hole; Figure 1) was agreed upon after measuring the shank (metatarsus) circumference of the left hind leg of 103 adult goats. Subsequently, the inner circumference of 50 closed LT with the chosen closing adjustment for adult goats was also measured.

Because European regulations require that animals must be officially identified at no later than 6 mo of age, the metatarsus circumference of 47 replacement (5 to 6 mo old) does was measured and compared with that of adult goats to decide on the suitability of LT at this age.

Each LT had a 3-digit animal ID printed code for farm management purposes. The pin of the LT buckles was designed to be coupled with female ear tag pieces by using adapted tagger pliers supplied by the LT manufacturer. Two types of button half-duplex transponders were used (Figure 1): **ET1** (weight, 3.9 g; o.d., 26 mm; open piece; $n = 90$; Allflex España, Madrid, Spain) and **ET2** (weight, 5.5 g; o.d., 25 mm; closed piece; $n = 130$; Rumitag, Esplugues de Llobregat, Barcelona, Spain). Transponder serial numbers included the manufacturer code (Allflex, 982; Rumitag, 964) and worked at 134.2 kHz, in accordance with International Organization for Standardization (**ISO**) standards on animal electronic ID (11784 and 11785; ISO, 1996a,b).

Prior to the start of this study, adult goats were identified with standard-size cylindrical rumen boluses (**RB**; $n = 220$; weight, 75.0 g; length $\times$ o.d., 68×21 mm; and specific gravity, 3.4; Rumitag) made of nontoxic, nonporous, and dense ceramic materials, according to Spanish regulations. These boluses were considered to be control devices as they had been tested in previous studies (Pinna et al., 2006; MAPA, 2007; Carné et al., 2009b). Each bolus contained an ISO half-duplex, glass-encapsulated transponder of 32×3.8 mm (Ri-Trp-RR2B-06, Tiris, Almelo, the Netherlands). Transponder serial numbers included the 3-digit manufacturer code (Rumitag, 964) in accordance with corresponding ISO standards (ISO, 1996a,b). Boluses were administered by trained operators as described by Caja et al. (1999) and Carné et al. (2009b). This type of bolus has been used since 2006 as the official RFID device for sheep and goats in Spain (Real Decreto 947/2005).

Because the use of button RFID ear tags has recently been regulated in Spain (Real Decreto 1486/2009), 47 adult goats on the Universitat Autònoma de Barcelona's experimental farm were also tagged with 1 button-button half-duplex electronic ear tag (**EE**; weight, 5.9 g; o.d., 24 mm; Allflex Europe, Vitré, France) attached to the left ear using tagger pliers recommended by the

Figure 1. Leg tags and attached transponders in the hind leg for the visual and electronic identification of dairy goats. LT = plastic leg tag (weight, 21 g; length $\times$ width, 18 $\times$ 4 cm; thickness, 2.2 mm; Animalcomfort, Jumilla, Murcia, Spain); ET1 = half-duplex open button transponder (weight, 3.9 g; o.d., 26 mm; Azasa-Allflex, Madrid, Spain) attached to LT; ET2 = half-duplex closed button transponder (weight, 5.5 g; o.d., 25 mm; Rumatag, Esplugues de Llobregat, Barcelona, Spain) attached to LT.

manufacturer (Universal Total Tagger, Allflex Europe). These goats simultaneously wore 3 RFID devices (RB, LT with attached ET2, and EE) during the experiment. Electronic ear tag transponders included the manufacturer code (Allflex, 982) and were in line with ISO standards (ISO, 1996a,b). Additionally, all goats wore 1 polyurethane visual ear tag (**VE**; flag-button; weight, 4.2 g; flag piece dimensions, 38 $\times$ 40 mm; n = 220; Azasa-Allflex, Madrid, Spain) on the right ear, with the button piece located inside the ear. Both pieces of the tag had a printed 6-digit alphanumeric code aimed at compulsory official ID; these ear tags were applied by Veterinary Service officers.

Measurements and Readings of ID Devices

Electronic devices were read in the milking parlor with ISO handheld transceivers (Ges 2S, Rumatag) able to read ISO transponders at a minimum distance of 12 and 20 cm for ear tags and boluses, respectively, as established by European regulations on this issue (EC 21/2004; EC 933/2008). Each RFID device was read immediately before and after administration to check for breakages or electronic failures during administration, and in the case of RB, to ensure the bolus's proper location in the reticulorumen. At the first post-tagging

reading, the ID code printed on the LT (3-digit numeric code for farm management) was typed and stored into the transceiver. Time required for leg tagging (band fastening and transponder attachment), reading, and ID typing on the handheld transceiver was recorded. Leg tags and RB were read at wk 1 to detect early losses or failures and every month for 1 yr thereafter. For VE, only 1 reading at the end of the study was conducted.

