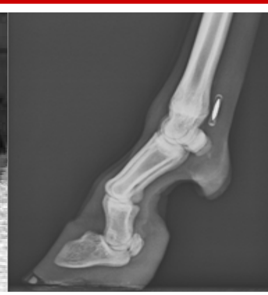
IDentification constitutes the unavoidable primary step to successfully implementing traceability systems of livestock and their products. The use of passive radio-frequency technology for the electronic identification (e-ID) of livestock has become a key issue in recent years, especially in the European Union, where compulsory double ID (visual and e-ID) and registration of small ruminants is legislated (EC 21/2004; EC 933/2008). European regulations allow each member state to choose between different e-ID devices (ear tags, marks on the pastern, and rumen boluses), in addition to visual ear tags, for the e-ID before 6 mo of age and when leaving the farm of origin.

In the case of goats, very few reports are available on the performance of visual and e-ID devices for the accurate long-term identification during the goat lifespan. Moreover, a remarkable variability of performances has been observed between devices. Regarding rumen boluses, unlike in sheep and cattle, inadequate retention rates have been observed in Spanish goat breeds, and further research is necessary on the features of devices for the efficient identification of goats.

Thus, the aim of this Ph.D. thesis is to compare different available methods for the identification of goats. Visual and electronic ear tags, different types of rumen boluses, as well as marks on the pastern (injectable transponders and leg bands with attached transponders) were tested. The influence of age at tagging, breed and management system (i.e. feeding) were also investigated.

According to obtained results, e-ID devices performed better than most visual ear tags. Injection of glass encapsulated transponders in the metacarpus was not recommended. Leg bands with button transponders were also not recommended if applied before 6 mo of age, although they were an adequate method for adult does. Despite differences according to types, adequately designed button-button e-ID ear tags showed the best readability rates in goats. Important differences in age at administration and retention rate between types of rumen boluses were found. Obtained values allowed a regression model to be constructed where high specific gravity (i.e. greater than in sheep) was recognized as the key aspect for their efficient retention in the reticulorumen of goats. As a result, the dimensions of new boluses for goats were defined.


Carné, S. 2010. Electronic identification of goats: comparison of different types of radio-frequency and visual devices. Ph.D. Thesis. Universitat Autònoma de Barcelona, Bellaterra, Spain. 140 pp.

Electronic identification of goats

Doctoral Thesis

Sergi Carné (2010)

Universitat Autònoma de Barcelona

Departament de Ciència Animal i dels Aliments

Electronic identification of goats: comparison of different types of radio-frequency and visual devices

Identificació electrònica de bestiar cabrum: comparació de diferents tipus de dispositius visuals i de radiofreqüència

Identificación electrónica de ganado caprino: comparación de diferentes dispositivos visuales y de radiofrecuencia

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Tesis presentada per Sergi Carné i Fructuoso, dirigida pel Dr. Gerardo Caja López del Departament de Ciència Animal i dels Aliments de la Universitat Autònoma de Barcelona, per obtenir el títol de Doctor.

Bellaterra, 9 d'abril de 2010

V^{o} B^{o}

Dr. Gerardo Caja López

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LIST OF ABBREVIATIONS

BW	Body weight
CP	Crude protein
d	Day
DRE	Dynamic reading efficiency
e-ID	Electronic identification
Exp.	Experiment
FDX-B	Full duplex
g	Gram
h	Hour
ha	Hectare
HDX	Half duplex
ICAR	International Committee for Animal Recording
ID	Identification
ISO	International Organization for Standardization
kHz	Kilohertz
MAPA	Spanish Ministry of Agriculture (Currently MARM)
Mcal	Megacalorie
min	Minute
mm	Millimeter
mo	Month
n	Sample size
NE_L	Net energy for lactation
No.	Number
L	Liter
o.d.	Outside diameter
P	Probability
R^2	Multiple coefficient of determination
R/O	Read only
RR	Retention rate
RFID	Radio frequency identification
s	Second
s.c.	Subcutaneous
SG	Specific gravity
SAS	Statistical Analysis Software
SEM	Standard error of the mean
SRE	Static reading efficiency
USDA	United States Department of Agriculture
V	Volume
W	Weight
wk	Week
yr	Year

ABSTRACT

This thesis aimed to evaluate different visual and radio frequency identification (RFID) devices for goats. As current European regulations lay down the official use of visual and RFID ear tags, rumen boluses, and marks on the pastern (injectable transponders and RFID leg bands), these devices were tested in 4 experiments.

In Exp. 1, application and long-term readability of visual ear tags (V1: tip-tag; V2: official), mini-boluses (B1: 13.8 g; and B2: 20.0 g), RFID ear tags (E1: flag-button; E2: double button), and injects on the fore-hind pastern (T1: 15 mm; T2: 12 mm) in replacement Murciano-Granadina dairy goat kids (n = 97) were tested; standard-sized boluses (B3: 75 g) were evaluated as control devices in their mothers (n = 29). At 1 yr of age, readability of B3, E1 and E2 was 100%. Lower readabilities corresponded to B1 (71.4%), V1 (82.9%), B2 (84.6%), and T1 (92%). At 3 yr of age, only E1 was 100% readable; readability of the rest of devices ranged from 69.6 to 96.4%. In conclusion, button RFID ear tags offered the best results for ID of dairy goats at early age.

In Exp. 2, a total of 295 adult and yearling goats from Alpine, Angora, Boer, and Spanish breeds, and managed under semi-extensive conditions, were used. Influence of management system and breed effects on the retention of 3 bolus types (B1: 20 g, n = 95; B2: 75 g, n = 100; and B3: 82 g, n = 100) and 1 visual ear tag were investigated. Effect of feeding management on early losses (mo 1) was evaluated by measuring ruminal pH. No early losses occurred, although ruminal pH varied by goat breed and feeding management (6.32 to 6.73). At 1 yr, bolus retention (98.1%) was greater than ear tag (91.7%). Lowest bolus retention was for B1 (96.3%), whereas it was 97.8% for B3, and 100% for B2. Ear tag retention varied between breeds (82.9 to 98.6%). In conclusion, standard-sized boluses offered suitable long-term retention for goats under semi-extensive conditions.

In Exp. 3, adult Murciano-Granadina goats (n = 220) were identified with visual ear tags (VE), rumen boluses (RB: 75 g), RFID ear tags (EE, n = 47), and leg tags (LT) with 2 types of button transponders (ET1, n = 90; ET2, n = 130). Long-term readability was evaluated. According to shank circumference, LT for kid ID was discarded and only adult does were used. At 1 yr, no losses of LT occurred, although 1.5% were removed due to limping; readability of RB, EE, VE, ET1, and ET2 was 96.5, 95.7, 97, 93.9, and 98.3%, respectively. Greater dynamic reading efficiency DRE for RB (95.2%) and LT (92.4%) were obtained with the antenna to the left and on the floor, respectively. In conclusion, adequately designed leg tags are a valid ID method for adult dairy goats.

In Exp. 4, 2,482 RFID rumen boluses from 19 bolus types were used to construct a regression model of bolus retention in goats. Bolus features varied in length (37 to 84 mm), o.d. (9 to 22 mm), weight (W, 5 to 111 g), volume (V, 2.5 to 26 mL), and specific gravity (SG, 1 to 5.5). Bolus retention varied (0 to 100%) according to bolus features. A logit regression model with W and V as covariates was constructed (R^2 = 0.98). Estimated W and SG to produce mini- (5 mL), medium- (15 mL) and standard-sized (22 mL) boluses for a retention rate of 99.95% were 42.9, 73.0, and 94.1 g, and 8.58, 4.87, and 4.28, respectively. Increasing bolus W and SG allowed V to be reduced. Suitable medium-sized RFID boluses for goats can be produced with radio translucent materials currently available.

In conclusion, under our conditions, visual ear tags and injects in the pastern were not recommended for official ID. Button electronic ear tags showed variable results according to type, and electronic leg tags were a valid method only for adult goats. As a result of the bolus retention model obtained, medium-sized boluses may be effectively produced for goat ID, but mini boluses are not recommended.

RESUM

L’objectiu d’aquesta tesi ha estat l’avaluació de diferents dispositius de identificació del bestiar cabrum, recentment contemplades a la legislació europea. S’han portat a terme 4 experiments per tal d’avaluar els següents dispositius: cròtals plàstics i de ràdio freqüència (RFID), bols ruminals, i identificadors a les extremitats (injectables i braçalets).

A l’Exp. 1 es van emprar 97 cabrits de raça Murciano-Granadina per estudiar l’aplicació i capacitat de lectura (CL) de cròtals visuals (V1: tip-tag; V2: oficial), cròtals de RFID (E1: bandera-botó; E2: doble botó), mini-bols (B1: 13,8 g; B2: 20 g), i injectables a l’extremitat anterior (T1: 15 mm; T2: 12 mm); les mares (n = 29) es van identificar amb bols de mida estàndard (B3: 75 g). Al cap d’un any, la CL de B3, E1 i E2 va ser del 100%. Les CL més baixes es van donar amb el B1 (71,4%), V1 (82,9%), B2 (84,6%) i T1 (92%). Als 3 anys, només l’E1 va mostrar una CL del 100%; en la resta de dispositius la CL va variar entre 69,9 i 96,4%. En conclusió, només un dels cròtals de RFID de tipus botó va permetre la adequada ID de cabrides de reposició de raça lletera.

A l’Exp. 2, es van emprar 295 cabres adultes i segalles de les races Alpina, Angora, Boer i Spanish, i explotades en condicions semi-extensives. Es va testar la retenció de 3 tipus de bols (B1: 20 g, n = 95; B2: 75 g, n = 100; B3: 82 g, n = 100) i 1 cròtal visual de tipus bandera-botó. Per tal de comprovar la relació entre el maneig alimentari i les pèrdues en el primer mes, es van prendre mesures de pH ruminal. No es van produir pèrdues de bols durant el mes 1, tot i que el pH diferí d’acord amb la raça i maneig (6,32- 6,73). Al ca de l’any, la retenció de bols (98,1%) va ser superior a la de cròtals (91,7%). La menor retenció es va obtenir amb el B1 (96,3%), mentre que va ser de 97,8% per al B3 i de 100% per al B2. La retenció dels cròtals varià en funció de la raça (82,9-98,6%). En conclusió, els bols de mida estàndard van oferir una retenció adequada a llarg termini per a la ID de cabrum en condicions semi-extensives.

