Comparison of visual and electronic devices for individual identification of dromedary camels under different farming conditions[1]

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ABSTRACT: The camel industry uses traditional (i.e., iron brands and ear tags) and modern (i.e., microchips) identification (ID) systems without having performance results of reference. Previously iron-branded (*n* = 45; 1 yr) and microchipped (*n* = 59; 7 yr) camels showed problems of healing (8.6% of brands) and reading (only 42.9% of brands and 69.5% of microchips were readable), which made their use inadvisable. With the aim of proposing suitable ID systems for different farming conditions, an on-field study was performed using a total of 528 dromedaries at 4 different locations (Egypt, *n* = 83; Spain, *n* = 304; Saudi Arabia, *n* = 90; and Tunisia, *n* = 51). The ID devices tested were visual (button ear tags, 28.5 mm diameter, *n* = 178; double flag ear tags, 50 by 15 mm, *n* = 83; both made of polyurethane) and electronic (ear tags, *n* = 90, and rumen boluses, *n* = 555). Electronic ear tags were polyurethane-loop type (75 by 9 mm) with a container in which a 22-mm transponder of full-duplex technology was lodged. Electronic boluses of 7 types, varying in dimensions (50 to 76 mm length, 11 to 21 mm width, and 12.7 to 82.1 g weight) and specific gravity (SG; 1.49 to 3.86) and each of them containing a 31-mm transponder of half-duplex technology, were all administered to the dromedaries at the beginning of the study. When a low-SG bolus was lost, a high-SG bolus was readministered. Readability rates of each ID system were evaluated during 1 to 3 yr, according to device and location, and yearly values were estimated for comparison. On a yearly basis, visual ear tag readability was not fully satisfactory; it was lower for rectangular ear tags (66.3%) than for button ear tags (80.9%). Yearly readability of electronic ear tags was 93.7%. Bolus readability dramatically varied according to their SG; the SG < 2.0 boluses were fully lost after 8 mo. In contrast, the SG > 3.0 boluses were efficiently retained (99.6 to 100%) at all locations. In conclusion, according to the expected long lifespan of camels, low ID performances were observed for iron brands, injectable microchips, and ear tags (visual and electronic), making their use inadvisable as unique ID systems in camels. The high readability of dense electronic boluses recommended their use as a permanent ID device of reference in camels.

Key words: bolus, ear tag, iron brand, radio frequency, transponder

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INTRODUCTION

Worldwide, there are 27 million of the Old World camels (FAO, 2015), where near 90% of them are dromedaries (*Camelus dromedarius* L.) or Arabian camels, spreading all over the arid flat lands between the 0 and 40°N (from the Canary Islands to Rajasthan) and the 20 and 30°S (Australian deserts) parallels. Camels are culturally reverenced and economically appreciated by their strategic values (i.e., milk, meat, draft, manure, hair, and hides), but there are also some concerns related to their overgrazing (El-Keblawy et al., 2009) and feral herds (Dennis et al., 2010) and to endemic (Fassi-Fehri, 1987) and emergent diseases (e.g., Middle East respiratory syndrome coronavirus; Chu et al., 2014). Dromedaries show a long lifespan (approximately 30 yr) and few distinctive coat traits, making a necessity to use the artificial marks for individual identification (**ID**). Traditional camel ID is based on the use of clan or family symbols ("wasm" or "lealama" in Arabic) engraved by red iron brands on visible body sites (e.g., cheek, neck, thigh). However, branding is questioned today for welfare reasons and is inadequate for modern ID and traceability standards. Modernization of livestock farms led to the adoption of ID devices (Caja et al., 2004) such as visual (e.g., brands, tattoos, ear tags, and collars) and electronic (e.g., injectables, ear tags, and boluses). Despite the sedentarization of herds and the creation of intensive dairy farms (Faye et al., 2012), little attention has been paid to camel ID and traceability. Camels are absent from the terrestrial animal health code of the World Organization for Animal Health (OIE, 2016), the Codex Alimentarius (WHO-FAO, 2016), or the guidelines of ICAR (2016). Camel ID is only regulated in the Emirate of Abu Dhabi based on the use of radio-frequency identification (**RFID**) injectable transponders or microchips (ADFCA, 2010). To our knowledge, however, there are no studies evaluating the performance of different ID devices in camels. Therefore, the aim of this research was to compare the performances of using visual vs. electronic camel ID systems in a wide range of geographical locations and different farming conditions.

MATERIALS AND METHODS

Animal care and experimental procedures used in this study were approved by the Ethical Committee on Animal and Human Experimentation (reference 3189) of the University Autonoma of Barcelona and followed the guidelines for animal performance recording of the Spanish Committee of Animal Electronic Identification (MAPA, 2007) and of ICAR (2016)

Animal and Management

Evaluation of the ID systems was conducted under a randomized incomplete block design performed at 4 locations using a total of 528 dromedaries of different breeds, ages, and farming conditions (stabled or grazing). These locations were 1) Egypt (Maghrebi breed, n = 83), 2), Spain (Canarian breed, n = 304), 3) Saudi Arabia (Maghatir breed, n = 37, and Majaheem breed, n = 53), and 4) Tunisia (Maghrebi breed, n = 51). All farms were located between the 28 and 34°N parallels, where the camel is habitual, and followed similar production cycles with natural mating and calving during the winter season.