Identification device performance was expressed as readability (visual or electronic), where readability = $(n \text{ read devices} / n \text{ monitored devices}) \times 100$

Breakage or damage of ear and leg tags was recorded, as was any incident during the application of identifiers and the subsequent period of study. Additionally, the mechanical resistance of the locking system of unused LT was measured in a sample of 5 button transponders of each type. For this purpose, a computer-controlled force testing system (MultiTest 1-i, Mecmesin Ltd., Slinfold, UK) was used, and fastened LT pieces were pulled at a constant displacement rate of 500 mm/min until breakage or unfastening, as is indicated for ear tags by the ICAR (2009).

Reading performance of ET2 and RB was evaluated in static conditions in the milking parlor at the end of the experiment. For this purpose, time required to

read each device type in groups of 24 goats in a double 12-stall parallel milking parlor (Westfalia-Separator Ibérica, Granollers, Spain) was recorded. Before the measurements, all devices were checked to ensure that readings were functional. Time measurements were obtained by using an electronic chronometer (Geonaute Trt'L 100, Decathlon, Alcobendas, Spain). For the readings, a full-ISO handheld transceiver (Smart Reader, Rumitag) connected to a 70-cm-long stick antenna (GasISO, Rumitag) was used. A total of 30 groups of goats were read for both ET2 and RB, corresponding to 720 readings for each type of device. Reading failures and crossed readings (devices read from adjacent goats) were registered as well. Some crossed readings with the bolus of an adjacent goat are possible when boluses are in the rumen rather than the reticulum. Considering the potential for crossed reading and the fact that current commercial handheld transceivers can be configured to prevent duplicate registers during a reading control, readings were performed starting from the left side of each milking stall to minimize the possibility of crossed readings with unread transponders from the right side of a flanking goat. Thus, a crossed reading of an adjacent goat to the left was detected when the transceiver's display showed a message indicating that the last read transponder had already been stored in the transceiver's internal memory. A crossed reading of an adjacent goat to the right would be likewise detected because when moving to the following goat, the transceiver would indicate that the device had already been read.

The dynamic reading efficiency of ET2 attached to LT was evaluated in the goats of the Universitat Autònoma de Barcelona's experimental farm at the end of the experiment. A rectangular (94 × 52 cm; Tiris) frame antenna without a panel, connected to a portable stationary transceiver (model F-210, Rumitag), was used for groups of 22 to 35 goats passing through a runway (width, 50 cm). As RB removal was not possible at the time the dynamic readings were made, only the EE were removed, and the collision effects between ET2 and RB were taken into account in dynamic reading efficiency results. Three antenna locations with respect to the goats passing through the runway were tested: (1) lateral (the frame antenna standing up in a vertical position and fixed on the left side of the runway), the goats passed by the antenna; (2) floor (the frame antenna fixed longitudinally lying on the floor of the runway), the goats walked over the antenna; and (3) going through (the frame antenna standing up vertically and in a transverse position to the runway), the goats passed through the middle of the antenna. Dynamic reading efficiency was expressed as (n read devices/n readable devices) × 100.

Statistical Analyses

Data on the shank and LT circumferences, as well as LT unfastening forces were analyzed by ANOVA using the PROC GLM of SAS (version 9.1; SAS Inst. Inc., Cary, NC). For the metatarsus circumference and the LT inner circumference, the model contained 1 categorical fixed effect with 3 categories (kid goats, adult goats, and LT), and the residual error. The model to evaluate the unlocking force of LT contained the effect of the button transponder type (ET1 and ET2) and the residual error.

Readability of ID devices at 1 yr after tagging (binary variable, 0 or 1) was analyzed with the PROC CATMOD of SAS, and a Logit model with an estimation method of maximum likelihood (Cox, 1970) was used. To compare the longitudinal readability of devices throughout the 1-yr study, the Kaplan-Meier nonparametric survival analysis and log-rank test of equality across strata (ID devices) were performed with the PROC LIFETEST of SAS, as previously used by Fosgate et al. (2006) and Carné et al. (2009a,b); the VE were not included in this last analysis as only 1 control at 1 yr was carried out.