A l’Exp. 3, 220 cabres de raça Murciano-Granadina es van identificar amb cròtals visuals (VE) i de RFID (EE, n = 47), bols ruminals (RB: 75 g), i identificadors a l’extremitat (LT) amb 2 tipus de transponedors tipus botó (ET1, n = 90; ET2, n = 130). Es va avaluar la CL durant 12 mesos. D’acord amb el perímetre de canya, es descartà l’ús de LT en cabrides i només s’utilitzà en cabres adultes. Al cap d’1 any, no es van produir pèrdues de LT però l’1,5% van ésser retirats per causar coixeses. Les CL de RB, EE, VE, ET1 i ET2 van ser de 96.5, 95.7, 97, 93.9 i 98.3%, respectivament. Les eficiències de lectura dinàmica més elevades per a RB (95,2%) i LT (92,4%) s’obtingueren amb l’antena posicionada a l’esquerra i a terra, respectivament. En conclusió, els braçalets resultaren un mètode vàlid per a la ID de cabrum d’edat adulta.

A l’Exp. 4, 2.482 bols ruminals pertanyents a 19 tipus diferents es van utilitzar per establir un model de regressió de la retenció de bols en cabrum. Els bols variaren en longitud (37-84 mm), diàmetre (9-22 mm), pes (W, 5-111 g), volum (V, 2,5-26 mL) i gravetat específica (SG, 1-5,5). La retenció dels bols varià (0-100%) segons les seves característiques. Es va poder establir un model logístic de retenció de bols (R^2 = 0,98), prenent W i V com a covariables. Els W i SG estimats per a bols mini (5 mL), mitjans (15 mL) i estàndards (22 mL) per a una retenció del 99,95% van ser de 42.9, 73.0, i 94.1 g, i de 8.58, 4.87, and 4.28, respectivament. L’augment de W i SG permetria reduir el V. Els materials ràdio-translúcids actuals permetrien obtenir RFID bols de mida mitjana adequats per a l’ús en cabrum.

En conclusió, en les nostres condicions, els cròtals visuals i els injectables en pota no s’aconsellen per ID oficial. Els cròtals electrònics de botó mostraren resultats variables segons el tipus, i els braçalets són un mètode vàlid tan sols en cabres adultes. D’acord amb el model de retenció de bols ruminals, es poden produir bols adequats de mida mitjana per a cabrum, mentre que els bols mini estan desaconsellats.

RESUMEN

El objetivo de esta tesis fue evaluar diferentes dispositivos de identificación en ganado caprino, recientemente contempladas en la legislación europea. Se realizaron 4 experimentos a fin de comparar los siguientes dispositivos: crotales plásticos y de radio frecuencia (RFID), bolos ruminales, e identificadores en pata (inyectables y pulseras).

En el Exp. 1 se utilizaron 97 cabritos Murciano-Granadinos para estudiar la aplicación y capacidad de lectura (CL) de crotales visuales (V1: tip-tag; V2: oficial), crotales RFID (E1: bandera-botón; E2: doble botón), mini-bolos (B1: 13,8 g; B2: 20,0 g), e inyectables en el metacarpo (T1: 15 mm; T2: 12 mm); las madres (n = 29) se identificaron con bolos estándar (B3: 75 g). Al año, la CL fue de 100% en B3, E1 y E2. Las CL más bajas se fueron las de B1 (71,4%), V1 (82,9%), B2 (84,6%) y T1 (92%). A los 3 años, sólo E1 presentó una CL del 100%, variando en el resto entre 69,9 y 96,4%. En conclusión, sólo los crotales RFID de botón resultaron adecuados para la ID de caprino lechero a edades tempranas.

En el Exp. 2, se utilizaron 295 cabras adultas i de reposición de las razas Alpina, Angora, Boer y Spanish, explotadas en condiciones semi-extensivas. Se ensayaron 3 tipos de bolos ruminales (B1: 20 g, n = 95; B2: 75 g, n = 100; B3: 82 g, n = 100) y 1 crotal visual. Para comprobar la relación entre manejo alimentario y la pérdidas de bolos tempranas (mes 1), se realizaron medidas de pH ruminal. No se produjeron pérdidas durante el mes 1, aunque el pH ruminal varió según raza y manejo (6,32 a 6,73). A 1 año, la retención de bolos (98,1%) fue superior a la de crotales (91,7%). La menor retención se observó en B1 (96,3%), mientras que fue de 97,8% en B3 y de 100% en B2. La retención de crotales varió según la raza (82,9 a 98,6%). En conclusión, los bolos ruminales de tamaño estándar mostraron una adecuada retención a largo plazo para la ID de caprino en condiciones semi-extensivas americanas.

En la Exp. 3, 220 cabras de raza Murciano-Granadina se identificaron con crotales visuales (VE), bolos ruminales (RB: 75 g), crotales de RFID (EE, n = 47), y pulseras en metatarso (LT) con 2 tipos de transpondedores tipo botón (ET1, n = 90; ET2, n = 130). Se evaluó la CL a 1 año. De acuerdo con el perímetro de caña, las LT se descartaron en cabritos de 5 meses y sólo se utilizaron en cabras adultas. Al año no se observaron pérdidas de LT, pero el 1,5% fueron retiradas por producir cojeras. Las CL de RB, EE, VE, ET1 y ET2 fueron de 96,5, 95,7, 97,0, 93,9 y 98,3%, respectivamente. Los valores más elevados de eficiencia de lectura dinámica para RB (95,2%) y LT (92.4%) se obtuvieron con la antena colocada a la izquierda y en el suelo, respectivamente. En conclusión, las pulseras resultaron un método válido para la ID de caprino adulto.

En la Exp. 4, 2.482 bolos ruminales pertenecientes a 19 tipos distintos se utilizaron para establecer un modelo de regresión de la retención de bolos en caprino. Los bolos variaron en longitud (37 a 84 mm), diámetro (9 a 22 mm), peso (W: 5 a 111 g), volumen (V: 2,5 a 26 mL) y gravedad específica (SG: 1-5,5). La retención de bolos varió (0 a 100%) en función de sus características. Se pudo establecer un modelo logístico de retención (R^2 = 0,98), tomando W y V como covariables. Los valores estimados de W y SG estimados para conseguir una retención del 99,95% en bolos mini (5 mL), medianos (15 mL) y estándar (22 mL), fueron de 42,9, 73,0 y 94,1 g, y de 8,58, 4,87 y 4,28, respectivamente; aumentar la W y SG mediante materiales radio-translúcidos actuales permitiría reducir el V y obtener bolos medianos adecuados para caprino.

En conclusión, en nuestras condiciones, no se aconsejan los crotales visuales y los inyectables en pata para la ID oficial. Los crotales electrónicos de botón mostraron resultados variables según el tipo, y las pulseras fueron un método adecuado sólo en cabras adultas. A partir del modelo de retención de bolos obtenido se pueden producir bolos medianos adecuados para caprino, pero se desaconsejan los mini bolos.

TABLE OF CONTENTS

CHAPTER 1

Introduction

CHAPTER 1

INTRODUCTION

Extremely limited information is available on the use of conventional and radio frequency (**RFID**) devices for the permanent identification (**ID**) of goats. For this reason, instead of developing a literature review, this chapter briefly presents the advances on this topic at the time this thesis was carried out. On the other hand, a state-of-the-art review of goat RFID is presented at the end of the experimental chapters, thereby allowing for a general discussion of advances achieved at present.

1.1. Traceability and animal identification

The concept of food traceability implies the assessment of the origin and the monitoring of the different processes undergone on products intended for animal and human consumption. According to European Regulation EC 178/2002, traceability is defined as “the ability to trace and follow a food, feed, and food producing animal or ingredients through all stages of production and distribution”. In the case of animal origin products, appropriate tools to ensure that livestock and their derived products are accurately traced are therefore fundamental for safeguarding public and animal health (Augsburg, 1990; Ammendrup and Barcos, 2006; Cheek, 2006).

These concerns have become a major issue in recent years, especially after the episodes of different animal disease outbreaks (Bovine spongiform encephalopathy, scrappie, foot-and-mouth disease, fever swine disease, etc.), food-borne pathogens (*Escherichia coli* O157:H7, and *Listeria monocytogenes*, *Salmonella*, etc), as well as the detection of certain forbidden or improperly used substances in the food chain (Pettitt, 2001; Dalvit et al., 2007; Sofos, 2008). Food safety breakdowns made it evident to consumers and public opinion that, at that moment, deployed systems for preventing or at least enabling the early detection of such cases were far from satisfactory. This is even more critical within a framework of increasing trade globalization.

In addition to food safety, concerns such as animal welfare, production efficiency, and product quality need to be presently addressed as well (Lambooij et al., 1999; Stanford et al., 2001; Smith et al., 2005; Dalvit et al., 2007; Altarriba et al., 2009).

To trace animals and animal products, a number of key points or links in the producing chain must be identified and monitored. In this respect, Hazard Analysis Critical Control Point (**HACCP**) systems offer a preventive and methodical approach to the monitoring of risks and registration of undertaken processes throughout the food chain, thereby providing valuable tools to track and trace back products at all stages from the origin up to the point of consumption (Caswell and Hooker, 1996; Cullor, 1997; Buchanan and Whiting, 1998); these HACCP programs are widely deployed at present in the food industry (Ropkins and Beck, 2000; McKean, 2001; Rajić et al., 2007).

For the proper implementation of HACCP systems where animal origin food or ingredients are involved, attention must be drawn to the reliable, permanent, and tamper-free ID of farm animals. Appropriate animal ID constitutes the unavoidable primary step to successfully implementing traceability systems of livestock and their derived products (Barcos, 2001; Dziuk, 2003; Caja et al., 2003, 2008).