Location Number 1 (Egypt). The camel farm was located at the Camel Experimental Station of the Animal Production Research Institute in Marsa Matrouh (Matrouh Governorate, Egypt) where 83 Maghrebi female dairy camels averaging 5.7 ± 0.5 yr (range 1.1 to 13.8 yr) and 461 ± 13 kg BW (range 248 to 691 kg BW) and in different physiological stages (open, pregnant, and lactating) were used. They were stabled in loose stalls on sand-bedded pens and fed berseem clover hay (1 to 2.5 kg/d), rice straw (1 to 2.0 kg/d), saltbush (1 to 2.0 kg/d), and concentrate (0.5 to 3.5 kg/d) according to their requirements (Wilson, 1989). Water was freely available in water troughs. Lactating camels were milked twice a day by hand after camel-calf stimulation.

Location Number 2 (Spain). The camel farm was located at the Oasis Park-Museo del Campo Majorero (La Lajita, Fuerteventura, Canary Islands, Spain) where 296 Canarian dromedaries of different ages (newborn, suckling, growing, and adult), physiological stages (open, pregnant, and lactating), gender (males, females, and castrates), and uses (camel rides and dairy camels) were used. All camels were stabled in loose stalls on sand-bedded pens and fed alfalfa hay (1 to 2.5 kg/d), palm fronds (1 to 1.5 kg/d), thornless acacia branches (*Acacia salicina* Lindl.; 1 to 2.0 kg/d), and concentrate (0.5 to 3.5 kg/d) according to their requirements (Wilson, 1989). Water and mineral blocks were freely available. Lactating camels suckled their calves for 1 yr and were machine milked once a day using a 2-stall tunnel milking parlor with a portable bucket machine.

Location Number 3 (Saudi Arabia). A total of 90 dairy camels aged 1 to 15 yr, located at the Al-Watania Agri farm (Al Jouf, Saudi Arabia; n = 50) and the Camel and Rangeland Research Center (Al Jouf, Saudi Arabia; n = 40), of 2 breeds (Maghatir or bright, n = 37, and Majaheem or dark, n = 53) and in different physiological stages (open, pregnant, and lactating) were used. Milking and growing camels were in loose stalls on sand-bedded pens, and dry and pregnant camels were under free-rangeland grazing conditions. Yearling camels were fed alfalfa hay (1 to 2 kg/d), concentrate (1.0 kg/d), and barley straw ad libitum. Lactating camels were fed alfalfa hay (2 to 5 kg/d), barley straw and corn stalks (2 to 7 kg/d), and concentrate (0.5 to 2 kg/d) according to their requirements (Wilson, 1989). Water and mineral blocks were freely available inside the pens. Lactating camels suckled their calves for 6 mo and were machine milked twice a day using a 10-stall tunnel and low milk pipeline (Al-Watania Agri farm) and a 2-stall tunnel with a portable bucket machine (Camel and Rangeland Research Center) milking parlors.

Location Number 4 (Tunisia). The camel farm was located at the Laboratory of Animal Husbandry and Wildlife of the Arid Regions Institute in Medénine (Tunisia) where a total of 51 Maghrebi dairy dromedaries (adult females 7 to 15 yr, n = 50, and yearling, n = 1) were used. Adult camels grazed during the day on saline rangelands and were sheltered during the night on sand-bedded pens and fed barley straw. Lactating camels suckled their calves for 6 mo and were fed concentrate at a flat rate of 4 kg/d (as fed) during the lactation period and were machine milked twice a day using a single milking stall and a portable bucket machine. The yearling camel was fattened with concentrate (1.5 kg/d) and barley straw ad libitum and was slaughtered 8 mo after identification. Water and mineral blocks were freely available in the shelter.

Identification Devices

Previous Identification. Forty-five adult Maghrebi camels (age > 7 yr) from location number 1 (Egypt) showed red iron brands (1 to 3 digits, 20 cm high) on the left thigh, which had been made by the technical personnel of the Camel Experimental Station of the Animal Production Research Institute 1 yr before the beginning of the study. These camels were used to assess the readability of the brand under on-farm conditions.

On the other hand, 59 adult castrated male Canarian camels (age 10 to 15 yr) from location number 2 (Spain), daily used for camel rides and previously injected (i.e., 7 yr before the beginning of the study) with glass-encapsulated RFID microchips, 12.0 by 2.1 mm, of full-duplex B technology according to ISO 11784:1996 (*Radio frequency identification of animals – Code structure*; ISO, 1996a) and ISO 11785:1996 (*Radio frequency identification of animals – Technical concept*; ISO, 1996b), were also used to assess the readability of the microchips. The injections were performed subcutaneously in the left side of the neck (at the halfway point between the ears and the withers) by the veterinarian of the Oasis Park-Museo del Campo Majorero according to the guidelines of the World Small Animal Veterinary Association (2016) for horses and camelids. Serial numbers of the injected microchips ranged from 982 009100063248 to 982 009100969093 (Azasa-Allflex, Madrid, Spain).

Visual Ear Tags. Two types of visual ear tags (**vET**) inserted in the left ear were used for camel visual ID: one was at location number 1 (**vET1**; n = 83; Egypt) and the other was at location number 2 (**vET2**; n = 304; Spain). The vET1 consisted of 2 rectangular flags of polyurethane (50 by 15 mm, 3 g; Hasco Tag Co., Dayton, KY), which were laser recorded with 3 digit numbers. The vET2 consisted of polyurethane double button ear tags (28.5 mm button diameter, 20.5 by 5.5 mm pin length by diameter, and 3.5 g total weight; Azasa-Allflex) and were laser recorded with an alphanumeric code consisted of 2 letters of the Spanish province (i.e., GC for Gran Canaria) followed by a serial code of 4 numbers and 2 letters (e.g., GC 3854 AB).