Reading times for LT and RB in static conditions in the milking parlor were analyzed with PROC GLM, and the model included the device type (ET2 and RB) as a fixed effect and the residual error. The PROC CATMOD was used for the evaluation of reading failures and false readings in the milking parlor, with the device type as the fixed effect of the model.

Least squares means of the dynamic reading efficiency of ET2 and RB, with the goats passing through a runway, were obtained using PROC GLM. Factors considered were the 3 positions of the frame antenna and the RFID device (ET2 and RB). Speed of passage of goats through the runway was analyzed with PROC GLM according to the antenna position.

RESULTS AND DISCUSSION

Application of LT

The metatarsal circumference of replacement Murciano-Granadina kid goats (<6 mo) was 79.5% of that in adult goats (88 ± 1 mm), with the inner circumference of the fastened LT = 107 ± 1 mm. Regarding body development, the Murciano-Granadina goat breed is a medium-frame breed (bucks, 50 to 70 kg of BW; does, 40 to 55 kg of BW; ACRIMUR, 2010). According to our results, the metatarsal circumference of the replacement does was inappropriate for the application of LT as a permanent ID at this age; tamper-evident LT fitting the shanks of kids might eventually cause leg constriction in adult goats.

Consequently, only adult goats were included in the ID device study. Although only adult goats were used, 3 (1.5%) LT were removed as the devices caused limping in the animals. In one case, the LT caused constriction of the metatarsus in an inflamed leg; this inflammation was unrelated to LT application. In the other 2 cases, the LT was too loose fitting and slid down under the sesamoid bones, where it was blocked between the sesamoid bones and the hoof.

Abecia and Torras (2009) reported on the suitability of Patuflex leg tag (Reyflex ITW, 2010) application in 5-mo-old Murciano-Granadina goat kids. The authors measured the kids' metatarsal circumference (76 mm, on average), which was slightly greater than the value obtained in the current study and which corresponded to 86.7% of the circumference of adult goats (88 mm). The inner circumference of fastened LT ranged from 106 to 127 mm depending on the fastening adjustment. In the same study, LT displacement under the sesamoid bones was reported in 6 kids (25%). These tags had to be relocated to their original position on several occasions. The authors suggested an age of 6 mo for the application of LT in goats, which corresponded to 90% of adult metatarsal circumference and 40% of adult BW. Taking these findings into account, accurate assessment of the suitable inner circumference of LT for tagging at early ages seems critical for preventing both the displacement of devices in young goats and possible damage due to leg constriction in adult goats.

Regarding LT application, the overall time for leg tagging, transponder reading, and typing of ID data into the transceiver was 53 ± 3 s. This value is within the range of time obtained with standard RB used in adult goats of different breeds (52 to 55 s; Carné et al., 2009b).

Readability of ID Devices

At the end of the 1-yr study, 197 (89.6%) goats continued to be monitored. The remaining 23 goats died ($n = 5$) or were culled ($n = 18$) and replaced from another herd. Identification device readability in the milking parlor is shown in Table 1 and Figure 2; no readability progress for VE ear tags during the study is shown in Figure 2 as only 1 control at the end of the study was carried out. Apart from the 3 LT that had to be removed because they caused limping, no losses or breakages occurred during the experimental period. However, 1 (0.5%) LT had the end of the band partially unfastened, although the button transponder was functional and properly fastened. The loose end of a LT in such an event might lead to additional losses from biting or getting caught on the premises.

Although 7 RB were lost, no difference between LT visual readability and RB readability was detected (98.5 vs. 96.5%, respectively; $P = 0.213$). Most LT had to be manually cleaned to allow for visual readability of the printed codes. Bolus readability remained within

Table 1. Readability of leg tags, rumen boluses, and visual and electronic ear tags in adult dairy goats during a 1-yr study¹

Item	Button transponders				Ear tags		
	LT	ET1	ET2	Overall	RB	EE	VE
Applied, n	220	90	130	220	220	47	220
Monitored, n	197	78	116 ²	194 ²	197	46	197
Removed, n (%)	3 (1.5) ³	0	0	0	—	0	0
Lost, n (%)	0	3 (3.9)	2 (1.7)	5 (2.6)	7 (3.5)	2 (4.3)	6 (3.0)
Damaged, n (%)	0	2 (2.6) ⁴	0	2 (1.0)	0	0	49 (24.9) ⁵
Readability, %	98.5 ^a	93.6 ^b	98.3 ^{ab}	96.4 ^{ab}	96.5 ^{ab}	95.7 ^{ab}	97.0 ^{ab}

^{a,b}Within a row, values with different superscripts differ ($P < 0.05$).