Animal ID has been used for centuries to ascertain ownership (Blancou, 2001; Landais, 2001; Caja et al., 2004), although herd or batch marking may be sufficient to fulfill that purpose. Conversely, the need to deploy programs for genetic improvement, disease control and eradication, and improvement of production efficiencies makes it necessary to set up systems which allow individual and unmistakable ID of animals (Augsburg, 1990; Barcos, 2001; Pettitt, 2001; Caja et al., 2004; Bass et al., 2008).

Both mandatory and voluntary ID methods currently in use are mostly subjected to the needs and goals of the communities where deployed, as well as the economical and practical possibilities of the methods being implemented. Although, thus far, some desirable traits to obtain an optimum ID method may not be entirely reached, different authors have pointed out the requirements an ID method should eventually achieve (Hooven, 1978; Sánchez-Belda, 1981; Artmann, 1999; Conill, 1999; Barcos, 2001; Standford et al., 2001; Garín, 2002; Caja et al., 2004; Ghirardi, 2006; Hernández, 2006), namely:

- To be easily and safely applied at birth or at least at early ages.
- To be permanent and readable during the animal lifespan.
- To guarantee the uniqueness of codes, that is, the accurate individual ID.
- To prevent unlawful removal, or at least to be tamper evident. This aspect is of major relevance in the event of setting up mandatory programs although its validity should not be disdained in voluntary programs because even if limited data is available, their reliability should be guaranteed.

- To preserve animal welfare, not causing any damage to the animals and not affecting their productive performances.
- To be easily removed at slaughter, therefore avoiding any risk of food chain contamination.
- To reduce costs and make the system profitable.

Later on, animal RFID has caused other aspects to arise that were not prioritized with traditional ID systems (Geers, 1994; Frost et al., 1997; Geers et al., 1997, 1998; Dziuk, 2003; Allen et al., 2008; Gonzales-Barron et al., 2008; Voulodimos et al., 2009):

- Automation of ID data acquisition, enabling an easy and swift uploading, management, and transfer of ID data into computerized databases.
- ID assessment without either animal restraining or ID devices on line-of-sight.
- Automation of management procedures and performance data acquisition.

1.2. Traditional techniques for permanent animal identification

The different traditional systems used to identify livestock permanently have been broadly described by different authors (Sánchez-Belda, 1981; Conill, 1999; Blancou, 2001; Landais, 2001; Standford et al., 2001; Garín, 2002; Caja et al., 2004; Ghirardi, 2006; Hernández-Jover, 2006). However, the main systems which are, to some extent, still in use can be divided into 3 groups:

2.1. External natural traits:

The use of external natural traits is based on the phenotypic expression of the genetic variability observed for certain characteristics, which can be used for effective and accurate differentiation of individuals (Caballero and Carrión, 1995). Coat color patterns (Sánchez-Belda, 1981; Standford et al., 2001) and nose printing (Minagawa et al., 2002) are the two most relevant methods in this group, principally in cattle.

Despite the fact that computer-based automated image matching techniques for biometric recognition may permit the reduction of the burdensome task of image management and treatment (Barry et al., 2007; Burghardt and Campbell, 2007), the use of imaging of external natural traits is unlikely to be implemented on a large-scale basis in the near future, as they are still very time-consuming tasks, which are incompatible with routine on-field practices.

2.2. Artificial body marks:

Body marking is mainly carried out by coat branding (hot-iron, freeze, and caustic), ear notching, and tattooing, which have been described in all sorts of livestock (Sánchez-Belda, 1981; Blancou, 2001; Caja et al., 2004). Branding and tattooing make possible the assignation of individual alphanumeric codes, although the amount of digits possibly used is limited due to lack of space; therefore, their use on a large scale within official ID programs is restricted because of the unfeasibility of using codes with many digits, which hinders the accomplishment of codification uniqueness (Garín, 2002). Moreover, readability accuracy of these marks throughout the animal lifespan is usually compromised due to alterations or defects of the original marks (Conill, 1999; Caja et al., 2004). Similar drawbacks can be expected with ear notching (Hernández, 2006). In addition, unlawful modification of the original marks can not be prevented, thereby becoming an important shortcoming for their official use.

2.3. Devices externally attached:

Collars, bracelets, and ear tags are the devices most frequently used for visual ID of livestock. The collars and bracelets are more subjected to unlawful removal and replacement than ear tags, and for this reason have adopted a secondary role, being broadly used for non-official management purposes (Balvay, 2007). Conversely, ear tags are widely adopted by the public authorities and private organizations with a concern on the permanent ID of livestock. Thus, ear tags are currently used for the deployment of official voluntary and mandatory ID programs in most countries with vastly developed agrifood sectors (Garín, 2002; Ghirardi, 2006; Bass et al., 2008; Bowling et al., 2008; Murphy et al., 2008; Sugiura and Onodera, 2008).

A number of factors affecting the retention and readability of ear tags have been indicated (age at tagging, healing of the tagging site, biocompatibility of manufacturing materials, tag design and durability, livestock management conditions, etc) (Johnston and Edwards, 1996; Conill et al., 2000; Fosgate et al., 2006; Caja et al., 2009). As a consequence, a great variability in losses and external damages has been reported, bringing about readability values which mostly remain under the 98% minimum threshold indicated by the ICAR at 1 yr after tagging (ICAR, 2007).

1.3. Biometrics in animal identification

Biometrics refers to the automatic recognition or verification of an individual identity based on its biological characteristics (Jain et al., 2004). DNA profiling (Dziuk, 2003; Dalvit et al., 2007; Smith et al., 2005) and retinal vascular pattern evaluation (Allen et al., 2008; Gonzales-Barron et al., 2008; Barry et al., 2008; Rojas-Olivares et al., 2009) can be highlighted, nowadays, for animal recognition and traceability purposes. In fact, a commercial device especially designed for capturing retinal images (Optireader, Optibrand Ltd.), along with the corresponding software for image treatment, has been tested by different authors (Allen et al., 2008; Barry et al., 2008; Gonzales Barron et al., 2008) and proposed as an alternative to traditional animal ID systems. According to these authors, the Optireader can operate relatively quickly and is not subjected to the readability inaccuracy observed with conventional ID systems. Similarly, digital imaging of the muzzle pattern has been suggested as a biometrics tool for cattle ID (Barry et al., 2007).

However, although biometrics provides precise and tamper-free livestock ID, limitations in their operational capabilities may still be found. In the case of DNA fingerprinting, testing costs and the impossibility of immediate on-field ID are the main drawbacks preventing their widespread use at present (Cunningham and Meghen, 2001; Dalvit et al., 2007; Caja et al., 2008). With respect to retinal imaging, restrictions have been pointed out in challenging on-field conditions (dirtiness and moisture), and when having to accomplish routine operations where swift livestock ID is required (Artmann, 1999; Standford, 2001; Rojas-Olivares et al., 2009).

Conversely, the deployment of the aforementioned techniques as tools for carrying out retrospective audits within the frame of traceability schemes has proved to be justified according to currently developed technology (Caja et al., 2008; Allen et al., 2008; Barry et al., 2008; Hernández-Jover et al., 2009; Rojas-Olivares et al., 2009).

1.4. Radio-frequency devices for animal identification

Radio-frequency technology is based on the use of electromagnetic waves generated by a transceiver (reader) so as to activate a transponder (tag) that subsequently sends back a telegram with the data encoded in its integrated circuit (silicon chip). Operating systems for livestock RFID were unified according to the International Organization for Standardization (ISO) 11784 and 11785 standards (ISO, 1996a,b), which have subsequently been partially modified.

The ISO standard 11784 details the structure or bit pattern of the data telegram of read-only transponders; this standard has been recently modified to specify the use of some reserved bits. Thus, the telegram structure is arranged on 112 to 128 bits that are split up into different functional fields (header, animal ID code, cyclic redundancy check error detector, trailer, and control). Animal ID data is encoded in a 64-bit block, where 48 bits correspond to the 12-digit individual animal ID number, along with the 3-digit country code defined in the ISO 3166-1 standard (ISO, 2006) or the manufacturer code (ICAR, 2010); the remaining 16 bits are reserved for special purposes (9 bits for application code, retagging counter, and data block indicator; and 6 bits for future needs).

According to ISO 11785 standard, transponders can operate in 2 different modes of data exchange: half-duplex (**HDX**) and full-duplex (**FDX-B**). HDX transponders send the data telegram in the periods of time where the electromagnetic field generated by the transceiver is not activated, therefore needing a capacitor to store the operating voltage. Conversely, FDX-B transponders shall transmit the telegram while the field is still activated. Full ISO transceivers have to operate according to these two modes of data exchange.

Animal RFID operate at an activation frequency of 134.2 kHz according to ISO 11784, as such low frequencies are less subjected to interferences and offer high penetration and low radiation (Caja et al., 2004). The main step forward to embrace this technology for animal ID was the appearance of passive transponders, that is, devices whose activation energy is obtained from the transceiver's activation electromagnetic field. The main shortcoming of passive RFID technology operating at low frequencies is that the transponders' reading distance is severely reduced.

However, the appearance of passive transponders allowed them to be miniaturized for their permanent location internally in the animals. These facts eventually brought about the appearance of the 3 main RFID device types which are currently in use for animal ID, namely:

1.4.1. Injectable transponder: Consisting of a glass encapsulated device with a wide range of sizes available. Transponder size (i.e. antenna size) determines the reading distance obtained. Different subcutaneous sites (armpit, ear base, leg, groin, chest, tail base, etc) for transponder injection have been described in livestock (Fonseca et al. 1994; Lambooij et al., 1995; Caja et al., 1998b; Conill et al., 2000, 2002;

Hogewerf et al., 2009). Feasibility of injects is mostly conditioned by the occurrence of losses, breakages due to hits at the region where injected, as well as proper retrieval in slaughtered animals (Fonseca et al., 1994; Lambooij et al., 1999; Abecia et al., 2004; Caja et al., 2005). Proper retrieval is additionally conditioned by transponder dislocation due to migration through the tissue, which is principally caused by a bioincompatibility reaction to the foreign body (Lambooij et al., 1992; Queiroga et al., 1994; Caja et al., 1998b). Recently, intraperitoneal injection has been evaluated, mainly in swine, with suitable readability results; in this case, no carcass contamination has been reported, although low rate of transponder retrieval from the abdominal content is achieved (Caja et al., 2005; Babot et al., 2006).