Electronic Ear Tags. Plastic-loop type electronic ear tags (**eET**) were applied in the left ear of 90 dromedaries at the Al-Watania Agri farm at the beginning of the study at location number 3 (Saudi Arabia). They consisted of white polyurethane (75.0 by 9.0 mm, length by width) with a pin-lock closing system (17.0 mm pin and 10.0 by 9.0 mm lock) and a container (31.0 by 9.0 mm) intended to lodge a glass encapsulated transponder of 22 by 4 mm and full-duplex B technology (Set-Tag; Shearwell Data Ltd., Minehead, Somerset, UK). The total weight of the eET was 2.5 g. Serial numbers of the microchips ranged from 940 000002204916 to 940 000002363335 (Shearwell Data Ltd.).

Electronic Rumen Boluses. Seven types of electronic rumen boluses (**eRB**; n = 555) varying in features were applied to all camels at all location sites. The eRB consisted of cylindrical capsules of different dimensions, made of several nontoxic and nonporous materials to reach different specific gravities (**SG**). Features of bolus types (eRB1 to eRB7) are shown in Table 1, where different ranges of capsule dimensions (50.0 to 76.4 mm length, 11.2 to 21.1 mm width, and 12.7 to 82.1 g weight) and SG (1.49 to 3.86) can be identified. Similar sizes and SG ranges of rumen boluses were previously used by Caja et al. (1999), Ghirardi et al. (2006a,b), and Carné et al. (2011) for assessing their readability in small and large domestic ruminants. It is worthwhile mentioning that when a low-SG bolus was lost, a high-SG bolus was readministered.

A random sample of 10 boluses of each type was collected to measure their physical features under laboratory conditions using a precision weighing scale (0.01 g accuracy; BP 3100 P; Sartorius AG, Göttingen, Germany) and a digital caliper (0.03 mm accuracy; Shaodong Feiyue Hardware Tools Factory, Yiwu, China). The SG of each bolus was measured according to the Archimedes principle by contrasting the weight of the bolus with the weight of its volume of displaced distilled water, similarly to Ghirardi et al. (2006a).

Table 1. Features of the electronic rumen boluses (eRB) used for the permanent identification of dromedary camels

Bolus code	Material	Electronic rumen bolus[1] features				Locations (country)				Total, no.
		Length by o.d., mm	Weight, g	Volume, mL	Specific gravity	1 (Egypt)	2 (Spain)	3 (Saudi Arabia)	4 (Tunisia)	
eRB1	Plastic[2]	50.0 by 15.0	12.7 ± 0.1	8.5 ± 0.1	1.49 ± 0.01	20	–	–	–	20
eRB2	Ceramic[3]	56.4 by 11.2	20.1 ± 0.2	5.2 ± 0.1	3.86 ± 0.01	17	138	–	–	155
eRB3	Plastic[2]	76.4 by 20.2	33.3 ± 0.3	22.1 ± 0.1	1.51 ± 0.01	15	–	–	–	15
eRB4	Ceramic[4]	67.7 by 16.9	51.6 ± 0.1	11.4 ± 0.1	3.59 ± 0.01	16	–	–	–	16
eRB5	Ceramic[5]	66.0 by 20.5	65.2 ± 0.1	21.0 ± 0.1	3.10 ± 0.03	–	20	–	51	71
eRB6	Ceramic[5]	68.0 by 21.0	75.1 ± 0.3	22.4 ± 0.1	3.35 ± 0.01	50	114	90	–	254
eRB7	Ceramic[6]	68.0 by 21.1	82.1 ± 0.2	22.8 ± 0.1	3.60 ± 0.01	–	24	–	–	24
–	Total, no.	–	–	–	–	118	296	90	51	555

[1]Each bolus contained a half-duplex glass encapsulated transponder (31 by 3.8 mm; Datamars Trazabilidad SL Barcelona, Spain).

[2]Hand-made prototype consisting of a plastic tube filled with concrete.

[3]Prototypes made of aluminiun oxide, Esplugues de Llobregat, Barcelona, Spain).

[4]Standard commercial bolus of aluminiun oxide (Teramo, Italy).

[5]Standard commercial bolus of aluminiun oxide (Datamars Trazabilidad SL).

[6]Standard commercial bolus of zirconium oxide (Rumitag).

Boluses were applied by trained operators according to the procedure described by Caja et al. (1999) and Carné et al. (2009a), using livestock balling guns (Datamars Trazabilidad SL, Barcelona, Spain) adapted to each bolus type. The full set of boluses (eRB1 to eRB7) was tested at locations number 1 and 2 in camels of all ages (newborn to adult) under intensive conditions to assess the ease of administration and the bolus readability at the mid-term (3 yr) duration. At locations number 3 and 4, only boluses of type eRB6 and eRB5, respectively, were administered to adult camels to confirm their retention at the mid term (3 yr) in adult camels under grazing conditions. Low-SG boluses were designed to be lost with the aim of determining the threshold of bolus features to be retained in camels. All boluses contained a 31 by 3.8 mm glass encapsulated transponder of half-duplex technology (Ri-Trp-RR2B-06; The Animal Registration and Identification System [Tiris], Almelo, the Netherlands) that worked at a low frequency (134.2 kHz) in agreement with the current standards of the International Organization for Standardization (**ISO**) on animal electronic ID (ISO, 1996a,b, 2009).