¹Devices: LT = plastic leg tag with a 3-digit code printed for individual visual identification (weight, 21 g; length $\times$ width, 181 $\times$ 39 mm; thickness, 2.2 mm; Animalcomfort, Jumilla, Murcia, Spain); ET1 = half-duplex button transponder (weight, 3.9 g; o.d., 26 mm; Azasa-Allflex, Madrid, Spain) attached to LT; ET2 = half-duplex button transponder (weight, 5.5 g; o.d., 25 mm; Rumitag, Esplugues de Llobregat, Barcelona, Spain) attached to LT; RB = ceramic rumen bolus (weight, 75 g; length $\times$ o.d., 68 $\times$ 21 mm; encasing a 32-mm half-duplex glass-encapsulated transponder; Rumitag); EE = half-duplex electronic button-button ear tag (weight, 5.9 g; o.d., 24 mm; Azasa-Allflex); VE = visual ear tag for official use (weight, 4.2 g; flag dimensions, 38 $\times$ 40 mm; Azasa-Allflex).

²Button transponders attached to the 3 LT removed were excluded from the Logit model analyses.

³Removed because of limping: 1 LT caused constriction of an inflamed leg; 2 LT got blocked between the sesamoid bones and the hoof.

⁴Damaged devices were unreadable.

⁵Breakage of the flag part in 45 (22.8%) ear tags was observed, resulting in button-like devices; all printed codes on the button piece were visually readable.

Figure 2. Evolution of readability of identification devices throughout 1-yr study in dairy goats: LT (■), RB (●), ET1 (▲), ET2 (△), and EE (◆), where LT = plastic leg tag with a 3-digit code printed for individual visual identification (weight, 21 g; length × width, 181 × 39 mm; thickness, 2.2 mm; Animalcomfort, Jumilla, Murcia, Spain); ET1 = half-duplex open button transponder (weight, 3.9 g; o.d., 26 mm; Azasa-Allflex, Madrid, Spain) attached to LT; ET2 = half-duplex closed button transponder (weight, 5.5 g; o.d., 25 mm; Rumitag, Esplugues de Llobregat, Barcelona, Spain) attached to LT; RB = ceramic-made rumen bolus (weight, 75 g; length × o.d., 68 × 21 mm; Rumitag); EE = half-duplex electronic button-button ear tag (weight, 5.9 g; o.d., 24 mm; Azasa-Allflex).

the wide range (92.0 to 99.6%) previously reported at 1 yr after administration in goats identified with similar bolus types (Capote et al., 2005; Pinna et al., 2006; Carné et al., 2009b).

At the end of the study, no electronic failures for ET1 or ET2 were detected. On the other hand, ET1 losses were not greater than those of ET2 (6.4 vs. 1.7%, respectively; $P = 0.110$). Because of losses or damages, button transponder readability was 96.4% (Table 1).

Unfastening force of LT by using ET1 button transponders was greater than with ET2 (421.4 ± 6.5 vs. 394.0 ± 3.8 N; $P < 0.05$), although both were above the threshold of 280 N indicated by the ICAR (2009) for the unfastening or breakage of ear tags used for official animal ID. Therefore, observed ET1 and ET2 losses are likely preceded by button breakage; in 2 (1.7%) ET1 losses, we observed parts of the button still attached to the LT.

On the other hand, because the LT design did not prevent the tag's movements around the metatarsus, the influence of the attached transponder location (lateral, medial, front, or rear) on LT breakage remains a topic for further research. The LT design used in our study allows for encasing a glass-encapsulated transponder as an alternative to the button transponder; readability performance with this sort of transponder should be

thoroughly evaluated as well. Recently, other LT designs with the transponder encased in the plastic body have appeared (Hilpert et al., 2009; Reyflex ITW, 2009; ICAR, 2010). An on-field study has been carried out in France since 2007 to evaluate the performance of visual and RFID LT in dairy goats (Balvay, 2010). Leg tag losses and electronic readability in French adult goats ranged from 1 to 12% and 95.5 to 98.4%, respectively, depending on time elapsed (6 to 16 mo) and LT model. Visual LT, which are enlargeable and allow for application in replacement does before 6 mo of age, showed losses similar to those for RFID leg tags, but had lower visual readability (90%). Irrespective of the retention obtained, a posteriori modification of the inner circumference of LT prevents their use as tamperproof devices to fulfill current EU regulations (EC 21/2004 and EC 933/2008).