1.4.2. Ear tag: The transponder is usually embedded (air coil) in the tag's plastic casing, although glass encapsulated transponders properly protected and attached to the tag are also used at present (ICAR, 2010). Readability performance is affected by losses, breakages and electronic failures (Stärk et al., 1998; Rusk, 2002; Schuiling et al., 2004). Similarly to their conventional counterparts, losses and damages caused to the ears in the events of tissue reaction, infection or ear splitting must be considered (Stärk et al., 1998; Schuiling et al., 2004). However, differences in weight and dimensions because of the presence of the transponder may greatly condition readability values as well (Caja et al., 1998a).

1.4.3. Rumen bolus: Aimed at ruminant livestock, this consists of a high dense capsule where the transponder is encased (usually a glass-encapsulated type), and with the objective of being permanently retained in the reticulum-rumen (Ribó et al., 1994c; Caja et al., 1999). Boluses are mostly made of dense ceramics, as radio translucent materials are required. The features of boluses affect the retention rate obtained (Fallon, 2001; Ghirardi et al., 2006a,b), and also condition the minimum age and body weight at which they can be administered (Garín et al., 2005; Castro et al., 2005, 2010). Despite being permanently subjected to misgivings with respect to safety and animal welfare, most reports indicate that no negative effects on production performance and apparent welfare are caused by its administration and its long-term permanence in the reticulorumen (Hasker and Bassingthwaighte, 1996; Caja et al., 1999; Fallon, 2001; Garín et al., 2003; Ghirardi et al., 2007).

Feasibility of passive radio frequency technology for livestock ID has been mainly carried out during the last two decades, being regarded as an improved alternative to traditional ID methods in different livestock species and under a variety of production systems. Most of this research has been undertaken within the framework of several research projects supported by the European Commission (FEOGA, 1993-94; AIR 2304, 1995-98, IDEA, 1998-2001; EID+DNA Tracing, 2001-05). Results obtained have confirmed straight improvements in the retention and readability of RFID devices, although they are strongly dependent on the features of devices and the application methodology.

Apart from reliable animal identification, RFID also allows the acquisition, transfer and management of ID data to be dealt with more easily (Trevarthen and Michael, 2008; Voulodimos et al., 2009), thereby maintaining properly up-to-date databases to support quick and accurate traceability (Ammendrup and Barcos, 2006). Additionally, RFID technology becomes a powerful tool for the automation of farm management and data recording (feeding control, milk recording, weighting, etc) (Speicher, 1981; Georgoudis and Gabriilidis, 1997; Halachmi et al., 1998; Pinelli et al., 2002; Ait-Saidi et al., 2007; Trevarthen and Michael, 2008; Voulodimos et al., 2009; Bocquier et al., 2009).

1.5. Antecedents on the use of conventional and radio frequency devices for goat identification

At the time of carrying out the experiments corresponding to the present thesis, available data on the performance of ID devices in goats were very limited in comparison with other livestock species. Information referring to goats corresponded to the evaluation of plastic ear tags (Caja et al., 1999a,b), electronic ear tags (Schuiling et al., 2004), electronic rumen boluses (Ribó et al., 1994; JRC, 2003; Capote et al., 2005; MAPA, 2002, 2007; Pinna et al., 2006), injectable transponders (Fonseca et al., 1994; Ribó et al., 1994; Caja et al., 1999b), and leg tags (Abecia and Torras, 2009).

To our knowledge, only 2 references in the literature show values regarding the performance of visual ear tags in goats (Caja et al., 1999a,b). According to these studies, and using ear tags for official ID, readability rates ranging from 80 to 94% were observed in Murciano-Granadina dairy goats. Although poor performance has also been reported in sheep, cattle, and swine (Caja et al., 1999a; Conill et al., 2000; Schembri et al. 2007), further evaluation of their performance in goats was warranted.

With respect to electronic ear tags, Schuiling et al. (2004) tested different tag types in goats, obtaining readabilities ranging from 93.3 to 98.0% and greatly varying between tag types and between herds under study; ear tag losses varied between adult goats and kids (5.1% vs. 1.5%), and so did the electronic failures (1.6% vs. 0.5%). Moreover, a high incidence of ear damage (8.5%) was still apparent at 4 mo after tagging, as well as wounds caused by the tag pressing inflamed ears (6.3%). According to results, authors concluded that improvements on ear tags features were still required before their use in practice could be recommended.

Injectable transponders were firstly tested in goats within the frame of the FEOGA European project (Caja et al., 1994), where readability of 32-mm transponders injected in different body sites (armpit, ear base, tail base, and groin) was evaluated in short- to medium-term experiments. Readability rates obtained ranged from 89.1 to 100% (Fonseca et al., 1994a), with most unreadable transponders being lost. Moreover, remarkable variations in subcutaneous migration was also reported, with the lower (26 mm) and greater (47 mm) values observed in the tail and armpit, respectively (Ribó et al., 1994a). According to results, the armpit was the body site recommended for injection in goats (Fonseca et al., 1994; Ribó et al., 1994a).

Results were confirmed in a long-term study (3-yr), where 2,160 Murciano-Granadina goats were injected in the armpit to automate milk recordings by using hand-held readers (Caja et al., 1999b); a readability of 98% was registered at the end of the project. On the other hand, although no references were found in goats, the retrieval of injects at slaughter in other livestock species has been shown to be undoubtedly deficient (Lambooij et al., 1999; Conill et al., 2002; Caja et al., 2005a). This is a major shortcoming, as it constitutes a public health issue.

In the case of rumen boluses, a relatively large amount of data was already available when starting this thesis, as initial experiments had been carried out in the framework of the FEOGA (Ribó et al., 1994) and IDEA (JRC, 2003) European projects on the on-field implementation of livestock RFID. In the FEOGA project, a lower retention of rumen boluses in goats than in sheep was suggested for the first time.

Subsequently, more than 30,600 goats were identified in the IDEA Project (JRC, 2003), with approximately 45% of them being located in Spain. Results confirmed the poorer retention in goats (<97%) with respect to sheep (>99.7%). Deficient bolus retention in goats was explained by average retention obtained in Spain (94.2%), as retention rates >99.6% were reported in other breeds in Italy and Portugal (JRC, 2003; Pinna et al., 2006). Subsequent studies in several Spanish autochthonous breeds showed a remarkable variability in the retention of boluses between breeds and even herds (89.7 to 100%; MAPA, 2002; San Miguel et al., 2005; Capote et al., 2005). Moreover, in many occasions the retention rate did not reach the 98% value recommended by the International Committee for Animal Recording (ICAR, 2007).

In addition to ear tags, injects, and rumen boluses, the use of leg bands placed on the pastern of the hind-leg is frequently used for the nonofficial ID of dairy goats in the milking parlor (Balvay, 2007). To our knowledge, only one study has been carried out so far to evaluate the long-term performance of visual and electronic leg tags for dairy goat ID. In this study, the retention of electronic leg tags at >6 mo after tagging ranged from 88 to 99%, and electronic failures ranged from 1.6 to 4.5%, depending on the model (Balvay, 2009). A visual leg band was also tested for goat ID at early ages, and a 99% retention rate was observed, although visual readability was 90% (Balvay, 2009). Abecia and Torras (2009) studied the suitable minimum age and body weight of Murciano-Granadina dairy goats for the permanent and tamper-free ID with electronic leg tags. The authors concluded that goat kids could be appropriately identified before 6 mo of age, as the shank circumference at 5 mo had already reached the 86.7% of the circumference in adult does.

1.6. European legislation on goat identification

1.6.1. Background

In order to successfully implement a system for the identification and registration (ID&R) of livestock, four main objectives or stages shall be covered:

1) Registration of premises where animals are held.
2) Permanent individual animal ID at early ages and in any case before leaving the holding of origin.
3) Registration of animal movements from one holding to another or to a slaughterhouse.
4) Computerized networked databases for quick and easy access and management of available data.

The ID&R systems that are being currently tackled in different countries round the world are already based on these goals. The order of objectives showed above can be considered as the most appropriate for a reasonable deployment of the whole system, but the system can not be fully operative until all the stages are wholly implemented.

In the case of the EU, the scope of current legislation is based on compulsory statements. This particularity of the European framework contrasts with other cases, like the National Animal Identification System (NAIS) in the United States, whose implementation is voluntary.

European Council Directive 92/102/EEC of 27 November 1992 was the first regulation purposely aimed at establishing an animal ID&R system on a European basis, and was focused on bovine, ovine, caprine and porcine livestock. This directive intended to give a response to the need for a reliable animal ID, a suitable recording of animal movements, as well as the registration of all premises where these animals were raised. With regard to the means of identification, visual plastic ear tags were the devices chosen to be used. In the case of goats and sheep, at least one ear tag should be applied, and only allotting ID was required.

The bovine spongiform encephalopathy (BSE) crisis, which caused a profound impact in the market on beef and beef products, showed the need for further improvement of the measures stated in Directive 92/102/EEC. In the case of sheep and goats, particularly the foot-and-mouth disease crisis and the possible relationship or confusion between scrapie and BSE also showed the need for more stringent rules to achieve a really efficient ID&R system.

1.6.2. Current legislation

Council Directive 92/102/EEC of 1992 was replaced in 2004 by Regulation EC 21/2004, establishing a system for the identification and registration of sheep and goats. This regulation has subsequently been amended by regulations EC 933/2008 and EC 759/2009. Regulation EC 21/2004 was officially deployable since its publication, although its mandatory implementation has been postponed and only sheep and goats born after 2009 are to be identified (EC 1560/2007). Each goat shall be identified with 1 visual and 1 RFID device. However, there is no such obligation for European Member States in which the total number of ovine and caprine animals is 600,000 or less, as well as for Member States with up to 160,000 caprine animals.

In the Member States where RFID is compulsory, the following visual and RFID devices can be combined to implement the double ID system indicated in the European regulations:

System 1: Visual	System 2: RFID
- Ear tag - Mark on the pastern - Tattoo (No intra-Community trade)	- Rumen bolus - Electronic ear tag - Electronic mark on the pastern (No intra-Community trade) - Injectable transponder (No intra-Community trade)

In the Member States where electronic identification is not obligatory, the following double ID systems combinations are currently regulated:

System 1: Visual	System 2: Visual
- Ear tag	- Ear tag - Mark on the pastern - Tattoo (No intra-Community trade)

As shown, the tattoo and the electronic marks in the pastern (inject or leg band) are not permitted as the second means of ID for goats intended for intra-Community trade.