Reading of Identification Devices

Visual Devices. Readability of each digit of the previous iron brands was made by sight at the beginning of the study at location number 1 (Egypt), and the results were manually recorded. Readability of the alphanumeric code of vET (vET1 and vET2) at locations number 1 (Egypt) and 2 (Spain) was also assessed by sight and the ID codes were manually recorded after 1 yr of insertion. When retained, the readable ear tags were not broken or seriously damaged. Any official ear tag lost at location number 2 (Spain) was replaced by veterinary officers only at the annual blood sampling campaign for camel tuberculosis. No replacement was done at the other location sites.

Electronic Devices. Readability of all RFID or electronic ID devices (i.e., microchips, eET, and eRB) was performed using full-ISO handheld transceivers, connected to a 70-cm-long stick antenna (GasISO; Datamars Trazabilidad SL) that is able to read ISO RFID transponders of half-duplex and full-duplex B technologies at a minimum distance of 12 and 20 cm for ear tags and boluses, respectively, as established by European Commission regulations EC 21/2004 (EC, 2004) and EC 933/2008 (EC, 2008b) on this issue. Gesreader 2S (Rumitag, Esplugues de Llobregat, Barcelona, Spain) handheld readers were used in at locations number 1 (Egypt), 3 (Saudi Arabia), and 4 (Tunisia), whereas the Gesreader 3 (Datamars Trazabilidad SL) was used at location number 2 (Spain).

Microchips previously injected at location number 2 were individually read at the beginning of the study while the camels were restrained in a sitting-down position. Readability of eET and eRB was evaluated under static conditions using the above-indicated handheld transceivers and stick antennas while the camels were in a standing position and restrained in a raceway (locations number 1, 2, and 4) or inside the milking parlor (location number 3). The time required for reading each ID device type was recorded at locations number 2 and 3 using an electronic chronometer (Geonaute Trt´L 100; Decathlon, Alcobendas, Spain).

Periodical readings of RFID devices were performed at different time intervals according to the location sites: d 0, 1, 2, 7, 14, 21, 30, 60, 120, 150, 180, and 210; at 2-mo intervals until yr 1.5; and finally at 3 yr at location number 1. Similar time intervals were used at locations number 2, 3, and 4 from 0 to 180 d and later every 6 mo until yr 3. Each device was read immedi-

Table 2. Actual performances of different identification systems in dairy camels and estimated readability in the long term

Identification system	Identification devices, no.		Years of study	Actual readability rate,[1] %	Yearly losses,[2] %	Estimated readability after[3]	
	Applied	Readable				10 yr, %	25 yr, %
Iron branding[4]	45	19	1	42.2	57.8	0	0
Injectable microchips[5]	59	41	7	69.5	5.1	59.5	27.3
Visual ear tags			1				
Rectangular flags[6]	83	55	1	66.3[b]	33.7	1.6	0
Button[7]	178	144	1	80.9[a]	19.1	12.0	0.5
Electronic ear tags[8]	90	74	3	82.2[a]	6.3	52.1	19.6
Total ear tags	351	–	–	–	–	–	–
Electronic rumen boluses (eRB)[9]							
eRB1	20	0	3	0[c]	100	0	0
eRB2	155	152	3	98.1[b]	0.4	95.8	89.7
eRB3	15	0	3	0[c]	100	0	0
eRB4	16	16	3	100[a]	0	100	100
eRB5	71	71	3	100[a]	0	100	100
eRB6	254	253	3	99.6[b]	0.1	98.7	96.8
eRB7	24	24	3	100[a]	0	100	100
Total rumen boluses	555	516	–	–	–	–	–

[a–c]Within the same identification system (i.e., ear tag or rumen bolus), values of readability with different superscripts differ ($P < 0.05$).

[1]Calculated as readability (R) = (number of readable devices/number of applied devices) × 100.

[2]Estimated as 100 − R_Y, in which R_Y is the yearly readability rate = $(R/100)^{1/Y} \times 100$, in which Y is the duration of the study in years.

[3]Estimated values of R, after 10 and 25 yr, respectively, using the corresponding values of R_Y previously calculated.

[4]Red iron brands (1 to 3 digits; 20 cm high).

[5]Glass encapsulated microchips of 12.0 by 2.1 mm of full-duplex B technology (Azasa-Allflex, Madrid, Spain).

[6]Two rectangular flags of polyurethane (50 by 15 mm; Hasco Tag Co., Dayton, KY).

[7]Double button of polyurethane (28.5 mm diameter; Azasa-Allflex).

[8]Plastic bands made of white polyurethane (75.0 by 9.0 mm length by width) with a container lodging a full-duplex B glass encapsulated transponder of 22 by 4 mm (Set-Tag; Shearwell Data Ltd., Minehead, Somerset, UK).

[9]Electronic rumen bolus containing a half-duplex glass encapsulated transponder (31 by 3.8 mm; Datamars Trazabilidad SL, Esplugues de Llobregat, Barcelona, Spain). Bolus details are shown in Table 1.

ately before and after administration to check for breakages or electronic failures that might happen during administration as well as, in the case of eRB, to ensure the proper location of the bolus in the forestomachs (C1 compartment of camel) before releasing the animal.

Statistical Analyses

The readability rate of ID devices was assessed by the ability of each type of device to be read under static conditions at each time point and at the end of the study; the actual readability was expressed as R (%) = (number of readable devices/number of applied devices) × 100. Obtained R values were compared on a yearly basis (Seroussi et al., 2011), whereas the yearly readability rate (R_Y; %) was estimated by the expression $R_Y = (R/100)^{1/Y} \times 100$, in which Y is the duration of the study in years (e.g., from Table 2: R_Y = 94.935% for R = 69.5% after 7 yr). No aging effects or reidentification are considered in this expression, so the actual values of readability in the long term would be lower in practice than those estimated.