With regard to EE, only 1 goat left the study. At 1 yr, 2 losses were registered, thereby leading to a readability of 95.7%. Moreover, 1 EE occasionally failed. Carné et al. (2009a) obtained 100% readability during a 3-yr study using similar button-button RFID ear tags applied to replacement Murciano-Granadina kids. The button ear tags were suggested to reduce the occurrence of losses, given that flag-button RFID ear tags showed a lower retention rate in the same experimental

Table 2. Estimated readability of identification devices with Kaplan-Meier non-parametric survival analysis and log-rank tests between devices in dairy goats throughout 1-yr study¹

Item	Button transponders				RB	EE
	LT	ET1	ET2	Overall		
Applied, n	220	90	130	220	220	47
Censored data, ² n	23	12	14	26	23	1
Events, ³ n	3	5	2	7	7	2
Readability estimates, %	98.6 ^a	94.1 ^{b,x}	98.4 ^{ab,y}	96.7 ^{ab}	96.6 ^{ab}	95.7 ^{ab}

^{a,b}Within a row, values with different superscripts differ ($P < 0.05$).

^{x,y}Within a row, values with different superscripts differ ($P < 0.10$).

¹Devices: LT = plastic leg tag with a 3-digit code printed for individual visual identification (weight, 21 g; length $\times$ width, 181 $\times$ 39 mm; thickness, 2.2 mm; Animalcomfort, Jumilla, Murcia, Spain); ET1 = half-duplex button transponder (weight, 3.9 g; o.d., 26 mm; Azasa-Allflex, Madrid, Spain) attached to LT; ET2 = half-duplex button transponder (weight, 5.5 g; o.d., 25 mm; Rumitag, Esplugues de Llobregat, Barcelona, Spain) attached to LT; RB = ceramic rumen bolus (weight, 75 g; length $\times$ o.d., 68 $\times$ 21 mm; encasing a 32-mm half-duplex glass-encapsulated transponder; Rumitag); EE = half-duplex electronic button-button ear tag (weight, 5.9 g; o.d., 24 mm; Azasa-Allflex).

²Devices that left the study before 1 yr without an event being recorded.

³Unreadable devices.

conditions (Carné et al., 2009a). In an 8-mo large-scale study ($n = 2,620$), Schuiling et al. (2004) reported 5.1% losses in adult goats identified with different types of RFID ear tags. Moreover, 1.6% electronic failures were registered, for a final readability rate of 93.3%. In addition, remarkable variability in losses (0 to 7.1%) and electronic failures (0 to 2.9%) between herds was observed, with our data supporting the aforementioned ranges.

Performance of compulsory official VE used in Spain at the time this work was carried out was evaluated at the end of the experiment. A total of 6 VE losses (3.0%) were identified, although damage to flag pieces was observed in 24.9% of cases; 22.8% corresponded to the breakage of a part of the flag piece near the base, making the VE appear as button-like devices. These broken ear tags usually were not replaced by the veterinary officials during the annual blood sampling of goat herds in Catalonia, Spain. In sheep, losses of this type of official ear tag averaged 3.3%, although no reference to damages was made (Ghirardi et al., 2006).

Only the visual readability of LT and electronic ET1 differed ($P < 0.05$) at the end of the study, corresponding to the highest and lowest readability results obtained, respectively. Furthermore, only LT visual readability and ET2 electronic readability were greater than 98%, as recommended by the ICAR for extended field tests lasting 1 yr (ICAR, 2009).

Results of estimated readability of ID devices, obtained with the Kaplan-Meier survival analysis, are shown in Table 2. This analysis permitted the incorporation of data corresponding to goats that could not be monitored until the end of the 1-yr study. Differences between actual and estimated readability were low, ranging from 0.1 to 0.5%; this was mainly due to the

high number of devices being monitored at the end of the study. As previously observed for actual results, estimated values of ET1 electronic readability and LT visual readability differed ($P < 0.05$). Moreover, ET1 and ET2 estimates tended to differ ($P = 0.08$). On the other hand, and similar to actual data, no differences ($P > 0.1$) between LT, RB, and EE were detected.

Static Reading Efficiency of LT and Boluses in the Milking Parlor

Results regarding to reading efficiency of LT with electronic transponders (ET2) and RB in static conditions from the pit side in the milking parlor are reported in Table 3. Due to the distance between EE and the operator placed in the pit of the milking parlor, EE reading was not possible. Reading time of ET2 in the milking parlor was 25% lower ($P < 0.001$) than for RB. This was due to easier access to the ET2 from the rear position of the animal, as the operator was located in the pit of the milking parlor. In the case of RB, the stick antenna was positioned close to the cranial left-side abdominal area, as boluses mostly remain in the reticulum of domestic ruminants (Garín et al., 2003; Castro et al., 2004; Antonini et al., 2006).