Both conventional ear tags and electronic transponders must contain non duplicated codes. These codes comprise, firstly, data on the Member State where the animal was identified, which may consist of a 2-letter or a 3-digit numeric country code, in agreement with the country codes laid down in the ISO 3166 standard (ISO, 2006). The country code shall be followed by a 12-digit numeric code corresponding to individual animal ID. Moreover, Member States may authorize the inclusion of additional information (bar codes, quality marks, etc.) to visual devices, provided that the ID number is not affected.

Animals must be identified not later than 6 mo after birth and, in all cases, before leaving the holding of origin. Competent authority may exceptionally extend this period up to 9 mo in goat herds managed under free-range farming conditions where ID at early age can hardly be accomplished.

Additionally, competent authority may authorize that animals intended for slaughter before 12 mo of age within a Member State, are identified with an ear tag bearing the country code and the code identifying the holding of birth. In that event, only lot or batch traceability of animals and their products is achievable.

Goats imported from third countries must be reidentified by the Member State of reception pursuant to current European regulations. In this case, the link between prior and new ID number will be registered. Only the animals whose first destiny in the EU is a slaughterhouse are exempt from being reidentified. Where a means of ID becomes illegible or gets lost, a replacement device with the same ID number must be applied as soon as possible; the ID number must also inform of the times a device has been replaced (retagging counter).

In response to current European regulations, Spanish legislation has been modified by introducing the Real Decreto 947/2004. According to the Spanish regulations, mandatory ID of goats is in place since 2006. In this regard, electronic rumen boluses were initially chosen by the Spanish competent authority as the electronic devices to be used. Nevertheless, as already mentioned, long-term retention rates of rumen boluses in some Spanish goat breeds do not reach the 98% value required by the ICAR (2007). For this reason, Spanish legislation also regards the alternative use, under approval of the competent authority, of button electronic ear tags and electronic marks (injects or leg bands) on the pastern of the hind-leg (Real Decreto 1486/2009). In the Spanish framework, animals aimed at intra-Community trade or exportation can be identified, exceptionally and under authorization, by a double visual ear tag.

In summary, permanent and tamper-proof ID of goats with devices that are safely recovered at slaughter remains an unsolved issue, especially when contrasting the inconsistent performance of rumen boluses with respect to sheep. Moreover, little information on the feasibility of the different systems currently available for visual and electronic goat ID is available if compared to other species. This is of major relevance considering the important changes which are being undertaken in recent years in the framework of European legislation on sheep and goat ID. This has been, therefore, the motivation for carrying out the present thesis.

CHAPTER 2

Objectives

CHAPTER 2

OBJECTIVES

The main objective of this thesis was to evaluate the suitability of different visual and RFID devices to optimize the permanent identification of goats while complying with the statements laid down in the current European regulations (EC 21/2004; EC 933/2008) on sheep and goat identification and registration.

The following specific objectives were developed:

1. Identification of dairy goats under intensive management conditions:
   Study of small- and standard-sized boluses, injectable transponders in the fore-leg, and visual and RFID ear tags applied at early ages.
   - Easiness of application.
   - Effect of extending the rearing period on the losses of mini-boluses.
   - Comparison of the long-term retention and readability.

2. Identification of goats under semi-extensive management conditions:
   Evaluation of small- and standard-sized boluses, and visual ear tags.
   - Easiness of application.
   - Effect of feeding management on early losses of rumen boluses.
   - Comparison of the long-term retention and readability according to device type and goat breed.

3. Leg tags for the identification of dairy goats in the milking parlor:
   Use of leg tags as an alternative to previous visual and RFID devices, in agreement with late modifications of European regulations (EC 933/2008).
   - Easiness and suitability of application in replacement and adult goats.
   - Long-term retention and readability.
   - Static reading efficiency in the milking parlor by using hand-held readers.
   - Dynamic reading efficiency by testing a frame antenna located in different positions in a runway, and under collision challenging conditions.

4. Modeling the retention of rumen boluses in goats:
   - Regression model of the retention of rumen boluses according to their physical features.
   - Assessment of bolus features to design bolus prototypes with optimum retention rate (>99%) irrespective of goat breed and production system.

This thesis was partially developed in the frame of the research project 'Use of electronic identification by passive transponders for registration and traceability of sheep and goats' ('Aplicación de la identificación electrónica mediante transpondedores pasivos para el registro y trazabilidad de ovinos y caprinos'; Plan Nacional I+D+i; Project AGL-2007-64541), funded by the Spanish Ministry of Education.

CHAPTER 3

Experiment 1: Visual and electronic identification of dairy goats at early ages

CHAPTER 3

Experiment 1: Long-term performance of visual and electronic identification devices in dairy goats

3.1. ABSTRACT

Dairy goat kids born during a 3-yr period (n = 97) and their mothers (n = 29) were used for a long-term evaluation of the performance of 9 types of identification (ID) devices. Kids wore multiple ID devices: visual ear tags (V1, tip-tag , n = 47; V2, official, n = 50), electronic ear tags (E1, button-button, n = 46; E2, flag-button, n = 46), electronic rumen boluses (B1, mini-bolus 14 g, n = 92; B2, mini-bolus 20 g, n = 28; B3, standard bolus 75 g, n = 34) and glass encapsulated transponders injected in the forefeet (T1, 15 mm, n = 75; T2, 12 mm, n = 100). Visual ear tags were applied at birth and removed in yearlings, whereas electronic ear tags were applied after bolusing with B1 (6.7 kg BW and 30 d, on average); B2 were administered in the event of a B1 loss, and B3 in case of a B2 loss and in goat does. At d 60 of age, kids were allocated into 2 groups to evaluate the effects of rearing system on ID. Treatments were: weaned (n = 46), and not weaned (n = 46) where kids suckled a milk substitute until d 150. Readability of ID devices (read/readable × 100) was monitored from 1 to 3 yr of age, depending on device and year of birth. Long-term readability was analyzed using a non-parametric survival analysis. A total of 3.3% infections and 6.5% tissue reactions were reported for electronic ear tags, but ears were fully healed in yearlings. Weaning numerically reduced B1 losses at d 150 (weaned, 84.8% vs. not weaned, 73.3%; $P = 0.184$). Readability of visual ear tags in yearlings (V1, 82.9%; V2, 94.0%; $P = 0.107$) was lower than for electronic ear tags (E1 and E2, 100%). Mini-bolus readability in yearlings did not differ by type (B1, 71.4%; B2, 84.6%) or with visual ear tags. No effect of inject type was reported (T1, 92.0%; T2, 96.0%). Survival analysis after yr 3 gave the greatest readability value for E1 (100%), which did not differ from B3 (96.8%) or T2 (96.0%). The lowest readability was estimated for B1 (66.3%), followed by E2 (79.8%), B2 (81.4%), and T1 (90.4%). In conclusion, button-button electronic ear tags and standard boluses were the more efficient devices under our conditions, their readability values being greater than injects, electronic mini-boluses, and visual and flag-button electronic ear tags. Transponders injected in the forefeet and mini-boluses used here are not recommended in practice. Further research on E1 and B3 electronic devices should be done in a higher number of goats to confirm the current results.

3.2. INTRODUCTION

Electronic identification of sheep and goats has become an important issue in the European Union since the publication of Regulation EC 21/2004 (recently amended by SANCO/1427/2008), which establishes a double identification (**ID**) system for replacement animals with both a plastic ear tag and a second device to be chosen by each

Member State. When the sheep and goat population within a Member State is greater than 600,000 animals, the second means of ID must be a passive radio-frequency device. Double ID was expected to be mandatory in 2008 but has been put off until 2010, although it has been officially deployable since July 2005. In Spain, the electronic bolus has been used as the second means of ID since January 2006 (Real Decreto 947/2005).

Optimum retention of boluses in sheep and cattle has been achieved by optimizing their physical features (Caja et al., 1999a; Fallon, 2001; Ghirardi et al., 2006). However, bolus retention in the case of goats has shown remarkable variability in practice, ranging from 89.7 to 99.6% (JRC, 2003; Capote et al., 2005; Pinna et al., 2006). That is why current Spanish legislation (Real Decreto 947/2005) permits the use (under authorization) of transponders injected in the metacarpus (forefoot) in goats. Although injection to this body site may prevent carcass contamination, animals can not be used for consumption. Little information is available on the comparison of injectable transponders, electronic ear tags and boluses in goats. In contrast to goats, over 99% retention has been achieved in lambs by using small size boluses (Garín et al., 2005; Ghirardi et al., 2007). No information is available on the use of electronic ID devices in replacement goat kids.

The aim of this study was to investigate the long-term performance of visual and electronic ID devices applied in kids and dairy goats, as well as to evaluate the influence of rearing management conditions on the variability of the retention rate of small size electronic boluses.

3.3. MATERIALS AND METHODS

The experimental procedures and animal care conditions were approved by the Ethical Committee on Animal and Human Experimentation (Reference CEEAH 606/06) of the Universitat Autònoma de Barcelona.

A total of 29 goat does and 97 goat kids of Murciano-Granadina dairy breed from the Experimental Farm of the S1GCE (Servei de Granges i Camps Experimentals), Universitat Autònoma de Barcelona, were used. Goat does were bred for an annual kidding season in the autumn and kidded during fall of 2004 (n = 27), 2005 (n = 18) and 2006 (n = 18), giving birth to 45, 26 and 26 kids, respectively. Kids were under study for 3, 2 and 1 yr depending on the year of birth.