The losses, electronic failures, and readability of ID devices were analyzed with the CATMOD procedure of SAS (version 9.4; SAS Inst. Inc., Cary, NC) on the basis of the categorical nature of these variables. A logit model with an estimation method of maximum likelihood (Cox, 1970) was used to evaluate the effects of each type of ID device. A log-rank test of equality across strata (i.e., type of ear tags or ID rumen boluses) was performed with the LIFETEST procedure of SAS.

For the analysis of data acquired by the eRB, the procedure PHREG (proportional hazard regression) for survival data of SAS was considered preferable to the logit model to avoid the possible bias produced by the different number of animals monitored until the end of the study in addition to introducing the effects of the location sites and bolus features (i.e., size and SG). Such analysis permitted the comparison of the longitudinal readability and the estimates of readability of the eRB throughout the entire period of study, without excluding censored data (data from animals that left the study before a device failed), as previously performed by Carné et al. (2009a). Furthermore, the readability data were compared on a yearly basis. The differences between means were declared significant at $P < 0.05$, unless otherwise indicated.

RESULTS

A total of 528 camels were finally identified in the 4 locations using 5 different ID systems (i.e., iron brands, injectable microchips, vET and eET, and eRB). The total number of ID devices applied and their long-term performance at all locations are summarized in Table 2.

Previously Applied Identification

Hot-Iron Brands. The previously iron-branded camels at location number 1 (Egypt) showed signs of healing problems in 8.6% of brands on the thigh, where most of them formed some kind of keloid (aberrant epidermal hyperplasia developed during the healing process) at the brand site, which, consequently, resulted in only 42.9% of brand digits being fully readable (Table 2).

Injected Microchips. The camels identified with RFID microchips at location number 2 (Spain), already injected 7 yr before the beginning of our study, showed a low readability (69.5%; Table 2) but equivalent to 94.9% of yearly readability. Moreover, they showed some difficulties for locating the injection site and reading with the Gesreader 3 transceiver (Datamars Trazabilidad SL) used. No detailed information was available on the precise injection site of the microchips in the neck of our camels and we needed 26 ± 4 s, on average, to locate and read them. No relevant migration was estimated from the injection site; all the microchips were located in the middle of the neck.

Newly Applied Identifications

Visual Ear Tags. Readabilities of vET devices measured at locations number 1 (Egypt) and 2 (Spain) after 1 yr were lower in vET1 (rectangular) ear tags than in vET2 (button) ear tags (66.3 vs. 80.9%, respectively; $P = 0.011$; Table 2); the annual losses were very high (33.7 and 19.1%, respectively). Both vET1 and vET2 were hard to read in camels because of the height of the camels and their biting and kicking behavior. Moreover, most ear tag losses were associated with breakages of the ear tissue (occasionally of the whole ear) or the ear tag, usually as a consequence of their behavior of fighting for dominance.

Electronic Ear Tags. Readability of plastic-loop eET applied at location number 3 (Saudi Arabia) measured in our study after 3 yr was 82.2% (Table 2), which, on the yearly basis, is equivalent to 93.7%. This value was similar to the readability of vET2 (button, $P = 0.793$) and greater than that of vET1 (rectangular, $P = 0.018$) in our camels and, in fact, supported the convenience of using small and light ear tags in camels.

The estimated eET yearly losses at location number 3 (Saudi Arabia) were 6.3% (Table 2), which were lower than the above-reported mean values of vET but within the range of losses previously observed for injected RFID microchips. On the other hand, with regard to reading time, the eET at location number 3 (Saudi Arabia) were read 65% faster (9 ± 1 s) than the injected RFID microchips at location number 2 (Spain).

Electronic Rumen Boluses. Administration of eRB was done easily and safely (i.e., no injuries or casualties) when performed by trained operators in yearling and adult camels using balling guns adapted to the size of the bolus and the age of the camels. The best restraining positions for bolus administration were standing up and sitting down for young and adult camels, respectively, and assistance was required in all cases. Boluses were mostly swallowed at the first attempt (95%) after being gently released at the end of the tongue (torus linguae) and when the mouth was maintained firmly closed until the involuntary deglutition reflex took place. Although time for bolus swallowing was not measured, we noted that eRB were swallowed faster if previously warmed to body temperature. Nevertheless, 2 eRB at location number 2 (Spain; 0.7%) were blocked in the neck of young suckling camels during administration (eRB2, 1 wk of age and 24 kg BW, and eRB6, 3 mo of age and 70 kg BW) by operators with little experience. Although the eRB6 (large) was easily unblocked by gently pushing with an esophageal probe in the 3-mo-old camel calf, we were unable to remove the eRB2 (small) with veterinary assistance in the case of a 1-wk-old calf, where the bolus was located in the trachea and causing asphyxia.

Necropsy reports of culled adult camels at location number 2 (Spain) and the yearling fattened camel slaughtered at location number 4 (Tunisia) revealed that the eRB were properly located in the C1 compartment of the camel forestomachs, without causing damages or signs of alteration of the mucosa. In 3 cases, however, the eRB were located at the water sacs of the C1 compartment. No relevant changes in health or apparent intake and behavior were observed in our camels as a consequence of the administration of the different eRB types used at different location sites and under different feeding and farming conditions.