The RB individual reading time (Table 3), obtained when reading the RB from the rear of the goats, supported previous reports (2.4 to 4.0 s) by Caja et al. (1996) for boluses administered to dairy sheep, in a similar milking parlor. In contrast, ET2 individual reading time was lower than that obtained for RB ($P < 0.001$; Table 3). Similarly, low individual reading times for electronic ear tags (1.9 to 2.8 s) were reported in dairy sheep read from the front in the milking parlor.

Table 3. Comparison of static reading efficiency in the milking parlor of half-duplex button transponders attached to leg tags, and rumen boluses in dairy goats with a handheld transceiver connected to a stick antenna (values are least squares means $\pm$ SE)¹

Item	Device ²		<i>P</i> <
	RB	ET2	
Readings, ³ n	720	720	—
Group reading time, ⁴ s/24 goats	61.2 $\pm$ 1.0	45.9 $\pm$ 0.7	0.001
Unitary reading time, s/goat	2.6 $\pm$ 0.1	1.9 $\pm$ 0.1	0.001
Static reading efficiency			
Reading failures, n	0	0	— ⁵
False readings, ⁶ n	2 (0.3%)	0	— ⁵
Readability, %	99.7	100	— ⁵

¹Smart Reader (Rumitag, Esplugues de Llobregat, Barcelona, Spain) connected to a 70-cm stick antenna.

²Devices: RB = ceramic rumen bolus (weight, 75 g; length $\times$ o.d., 68 $\times$ 21 mm; encasing a 32-mm half-duplex glass-encapsulated transponder; Rumitag); ET2 = half-duplex button transponder (weight, 5.5 g; o.d., 25 mm; Rumitag).

³Number of read devices, carried out in groups of 24 goats in the milking parlor.

⁴Groups of 24 goats in a double 12-stall parallel (side-by-side) milking parlor.

⁵No statistical contrasts could be carried out when no reading incidences or 100% readability were registered.

⁶Readings of transponders from adjacent goats in the milking parlor.

As anticipated, no crossed reading with goats to the right in the milking parlor occurred. Crossed readings might occur if the reader intended to read a goat that had lost its RB. In addition to crossed readings, in 3 (0.4%) cases the transceiver was unable to read the RB after having the electromagnetic field activated for 2 s (as previously configured in the transceiver settings); in these cases, successful readings were accomplished at the second reading attempt. Ait-Saidi et al. (2008) found 0.6% of reading errors in similar experimental conditions when carrying out semi-automated milk recordings. In our work, the aforementioned reading methodology and transceiver configuration for avoiding duplicate recording prevented mistaken assigning of the transponder to a different goat.

Dynamic Reading Efficiency of LT and RB

Results of dynamic reading performance of RB and ET2 in a runway are in Table 4. The speed of passage of goats through the runway was slower ($P < 0.05$) when goats were forced to pass through the antenna, as goats tended to slow down just before passing through it. Nevertheless, the speed of passage was in all cases less than 1 goat/s, which supports conditions for proper dynamic reading (JRC, 2003; Ghirardi et al., 2006). Goats in our study wore both RB and ET2 transponders (estimated distance between transponders is nearly 30 cm), which led to difficulty as herds were identified with several types of RFID devices. Under such conditions, the incidence of reading collisions due to the presence of more than 1 transponder inside the electromagnetic field generated by the transceiver was maximized and

resulted in some portion of the transponder reading failures. Dynamic reading efficiency results (Table 4) demonstrate that the greatest reading efficiency was obtained when RB were read with the antenna located laterally to the left of the runway. The next best efficiencies were obtained with RB when goats had to pass through the antenna, as well as for ET2 read with the antenna placed on the floor. No antenna location offered maximum reading performance for both types of devices. The best antenna position for ET2 reading was the worst option for a proper RB reading. As anticipated, the reading collision reduced the reading efficiency of devices, when compared with previous studies with sheep identified with standard-sized electronic boluses, and under similar reading conditions, in which average dynamic reading efficiencies $>99\%$ were obtained (Ghirardi et al., 2006). Likewise, the only reference available, to our knowledge, on the dynamic reading efficiency of RB using a frame antenna located on the floor of a runway yielded 74.2% efficiency (MAPA, 2007), which was higher than the value obtained in our study.