3.3.1. Visual identification

Each kid was identified at birth with 1 visual ear tag applied on the left ear. Two types of rectangular visual ear tags made of plastic (Figure 3.1) from the same manufacturer (Azasa-Allflex, Madrid, Spain) were used; ear tags features (weight, flag dimensions and pin dimensions) were: **V1** “tip-tag” ear tag (1.4 g, 35.5 × 9.3 mm, 15.5 ×3.9 mm; opened female piece; n = 47) commonly used by the farmers for their low cost; and, **V2** “official” tamperproof ear tag (2.8 g, 40 × 14.5 mm, 22 × 5 mm; closed female piece; n = 50) made to fulfill the new requirements of the European Union Regulation EC 21/2004. Both V1 and V2 ear tags were considered as temporary ID and were removed at 12 mo of age when yearling kids joined the breeding herd. All ear tags had printed both a serial animal number (7 digits), and the holding number (14 digits) as required by Regulation EC 21/2004.

Goat does wore 2 flag plastic ear tags of large size (48 × 38 mm, yellow color; Azasa-Allflex) in the left ear. These large ear tags were manually marked with individual codes of 3 digits (27 × 10 mm each) with black plastic ink (Allflex Tag Pen, Dallas, TX) and were used for milk recording (Ait-Saidi et al., 2008).

3.3.2. Rearing treatments and management

Kids were separated from their mothers in the first 8 h after birth, moved to straw bedded pens (0.5 m^2/kid) and fed colostrum 3 times a day until d 3. Afterwards, kids were provided ad libitum milk replacer (CP, 23.8%; ether extract, 25.0%; crude fiber, 0.3%; ash, 6.6%; F 463, Sofivo, Condé sur Vire, France) in a concentration of 150 g/L until wk 8 by using an automatic milk dispenser (Model M-E250, Industrias J.R., Valdelafuente, Spain). From wk 3 of age, kids were also fed ad libitum with barley straw and a commercial concentrate (CP, 17.4%; ether extract, 3.3%; crude fiber, 4.1%; ash, 5.8%; O-118-G, La Gironina, Sant Gregori, Spain). Kids had free access to water as well. In order to evaluate the effect of rearing management on losses of ID devices administered at early ages, kids of 60 ± 3.1 d (10.2 ± 0.2 kg BW) were allocated into 2 balanced groups according to BW and randomly assigned to 2 experimental rearing treatments: weaned (**W**; n = 46), where kids were weaned with no transition period; and not weaned (**NW**; n = 46), where each kid received a daily (1700) supplement of approximately 1 L of a 1:1

dilution of goat milk in warm water (35 ºC) until mo 5 of age. Diluted milk supplement was administered by using buckets (9 L) with rubber teats, similarly as described when attempting to maintain an active esophageal groove reflex (Ørskov et al., 1970). This conditioned reflex is a physiological mechanism of suckling ruminants to allow milk to by-pass the reticulo-rumen and reach the abomasum. Rubber nipples were placed at approximately 25 cm from the ground to allow for a natural position of suckling kids; that is, with the head and cranial esophagus in a lower position with respect to thoracic esophagus and forestomachs.

Concentrate was gradually replaced, from 2 to 4 mo of age, by whole barley grain and alfalfa pellets (1:1) ad libitum. At the age of 4 mo, kids passed to a semi confined system, grazing 6 h daily (0900 to 1500) in cultivated Italian ryegrass pasture and supplemented with a dehydrated mixture of whole-plant corn and alfalfa hay (1:1) fed ad libitum, and a commercial concentrate (CP, 17.5%; ether extract, 3.8%; crude fiber, 4.0%; ash, 7.1%; 1.53 Mcal of NE_L/kg) according to the physiological stage. At the age of 18 mo, 47 (51%) animals were sold to 2 nearby herds and they continued to be monitored at least every 3 mo until the end of the study, or until death or slaughter.

In addition, 29 adult goats were used as a control for long term retention of ID devices. Animals that died during the study were sent to the Pathology Service of the Universitat Autònoma de Barcelona for necropsy.

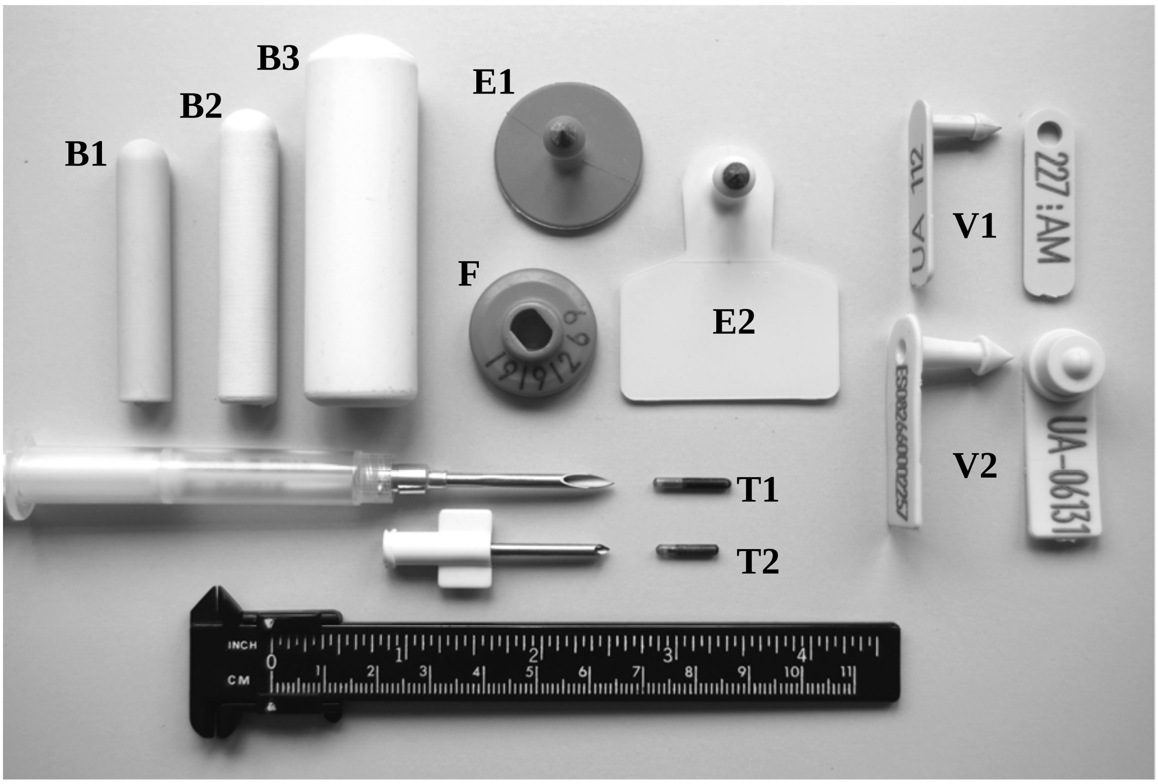
3.3.3. Electronic identification devices and administration procedures

3.3.3.1. Rumen boluses

Three types of cylindrical boluses (Rumitag, Esplugues de Llobregat, Spain) were used (Figure 3.1). Boluses were made of atoxic, nonporous and highly dense ceramic materials and their features were as follows (material, weight, length × o.d. and specific gravity): **B1** (zirconia, 13.7 g, 51 × 10 mm and 3.5; n = 92), **B2** (zirconia, 20.1 g, 56 × 11 mm and 3.9; n = 28), and **B3** (alumina, 75.0 g, 68.2 × 21.0 mm and 3.4; n = 34). The first 2 types were small size boluses specially designed to be administered to lambs and kids at early ages. The third type was a standard dimensioned bolus previously used for cattle, sheep and goat (JRC, 2003; Capote et al., 2005; Pinna et al., 2006) and used as a control. Each bolus contained a half-duplex (**HDX**), read-only, glass encapsulated transponder of 32 × 3.8 mm (Ri-Trp-RR2B-06, Tiris, Almelo, The Netherlands). In kids born after July

2005, transponders included the country (Spain, 724), species (sheep and goat, 04) and the autonomous community (Catalonia, 09) codes and a 10-digit serial number, according to the current Spanish legislation (Real Decreto 947/2005) and in agreement with ISO 11784 and 11785 standards on animal electronic ID (ISO, 1996a,b). For the rest of the animals, ISO transponders with the ICAR (2008) official manufacturer code (Rumitag, 964) and a 12-digit serial number were used.

Figure 3.1. Electronic and conventional devices used for the identification of dairy goats. Abbreviations: V1, "tip-tag" ear tag (Azasa-Allflex, Madrid, Spain); V2, "official" tamper-proof ear tag (Azasa-Allflex); B1, mini-bolus 13.7 g and 51.0 × 10.5 mm (Rumitag, Esplugues de LLobregat, Spain); B2, mini-bolus 20.1 g and 56.4 × 10.5 mm (Rumitag); B3, standard bolus 75 g and 68.2 × 21.0 mm (Rumitag); E1, plastic button male ear tag piece (Azasa-Allflex); E2, ear tag made of plastic flag male piece (Azasa-Allflex); F, electronic button female piece (Allflex Europe, Vitré, France) for E1 and E2; T1, injectable transponder 15 × 2.1 mm (Avid Microchip España, Barcelona, Spain); T2, injectable transponder 12 × 2.1 mm (Cromasa, Berriozar, Spain).



For B1, to determine the minimum age and BW at safe bolusing, application was attempted on kids older than 15 d of age twice weekly. Boluses were administered by a trained operator by using an adapted balling gun (Rumitag). For bolus administration, kids were restrained between the operator's legs, holding the animal caudally to its shoulder blades. Then, the operator bent down and introduced the balling gun laterally into the animal's mouth while holding with the other hand its lower jaw at the region without teeth (diastema). The bolus was released into the bottom of the oropharyngeal cavity (base of the tongue) to stimulate the involuntary reflex of deglution, similarly as described by Caja et al. (1999a).

Figure 3.2. Administration of a 5-mL bolus in a Murciano-Granadina goat kid.

If swallowing difficulties were observed, the bolus was expelled by means of an upward external massage on the throat and administration was delayed until the following bolusing session. In order to solve difficulties in the passage of a swallowed bolus through the esophagus tract, a plastic probe (length × o.d., 500 × 10 mm) was prepared and used if necessary to gently push the bolus into the reticulo-rumen as previously done by Garín et al. (2005) and Ghirardi et al. (2007) in suckling lambs. The B2 bolus was administered in case of a loss of a B1 bolus by using the same procedures described above. Likewise, B3 boluses were administered in the event of a B2 loss. The B3 were administered by 1 operator and 1 assistant when animals had a BW greater than 20 kg, as indicated by Caja et al. (1999a). Adult goats used as a control were identified with B3 boluses when yearlings, before joining the rest of the herd; one goat was rebolused with B3 before starting the study.