As shown in Table 2, readability of eRB widely varied according to bolus type (0 to 100%); the eRB1 (small) and eRB3 (large) were not retained at all (regurgitated) in the camel forestomachs, whereas the rest of the eRB showed a high final retention (98.1 to 100%), in all cases agreeing with the International Committee for Animal Recording (2016) recommen-

Table 3. Predicted yearly readability of electronic rumen boluses (eRB) by the Cox proportional-hazards regression for survival data from all the experiments and taking into account the specific gravity and size of the boluses

Item	Electronic rumen bolus type[1]							Total, no.
	eRB1	eRB2	eRB3	eRB4	eRB5	eRB6	eRB7	
Specific gravity	1.49	3.86	1.51	3.59	3.10	3.35	3.60	–
Size[2]	Small	Small	Large	Large	Large	Large	Large	–
Administered, no.	20	155	15	16	71	254	24	555
Censored,[3] no.	0	152	0	16	71	253	24	516
Lost, no.	20	3	15	0	0	1	0	39
Readability estimates, %	0 ± 0^c	99.9 ± 0.1^a	0 ± 0^c	99.6 ± 0.2^a	97.4 ± 1.1^b	99.1 ± 0.5^a	99.7 ± 0.2^a	–

[a–c]Within a row, values with different superscripts differ ($P < 0.05$).

[1]Bolus details are shown in Table 1. Rumen bolus contained a half-duplex glass encapsulated transponder (31.0 by 3.8 mm; Datamars Trazabilidad SL, Barcelona, Spain).

[2]Small are <60 mm long and large are >60 mm long.

[3]Devices present at the end of the study.

dation (>98%). According to bolus features (Table 1), the lost bolus types were those with the lowest weights and SG values, which were regurgitated.

Results of the predicted yearly readability of eRB at all location sites by using the Cox's proportional-hazards regression model for survival data (Table 3; Fig. 1) revealed that SG was the most critical factor ($\chi^2 = 562.9$, $P < 0.001$) for the retention of eRB in the camel forestomach and its mid- and long-term readability. As shown in Fig. 1, the estimated readability values were >98% for SG > 3.0 boluses (eRB2, eRB4, eRB5, eRB6, and eRB7), whereas it dramatically dropped early after administration (at d 7, approximately 70%; at d 30, approximately 40%; and at d 365, approximately 0%) for SG < 1.5 boluses (eRB1 and eRB3). Bolus size ($\chi^2 = 188.9$, $P < 0.001$) and location site ($\chi^2 = 61.1$, $P < 0.001$) were also significant factors for eRB readability, but their inclusion in the model explained less than 25% of the effects.

Differences between actual (Table 2) and estimated (Table 3) values of yearly readability for eRB were moderate, ranging from −2.6 to 0.3%. These observations were mainly due to the high number of eRB being monitored until the end of the study (positively censored). The estimated values of readability for low-SG (eRB1 and eRB3; SG from 1.49 to 1.51) and high-SG (eRB2, eRB4, eRB5, eRB6, and eRB7; SG from 3.10 to 3.86) boluses markedly differed ($P < 0.001$). Similar to the observed case of the actual data, no differences within SG < 2.0 or SG > 3.0 bolus groups were detected ($P = 0.895$).

On average, the time required for reading the camels identified with eRB at location number 2 (Spain) was 12 ± 5 s, which was 14 s (54%) shorter and 3 s (33%) longer, respectively, than the above-indicated reading times for injected RFID microchips and eET using similar reading procedures. Nevertheless, reading difficulties were observed using the Gesreader 2S (Rumitag) transceiver in pregnant camels at the end of pregnancy at locations number 1 (Egypt, $n = 1$) and 3 (Saudi Arabia, $n = 5$). All boluses were again readable after parturition.

DISCUSSION

The paper is based on observational and experimental data obtained from commercial camel herds. The main limitation of our experiment in extracting causal relationships is because all treatments were not possible at all locations due to differences in farm conditions and in available facilities. This is the case of iron brands, which were applied before starting the experiment in Egypt and are not currently allowed in some countries due to welfare regulations. On the other hand, having the concern of residues in camel meat for human consumption, we considered a unique opportunity to report the mid-term performances of microchips already injected by a veterinarian in a group of riding dromedaries in Spain. Moreover, the unsatisfactory readability results observed for both iron brands and microchips motivated the interest for testing alternative ID systems. Time differences between types of ID devices were standardized on a yearly basis for comparison, and differences between means were separated by using a logit model with an estimation method of maximum likelihood. A more detailed analysis of the relation between treatments and ID performances was therefore not possible, but the explanation of the results was completed with relevant literature data and local experts' knowledge about dromedary husbandry.

Previously Applied Identification

Hot-Iron Brands. Low readability results similar to ours (Table 2) were reported by Aurich et al. (2013) in horses, where breed-specific symbols of iron brands were readable in 84% of the horses, whereas the double-digit individual branding number was read-

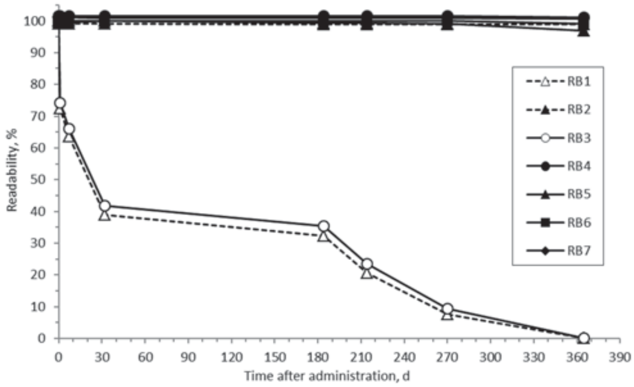

Figure 1. Predicted yearly readability of electronic rumen boluses (eRB) from all the experiments by using the Cox proportional-hazards regression model for survival data taking into account their size (dashed line = small sized [<60 mm] and solid line = large sized [>60 mm]) and specific gravity (open symbols (Δ and ○) = specific gravity < 2.0 and closed symbols (▲, ●, ■, and ♦) = specific gravity > 3.0). Bolus features are shown in Table 1.