With regard to the performance of transponders attached to LT, no literature on their dynamic reading efficiency is available. Nevertheless, a dynamic reading efficiency of 99.7% was reported when 15-mm transponders were injected in the foreleg pastern of Murciano-Granadina adult goats and the transceiver's antenna was placed on the floor (MAPA, 2007).

In our study, only RB read with the lateral antenna reached the 95% minimum dynamic reading efficiency recommended by MAPA (2007) for sheep and goat ID under field conditions. The recommended minimum value allows $>99.7\%$ readability of electronic devices

Table 4. Dynamic reading efficiency of electronic rumen boluses and button transponders attached to leg tags in dairy goats according to the position of the transceiver's antenna¹

Antenna position	Speed of passage, goats/min	RB		ET2		P<
		n	DRE, %	n	DRE, %	
Lateral	54 ± 3.7 ^a	495	95.2 ± 1.7 ^a	525	68.2 ± 3.4 ^c	0.001
Floor	49 ± 3.2 ^a	495	16.0 ± 1.3 ^b	525	92.4 ± 1.9 ^a	0.001
Passing through	40 ± 3.1 ^b	363	93.0 ± 1.9 ^a	385	83.4 ± 1.5 ^b	0.001

^{a-c}Within a column, values with different superscripts differ ($P < 0.05$).

¹Dynamic reading efficiency measured by assessing number of goats passing through a runway (width, 50 cm) fitted with a frame antenna (94 × 52 mm; Tiris, Almelo, the Netherlands) connected to an F-210 portable stationary transceiver (Rumitag, Esplugues de Llobregat, Barcelona, Spain); DRE = (n read devices/n readable devices) × 100. Devices: RB = ceramic rumen bolus (weight, 75 g; length × o.d., 68 × 21 mm; encasing a 32-mm half-duplex glass-encapsulated transponder; Rumitag); ET2 = half-duplex button transponder (weight, 5.5 g; o.d., 25 mm; Rumitag) attached to a leg tag. Reading sessions carried out in groups of 22 to 35 goats.

when 2 consecutive readings of the same herd are performed and the obtained ID data files are combined. For LT and RB in our study, final readability values of 99.4 and 99.8% would be obtained if 2 consecutive readings were performed with the antenna placed on the floor or laterally, respectively.

CONCLUSIONS

Leg tags in the hind leg of adult goats offered suitable (>98%) visual and electronic readability. Nevertheless, both the design and inner circumference of the fastened LT should be thoroughly evaluated to avoid causing limping, as was observed in some cases of early LT application in replacement stock. In this study, standardized RB and electronic ET did not reach recommended readability rates (>98%) for official identification of goats.