3.3.3.2 Electronic ear tags

Along with the B1 bolus administration, each kid was tagged with an electronic ear tag (Figure 3.1) on the right ear. One type of ear tag button female piece (**F**; weight, 4.1 g; o.d., 24 mm; and height, 11 mm; Allflex Europe, Vitré, France; n = 92) containing an HDX transponder was used. Transponder serial numbers included the manufacturer code (Allflex, 982) and worked in accordance with ISO standards (ISO, 1996a,b). Two types of male pieces were used: **E1** button type (Azasa-Allflex, Madrid, Spain; weight, 1.8 g; button o.d., 28.5 mm; pin length × o.d., 20.5 × 5.5 mm; n = 46) and **E2** flag type (Azasa-Allflex; 3 g; flag length × width, 48.5 × 42 mm; pin length × o.d., 20.5 × 5.5 mm; n = 46). Ear tags were applied to the middle of the ear at one third from the ear base, using tagger pliers recommended by the manufacturer (Universal Total Tagger, Allflex Europe); the F piece was placed on the internal side of the ear.

3.3.3.3. Injectable transponders

A total of 175 full-duplex (**FDX-B**) read-only and glass-encapsulated transponders from 2 manufacturers were injected subcutaneously in the forefeet of 91 goat kids at 90 d of age. Transponders were (Figure 3.1): **T1** (Avid Microchip España, Barcelona, Spain; length × o. d., 15 × 2.1 mm; n = 75) and **T2** (Cromasa, Berriozar, Spain; 12 × 2.1 mm; n = 100). Serial numbers of transponders agreed with ISO standards (ISO, 1996a,b) and included the manufacturer code (Avid, 977; Cromasa, 953).

Injections of T1 were done using sterile single-use disposable syringes (Avid Microchip España) equipped with 31 × 2.8 mm needles with a bevel of 10.3 mm length (Figure 3.1). Injections of T2 were done using a single-shot injector (Cromasa) with multiple-use 23 × 2.5 mm needles with a bevel of 3 mm length. In this case, each needle was replaced after 20 to 25 injections. The T2 were presented in 20-unit dispensers (Identron-GT 212; Cromasa) and individually roofed in an iodine solution; each transponder was charged by introducing the injector needle into the transponder dispenser, resulting in the needle being immersed in the iodine solution before each injection. To perform the injections, 1 assistant restrained the animals on its back on a V-shaped restraining table, stretching their extremities out. The operator then held the forefoot and injected the transponder subcutaneously in a downward proximo-distal direction into the rear face of the metacarpal area, resulting in the transponder being placed at 1-2 cm over the proximal sesamoid bones (ossa sesamoidea proximalia). A gentle external pressure with a finger was exerted on the injection site when withdrawing the needle to diminish the backward movement of transponders during this process. After injection, an antibiotic for topic use (Veterin tecnicol, Laboratorios Intervet, Salamanca, Spain) was sprayed on the injection site. All the injections were performed by previously trained operators.

Figure 3.1. Injection and location of a 15-mm transponder in the rear metacarpal area of a Murciano-Granadina goat kid.

3.3.4. Monitoring of kids and identification devices

Kids were weighed weekly until 60 d of age by using a portable scale with an accuracy of 10 g (FX-31, Allflex NZ, Palmerston, New Zealand). Kids were thereafter weighed every second wk until 150 d old by using a Tru-Test AG 500-02 (Pakuranga, Auckland, New Zealand) electronic scale with an accuracy of 100 g. Electronic devices were read in static conditions (animals restrained) by using ISO handheld transceivers (Gesreader 2S, Rumitag) which were able to read ISO HDX and FDX-B transponders at a minimum distance of 12 and 20 cm for ear tags and boluses, respectively, as specified in the technical guidelines for the implementation of European Regulation EC 21/2004. Each electronic device was read immediately before and after administration to check possible breakages or electronic failures during administration procedures. Readings were performed with the reader at a close distance to the device being checked to avoid interferences with other transponders applied in the same animal. At post-administration readings, individual kid data was typed and stored into the reader. For the boluses, a directional caudo-cranial sweep on both sides of abdomen area was performed with the reader to check the proper descent of bolus into the reticulorumen. Age and BW at administration of ID devices were registered as well as time required for administration of boluses and injectable transponders. Any incidence during administration procedures was also recorded.

Readings were taken at every weighing session under static conditions, until 150 d of age. From 5 to 18 mo of age all devices were read and checked monthly, and thereafter every 2 mo. In addition to losses, ear tags were monitored for electronic failures and damages (breakages, signs of nibbling, etc), as well as kid healthiness (hair appearance, growth, normal behavior, etc) and ear tissue reactions. When evaluating the performance of injectable transponders, differentiation among losses, breakages and electronic failures was ensured by palpation as described by Conill et al. (2000), and an electronic failure was assumed when the transponder was deemed neither lost nor broken. Boluses applied in adult goats (B3) were read with the same regularity as devices applied in kids.

Performance of ID devices was expressed as readability, being:

$$\text{Readability} = (\text{no. read devices/no. readable devices}) \times 100$$

Unreadable devices included losses, failures and devices with damages that made them unreadable.

Dimensions of a total of 50 F pieces and 50 male pieces (E1, n = 25; E2, n = 25) of the electronic ear tags were measured by using an electronic digital caliper (Accuracy = 0.03 mm; Shaodong Feiyue Hardware Tools Factory, Yiwu, China). The mechanical resistance of the locking system of these devices was measured by suspending a ballast and applying progressive weights (0.1 kg) until achieving 40 kg.

3.3.5. Statistical analyses

Least squares means of age and BW at administration of devices were obtained with the GLM procedure of SAS (v. 9.1, SAS Inst. Inc., Cary, NC). Factors considered were type of ID device, year of birth and the interaction type of ID device × year of birth. Non-significant ($P > 0.20$) effects were removed from the model. Data on physical features and resistance of the locking system of electronic ear tags were analyzed with the GLM procedure of SAS.

Losses, electronic failures and readability of ID devices were analyzed with the CATMOD procedure of SAS on the basis of the categorical nature of these variables. A Logit model with an estimation method of maximum likelihood (Cox, 1970) was used, evaluating the effects of type of ID device, year of birth, and the interaction type of ID device × year of birth. For the B1 and B2 bolus, effect of rearing treatment (W vs. NW) was also included. Significance was declared at $P < 0.05$ and interactions that were not significant ($P > 0.20$) were removed from the final models. Statistical analyses did not allow for comparisons with ID devices with no registered losses (100% readability).

For the analysis of readability at the end of yr 3, the Kaplan-Meier non-parametric survival analysis was considered preferable to the logit model to avoid the possible bias produced by the low number of animals monitored. A log-rank test of equality across strata (ID devices) was a performed with the LIFETEST procedure of SAS. This analysis permitted to compare the longitudinal readability of ID devices throughout the entire period of study without excluding right censored data (data from animals that left the study before a device failed), according to Cantor (2003) and Kleinbaum and Klein (2005), as well as the Kaplan-Meier estimates of readability for each type of device used. Survival monitoring started at device administration and, as continuous goat monitoring was not possible, time of device loss was registered as interval-censored data. In addition to Kaplan-Meier's readability estimates, survival curves for each ID device were also produced.

3.4. RESULTS AND DISCUSSION

3.4.1. Administration of identification devices

Total number of ID devices and administration records are shown in Table 3.1. Both V1 and V2 visual ear tags were inserted in kids of 1 d of age without incidences. Five kids (5.2%) died during the first 2 wk of suckling before being assigned to the extended rearing treatments and 5 more kids (5.2%) died during yr 1 of the long-term study. Overall yearling mortality was 10.3% which was lower than the average values reported under similar management conditions (Daza, 2004; 15 to 20%). No relationship was established between kid casualties and the ID system used despite the long term presence of boluses in the forestomachs and of injects in the pastern. The data from kids that died (n = 5) before being identified with e-ID devices were eliminated from the study and only 92 kids were used.

3.4.1.1. Rumen boluses

Four cases (4.3%) of bolus blockage into the esophagus occurred during administration of B1 in 1 mo of age suckling kids (Table 3.1). Within a few minutes of bolusing these kids showed profuse foamy sialorrhea along with nasal discharge, dyspnea and apathy. Similar findings have also been reported when studying the minimum age and BW at mini-bolus administration in fattening lambs (Ghirardi et al., 2007). External palpation and directional caudo-cranial readings with a handheld reader were carried out to confirm the bolus blockage. The esophageal probe was used to gently push the bolus into the reticulum-rumen as indicated by Garín et al. (2005) and Ghirardi et al. (2007). Affected kids fully recovered and no further incidences or secondary effects were reported. Safe bolus administration at early ages mainly depends on the anatomical development of the pharynx and esophagus and on the dimensions (length and o.d.) of boluses used. With regard to kid anatomical development, BW seems to be more accurate than age in order to assess the threshold for the safe administration of boluses. The BW and age at which B1 administration was possible were 6.8 kg and 30 d on average (Table 3.1). Using the same bolus type, Ghirardi et al. (2007) reported a BW at administration of 8.6 and 9.6 kg in lambs of local and dairy breeds, respectively. Using standard boluses of 66 × 20 mm (65 g), Caja et al. (1999a) recommended a BW greater than 20 and 25 kg for goats and sheep, respectively. Our results confirmed that boluses can be administered at earlier age and lower BW in goats than in sheep.

A total of 19 B1 were lost until 5 mo of age (readability 79.1%; Table 3.3) and were replaced by B2 which were administered at 14.9 ± 0.3 kg BW and 105 ± 7 d on average. No administration incidences were observed at this time. In addition, another 7 and 2 B1 were lost and replaced by B2 until yr 1 and 3 of the experiment, respectively, with a total of 28 B2 boluses administered (Table 3.1 and 3.3). Time needed for bolus administration, reading and recording of ID data into the reader did not differ between B1 and B2 boluses (Table 3.1; $P = 0.505$) and was lower than that reported by Ghirardi et al. (2007) for mini-bolus administration in lambs; however, these authors included restraining time in the application time.