able in only less than 39% of the horses. The risk of skin lesions by branding, which is equivalent to third-degree thermal injuries (Aurich et al., 2013), and the associated pain, as reported in iron-branded steers (Schwartzkopf-Genswein et al., 1997), together with the low readability values makes the generalized use of iron branding inadvisable for camel ID. Although iron branding is a traditional method for the permanent ID of livestock, the use of this method is currently banned in many countries (e.g., Denmark, Germany, Netherland, Scotland), due to animal welfare concerns (Erber et al., 2012). Whatever the case, no iron branding should be applied without the appropriate analgesia.

Injected Microchips. The time it took to find the microchips in the middle of the neck in our results agreed with that reported by Stein et al. (2003) in equids injected before 4 to 5 yr. Besides, small-sized microchips (11.4 by 2.2 mm), similar to those injected in our camels, were applied in the neck of horses (between poll and withers into the nuchal ligament or into musculature according to the European regulation EC 504/2008 (EC, 2008a) by Konermann (1991) and Wulf et al. (2013), who reported 89.5 to 100% readability during short-term studies (9 and 6 mo, respectively).

No long-term studies have been made in camels or horses using microchips in the neck, but Løken et al. (2011) injected small-sized microchips (13.5 by 2.2 and 13.9 by 2.2 mm; glass- or polymer-encapsulated) in the ear (ear base or ear lobe) of testing bulls in a 8- to 30-mo study and reported, on average, 92.3% readability. No differences between glass- and polymer-encapsulated microchips were detected by Løken et al. (2011). The use of longer glass-encapsulated transponders (23 or 32 by 3.8 mm) in suitable body sites (ear scutulum and armpit) of fattening calves slaughtered at 8 to 12 mo by Conill et al. (2000) showed 93.0 to 98.5% readability, which differed according to body site and transponder size. When comparing our results of microchip readability of the long term (7 yr) in camels with short and mid term (0.5 to 2.1 yr) in horses and cattle, it is clear that the values of estimated yearly losses by using the Seroussi et al. (2011) expression in our camels (5.1%; Table 2) were consistent and within the range of those previously calculated in horses (0 to 13.7%) and cattle (1.8 to 8.4%).

A main concern related to the injection of RFID microchips in the neck of camels is the difficulties of recovery at slaughter and their possible presence in the meat as a residue and hazard object (i.e., glass capsule and electronic components). The World Small Animal Veterinary Association (2016) strongly recommended that any microchipped food-producing animal should carry an external ID to indicate that a microchip is present (i.e., to be recognized and recovered at slaughter) and in some cases their use may not be permitted. Conill et al. (2000) reported recovery times of approximately 1 min at the slaughterhouse when 23 and 32 mm transponders were injected in the ear base and armpit of fattening calves. The smaller size of RFID microchips used in camels (i.e., 12 to 15 mm, as in horses and pets), the uncertainty of their presence (i.e., high losses), and location difficulties (i.e., short reading distance) will compromise the safety of camel meat (i.e., neck) for consumers, making it not fully recommendable in the camel industry.

Newly Applied Identifications

Visual Ear Tags. There are few researches reporting vET readability in livestock, and their performances dramatically vary according to the species and the exploitation conditions. Edwards et al. (2001) studied the inflammatory reaction after the insertion of different ear tag types in sheep (i.e., metal loop, plastic loop, single or double plastic flags, etc.) and reported that metal-loop tags produced more severe lesions that persisted longer than other ear tag types, therefore making their use inadvisable. Fosgate et al. (2006) reported 87.6% of annual losses of plastic vET in a study on domestic water buffalo that lasted 3 yr under extensive conditions, with the overall median ear-tag retention being 272 d and the final retention zero, and they concluded that ear tags were inadequate for the long-term ID of buffaloes under extensive conditions. In the case of goats, Carné et al. (2009a) reported vET losses varying between 6.0 and 17.1% for official and unofficial (i.e., tip-tag ear tags) plastic vET in a 3-yr study. Moreover, Carné et al. (2009b) reported that goat breed is also key for vET retention (i.e., ear length differences), where the annual losses varied between 1.4 and 17.1% in 4 U.S. goat breeds under semi-intensive farming conditions.

Losses of official vET in sheep (Ghirardi et al., 2006b) and in fattening calves (Conill et al., 2000) ranged from 3.3 to 11.4%, respectively. Mean annual losses of 3 different plastic official vET, measured in a study that lasted 3.2 yr in dairy cattle under intensive conditions (Seroussi et al., 2011), varied between 11 and 20%, makes visual ear tag losses greater than expected according to the International Committee for Animal Recording (2016) requirements (losses <2%).

When data from buffaloes was not taken into account, the overall annual losses for vET ranged between 2.0 and 20.0% (i.e., cattle and goats), which are lower than the values observed in our camels (19.1 to 33.7%; Table 2). Unlike the regulations indicated above for cattle, sheep, or goats, there are no specific regulations for official camel ear tag design. However, despite not expecting high retention rates for vET, our results suggest that button ear tags should be preferable to flag ear tags for camel ID in practice.