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REFERENCES

- Abecia, J. A., and J. Torras. 2009. Aplicación de la pulsera electrónica Patuflex: Identificación de corderas y cabritas de reposición. *Albéitar* 129:54–57.
- Ait-Saidi, A., G. Caja, S. Carné, A. A. K. Salama, and J. J. Ghirardi. 2008. Comparison of manual vs. semi-automatic milk recording systems in dairy goats. *J. Dairy Sci.* 91:1438–1442.
- Antonini, C., M. Tralbalza-Marinucci, R. Franceschini, L. Muggetti, G. Acuti, A. Faba, G. Asdrubali, and C. Boiti. 2006. In vivo mechanical and in vitro electromagnetic side-effects of a ruminal transponder in cattle. *J. Anim. Sci.* 84:3133–3142.
- ACRIMUR. 2010. La cabra Murciano-Granadina: Estándar racial. <http://www.acrimur.es/lacabra.php> Accessed Feb. 10, 2010.
- Balvay, B. 2007. L'identification électronique dans la filière caprine. I Journées techniques caprines. http://www.inst-elevage.asso.fr/html1/IMG/pdf_CR_120757002.pdf Accessed Feb. 10, 2010.
- Balvay, B. 2010. Identification électronique: Présentation du projet «RFId Caprine». Institut de l'Élevage. http://www.inst-elevage.asso.fr/html1/IMG/pdf_Actualites_de_la_filiere.pdf Accessed Apr. 23, 2010.
- Caja, G., F. Barillet, R. Nehring, C. Marie, O. Ribó, E. Ricard, G. Lagriffoul, C. Conill, M. R. Aurel, and M. Jacquin. 1996. Comparison of different devices for electronic identification in dairy sheep. Pages 349–353 in *Performance Recording of Animals*. EAAP Publication No. 87. J. Renaud and J. van Gelder, ed. Wageningen Pers, Wageningen, the Netherlands.
- Caja, G., C. Conill, R. Nehring, and O. Ribó. 1999. Development of a ceramic bolus for the permanent electronic identification of sheep, goat and cattle. *Comput. Elec. Agric.* 24:45–63.
- Capote, J., D. Martín, N. Castro, E. Muñoz, J. Lozano, S. Carné, J. J. Ghirardi, and G. Caja. 2005. Retención de bolos ruminales para identificación electrónica en distintas razas de cabras españolas. *ITEA Prod. Anim.* 26(Vol. extra):297–299.
- Carné, S., G. Caja, J. J. Ghirardi, and A. A. K. Salama. 2009a. Long-term performance of visual and electronic identification devices in dairy goats. *J. Dairy Sci.* 92:1500–1511.
- Carné, S., T. A. Gipson, M. Rovai, R. C. Merkel, and G. Caja. 2009b. Extended field test on the use of visual ear tags and electronic boluses for the identification of different goat breeds in the United States. *J. Anim. Sci.* 87:2419–2427.
- Castro, A., D. Martín, J. L. López, M. C. Montesdeoca, and J. Capote. 2004. Efecto de la identificación electrónica con bolo ruminal en los parámetros histológicos de los estómagos de cabritos. Pages 88–90 in *XXIX Jornadas Científicas de la SEOE, Lleida, Spain*.
- Cox, D. R. 1970. *The Analysis of Binary Data*. Chapman & Hall, London, UK.
- Fosgate, G. T., A. A. Adesiyun, and D. W. Hird. 2006. Ear-tag retention and identification methods for extensively managed water buffalo (*Bubalus bubalis*) in Trinidad. *Prev. Vet. Med.* 73:287–296.

- Garín, D., G. Caja, and F. Bocquier. 2003. Effects of small ruminal boluses used for electronic identification of lambs on the growth and development of the reticulorumen. *J. Anim. Sci.* 81:879–884.
- Ghirardi, J. J., G. Caja, D. Garín, M. Hernández-Jover, O. Ribó, and J. Casellas. 2006. Retention of different sizes of electronic identification boluses in the forestomachs of sheep. *J. Anim. Sci.* 84:2865–2872.
- Hilpert, J. J., J. H. Le Drean, and B. Ravina, inventors. 2009. Device for identifying animals. International Cooperation Treaty (PCT) Publ. No. WO 2009/034058. Allflex Europe SAS, assignee.
- ICAR. 2009. International Agreement of Recording Practices. Guidelines approved by the General Assembly, Niagara Falls, NY, June 2008. International Committee for Animal Recording, Rome, Italy.
- ICAR. 2010. Animal identification: List of manufacturer codes. http://www.service-icar.com/Manufacturers_DB/_manufacturer_codes_main.asp Accessed Jan. 10, 2010.
- ISO. 1996a. Agricultural equipment. Radio-frequency identification of animals-Code structure. ISO 11784:1996 (E). 2nd ed. Geneva, Switzerland.
- ISO. 1996b. Agricultural equipment. Radio-frequency identification of animals-Technical concept. ISO 11785:1996 (E). 2nd ed. Geneva, Switzerland.
- JRC. 2003. IDEA Project, large scale project on livestock electronic identification. Final Report. v. 5.2. <http://idea.jrc.it/pages%20idea/final%20report.htm> Accessed Dec. 20, 2009.
- MAPA. 2007. Identificación electrónica animal: Experiencias del MAPA. MAPA, Madrid, Spain.
- Pinna, W., P. Sedda, G. Moniello, and O. Ribó. 2006. Electronic identification of Sarda goats under extensive conditions in the island of Sardinia. *Small Rumin. Res.* 66:286–290.
- Reyflex ITW. 2009. Patuflex RFID device. <http://www.reyflex.com/en/produits-el-patuflex.php> Accessed Jan. 10, 2009.
- Saa, C., M. J. Milán, G. Caja, and J. J. Ghirardi. 2005. Cost evaluation of the use of conventional and electronic identification and registration systems for the national sheep and goat populations in Spain. *J. Anim. Sci.* 83:1215–1225.
- Schuilting, H. J., J. Verkaik, G. Binnendijk, P. Hogewerf, D. Smits, and B. van der Fels. 2004. Elektronische oormerken voor I&R bij schapen en geiten. PraktijkRapport Schapen 02. Animal Sciences Group, Wageningen, the Netherlands.