Electronic Ear Tags. There is controversy in the literature on comparing the performances between eET and vET, as reported by Babot et al. (2006) in pigs and Carné et al. (2009a, 2010) in goats. Nevertheless, eET are considered less damaging for the ear than vET due to their optimized design (Edwards et al., 2001). It should be stressed that ear tag weight must be limited when applied in young animals (Caja et al., 1997), due to the low strength of the thin ear tissue, which, as a consequence, reduces the reading distance (i.e., smaller antenna) and dynamic reading efficiency of the eET.

There are few data reporting eET readability in livestock. Caja et al. (2014) reviewed the state of the art of different ID devices in goats and reported 92.9% readability (range between 79.8 to 100%) for eET in goats under different conditions. On the other hand, the fast readability of eET in our results was mainly a consequence of the easy location by sight as well as the fact that camels were not afraid of the stick antenna when gently approached from the back of the head.

Electronic Rumen Boluses. We did not expect side effects of eRB administration as we followed the procedures described by Caja et al. (1999) and Carné et al. (2009b) in large and small ruminants. Nevertheless, previous complete training and administration skills were considered key for implementing eRB in the camel industry. Antonini et al. (2006) reported that bolus administration did not affect, at the mid term, the productive performance or produce specific lesions in the reticulorumen mucosa of cattle of different ages. Moreover, Martín et al. (2006) and Castro et al. (2010) reported that bolus administration did not affect the intake and digestive performances of adult goats as well as the growth and the forestomach development of milk fed kids, respectively.

The positive relationship between eRB readability in the forestomachs of camels and the bolus SG was expected. In fact, other authors previously stressed the key role of the SG (i.e., >3.0) for the retention of boluses in the reticulorumen of cattle (Ghirardi et al., 2006a), sheep (Ghirardi et al., 2006b; Hentz et al., 2014), and goats (Carné et al., 2011). The difficulties in reading the eRB observed when using the Gesreader 2S (Rumitag) transceiver in pregnant camels at the end of pregnancy at locations number 1 (Egypt) and 3 (Saudi Arabia) was explained by the limited reading distance of the transceiver. This leads us to recommend the use of the Gesreader 3 (Datamars Trazabilidad SL) or other available transceivers with a greater reading distance in camels.

According to our results, for a camel productive life of 25 yr, the estimated readability of the studied ID systems would vary between 0 and 100%, with the adequately designed eRB (i.e., SG > 3.0) being the only system agreeing with the International Committee for Animal Recording (2016) requirement (yearly losses < 2%). The highest values of predicted yearly readability by the Cox's proportional hazards survival analysis, warranting the permanent ID of dromedaries in the long term, were obtained with the eRB2, eRB4, eRB6, and eRB7 (99.1 to 99.9%). The greater number of camels used in the case of eRB2 and eRB6 made the decision of choice more robust with regard to their use in practice. Comparatively, less than 60% of ear-tagged or microchipped camels would be identifiable after 10 yr and less than 30% after 25 yr, clearly showing the advantages of using eRB.

Agreeing with our conclusion, Moreki et al. (2012) reported that boluses were the most tamperproof and highly retained ID device in a study comparing different methods for cattle ID (i.e., vET, eET, and electronic boluses) under range-extensive conditions in Botswana. Additionally, Hentz et al. (2014) stated that boluses have advantages over ear tags in warm and hot climates (e.g., Brazil), as the internal devices (i.e., forestomach) reduce the risks of ear tag losses, tissue damage, and lesions on the ear.

Nevertheless, the above-mentioned eRB4 to eRB7 had large dimensions (66.0 to 68.0 mm length and 16.9 to 21.1 mm diameter), which made their use inadvisable in young suckling camels. Therefore, these types of boluses should be used in camel calves older than 3 mo and heavier than 90 kg BW. The age is important for safe bolus administration, which depends on the anatomical development of the pharynx and esophagus and on the dimensions (length and diameter) of the eRB used (Carné et al., 2009a). Despite the administration of eRB being possible during wk 1 of life, our advice for identifying young suckling camels is to administer small-sized boluses, such as the eRB2, when the calves have passed the perinatal period and look vigorous (e.g., after 1 to 2 wk of age and >50 kg BW). For weaners and adult camels, any of the eRB4 to eRB7 are recommended for the long-term ID under extensive and intensive conditions.

Conclusions

For the first time, the performances of visual and electronic ID devices have been studied in dromedary camels under a wide range of locations and different farming conditions. Results and conclusions would be useful to farmers and administration bodies in assessing which are the most suitable devices for camel ID in practice.

No iron branding or injected microchips are recommended for the ID of camels due to readability and to welfare and meat safety concerns, respectively. Additionally, the low ID performances reported for the long term makes their use inadvisable as a reference system for the camel industry. The use of vET as a single ID device is also not recommended for the permanent ID of camels due to the high losses and elevated risk of ear breakages. Whatever the case, small-sized ear tags (e.g., button shape) or plastic-loop ear tags (e.g., eET) would be preferable to ear tags with large flags. The high readability of dense and adequately designed eRB in the long term and under different farming conditions makes their use the most recommendable as the ID device of reference for the permanent identification of camels. Nevertheless, like required by international regulations in other livestock species, the use of a second visual ID device might be suggested for an easy management in large farms of dairy dromedaries, although further studies are needed to confirm this recommendation.

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