After 1 yr of age, yearling kids having lost B2 (n = 4) were administered B3 and no incidences were reported. Time for B3 administration was not recorded.

3.4.1.2. Electronic ear tags

Three cases (3.3%) of profuse bleeding that stopped within a few minutes were observed after ear tag insertion. Whereas 90.2% of ears were completely healed at 2 mo after tagging, 3 (3.3%) ears showed infection with purulent secretion and 6 (6.5%) more ears showed a marked tissue reaction to the attached ear tags. Tissue reaction appeared as perceptible swelling of the ear and noticeable irritation under the ear tag but without bleeding or apparent signs of infection. Edwards et al. (2001) tested both plastic and metal ear tags in sheep and only reported the presence of tissue reaction to the metal tags. In our study, these findings remained apparent until 4 mo and then progressively decreased until eventually disappearing at 6 mo post-application. Length of healing period did not affect the size of the hole made at ear tagging, although some cases of increased ear thickness and hair loss around the tagging hole were observed. Ear tag readability was not affected by the healing process.

3.4.1.3. Injectable transponders

Size of injectable transponders was a relevant shortcoming for the injection in the rear metacarpal area of kids. Experiments carried out so far in this body site have evaluated the use of injectable transponders varying in length (12 to 15 mm) and o.d. (2.1 to 3 mm) in lambs and in adult sheep and goats (Abecia et al., 2004; MAPA, 2007). In our study, transponders of 15 × 3 mm were anticipated to be too large to be used in kids and only 2.1 mm o.d. were used. Age and BW at which T1 and T2 were injected are shown in Table 3.1. Four (5.3%) and 6 (6%) cases of bleeding after injection were observed for T1 and T2, respectively. Only 1 case (1%) of limping was observed after injecting a T2 transponder which disappeared at the following day with no treatment. No inflammation or signs of infection were observed and injection wounds totally healed within the following 2 wk. Time required for injection, reading and animal data recording (Table 3.1) did not differ between T1 and T2 ($P = 0.122$) and averaged 36 ± 1 s. Abecia et al. (2004) reported values of injection time also ranging from 30 to 40 s in lambs and adult sheep, including restraining time but without taking into account time for reading and storing ID data.

Table 3.1. Identification devices[1] administered to kids (n = 97) and adult dairy goats (n = 29) during a 3-yr period study.

	Visual ear tags[2,3]		Electronic boluses			Electronic ear tags[4]		Injectable transponders	
Item	V1	V2	B1[5]	B2[6]	B3[7]	E1	E2	T1	T2
Devices, n	47	50	92	28	34	46	46	75	100
Administration records									
Age, d	1	1	30 ± 1	171 ± 26	Adult	30 ± 1	30 ± 1	90 ± 4	92 ± 4
Weight, kg BW	2.1 ± 0.1^{a}	2.3 ± 0.1^{a}	6.8 ± 0.1^{b}	19.3 ± 3.9^{c}	43.6 ± 1.2^{d}	6.9 ± 0.1^{b}	6.8 ± 0.1^{b}	14.6 ± 0.3^{c}	15.1 ± 0.3^{c}
Time, s	—	—	28 ± 1^{a}	26 ± 1^{a}	—	—	—	34 ± 1^{b}	37 ± 1^{b}
Incidences, n	0	0	4[8]	0	0	3[9]	3[9]	4[10]	6[11]

[a,b]Within a row, values with different superscripts differ ($P < 0.05$)
[1]Abbreviations: V1, 'tip-tag' ear tag (Azasa-Allflex, Madrid, Spain); V2, 'official' tamper-proof ear tag (Azasa-Allflex); B1, mini-bolus 13.7 g and 51.0 × 10.5 mm (Rumitag, Esplugues de LLobregat, Spain); B2, mini-bolus 20.1 g and 56.4 × 10.5 mm (Rumitag); B3, standard bolus 75 g and 68.2 × 21.0 mm (Rumitag); E1, ear tag made of plastic button male piece (Azasa-Allflex) and electronic button female piece (Allflex Europe, Vitré, France); E2, ear tag made of plastic flag male piece (Azasa-Allflex) and electronic button female piece (Allflex Europe); T1, injectable transponder 15 × 2.1 mm (Avid Microchip España, Barcelona, Spain); T2, injectable transponder 12 × 2.1 mm (Cromasa, Berriozar, Spain).
[2]Applied on the left ear at 1 d of age.
[3]Five goat kids died during the first 2 wk of the suckling period.
[4]Applied on the right ear just after B1 administration.
[5]One goat kid died at 79 d of age because of pneumonia.
[6]Administered after detecting a B1 being lost.
[7]Administered after detecting a B2 being lost (n = 5) as well as in adult goats (n = 29).
[8]Boluses were blocked in the esophagus and gently pushed with a probe (500 × 10 mm) to the reticulum-rumen without health consequences.
[9]Profuse bleeding in 3 ears which stopped within a few minutes; 3 more ears showed infection with purulent secretion which healed at 2 mo. Six more ears showed tissue reaction (swelling and irritation) to ear tags but fully recovered at 6 mo.
[10]Bleeding after injection without posterior infection.
[11]Bleeding after injection without posterior infection was observed and 1 kid more showed limping which recovered 1 d after.

3.4.2. Effects of kid rearing on readability of identification devices

A total of 6 NW kids (13%) refused to suckle the milk from buckets during the rearing treatments, and were bottle fed. Kid daily growth was greater in NW during the first 2 wk of treatment (data not shown) but BW at the end of the rearing treatments (5 mo of age) did not differ between groups (W, 18.2 ± 0.4 kg; NW, 18.6 ± 0.6 kg; $P = 0.826$).

Regarding ID devices, 6 losses of V1 (14.6%) were reported by the end of the rearing treatments. Ear tag losses occurred without producing split ears and were not related to year and rearing treatments ($P > 0.05$). No losses of V2 were observed during this period, most likely because of an improved design and the tamperproof closing system. Nevertheless, 1 (2.0%) V2 showed severe damage caused by bites, and was illegible. As a consequence, readability of V1 (85.4%) and V2 (98.0%) at 5 mo tended to differ ($P = 0.053$). No losses or failures were observed for E1 and E2 during the whole rearing period and readability for electronic ear tags was 100%. Nevertheless, 4 (8.7%) cases of damages in the flag piece of E2 were registered.

Table 3.2. Effect of extending the suckling period until 5 mo of age on the readability of electronic mini-bolus[1] in goat kids (values are averaged data for 3 yr).[2]

Item	Rearing treatment		Overall	Effect
	Weaned	Not weaned[3]		(*P* =)
Bolus, No.				
Administered	46	45	91	-
Lost	7	12	19	-
Read	39	33	73	-
Readability, %	84.8	73.3	79.1	0.184

[1]B1 mini-bolus (13.7 g, 51.0 × 10.5 mm; Rumitag, Esplugues de Llobregat, Spain).
[2]Year effect was not significant ($P = 0.881$).
[3]One goat kid died at 79 d of age because of pneumonia.

With regard to bolus readability, no differences between years were observed ($P = 0.881$) and annual data were joined. The anatomical changes produced in the reticulorumen during the esophageal groove reflex activation did not affect bolus retention in the suckling kids, although a numerically greater retention of B1 at 5 mo of age was observed in W vs. NW kids (Table 3.2). Ghirardi et al. (2007) reported 99.4% retention of B1 boluses in weaned and fattened lambs. Although no losses could be observed in situ in our study, bolus losses by regurgitation have been already observed in calves being fed milk from buckets (J. J. Ghirardi, unpublished data).

Regurgitation is recognized to be the main mechanism of bolus losses (Riner et al., 1982; Caja et al., 1999a; Garín et al., 2005), although intestinal passage after going through the critical barrier of the reticulo-omasal orifice can not be discarded, especially when dealing with mini-boluses (Garín et al., 2005; Ghirardi et al., 2007). Studies on slaughtered animals indicate that, at the same BW (24 kg), diameter of the reticulo-omasal orifice is approximately twice greater in kids (Martín et al., 2004; 24.0 mm) than in lambs (Ghirardi et al., 2007; 14.2 mm) and than the outer diameter of the B1 mini-boluses used (10 mm o.d.). Losses by intestinal passage could be exacerbated in goats if less selective passage through the reticulo-omasal orifice occurs (Katoh et al., 1988; Clauss and Lechner-Doll, 2001). Regarding feeding management, an abrupt diet change may also increase bolus losses (AMLC, 1995; Ghirardi et al., 2007). Garín et al. (2005) found no effect on losses of small size boluses when applied in lambs 1 wk before and after weaning. In our results, no effect on bolus retention could be established with the 2 weaning systems used (60 and 150 d of age) and after the kids started grazing (4 mo of age).

Losses of B1 bolus started at 2 mo of age (1 mo after administration) whereas the first loss of B2 was registered at 7 mo of age (5 mo after administration) which agrees with their features, the B1 being smaller and lighter than B2.

3.4.3. First year readability

Readability after 1 yr of application is considered as the key value for the official approval of ID devices in livestock (ICAR, 2007). Devices granted by ICAR must fulfill a readability >98%. Actual readability values of the different ID devices throughout our study are shown in Table 3.3. All the visual ear tags readable at mo 5 were retained at 12 mo of age. From them, 1 V1 and 2 V2 showed severe damages caused by biting, but no readability differences between V1 and V2 were detected (82.9 vs. 94.0%, respectively; *P* = 0.107) at the end of the first year, when they were removed. Visual tags did not fulfill the ICAR requirement for official use.

Losses of B1 and B2 mainly occurred during the first year, resulting in a readability numerically greater in B2 than B1 (84.6% vs. 71.4%, respectively; $P = 0.182$), which was unsatisfactory for official use according to ICAR requirements; no more administrations of B1 and B2 were performed after being lost. By contrast, standard-sized B3 bolus used as control device in adult goats were fully readable (100%) at the end of yr 1 and are suitable for official use.

No electronic failures or losses were observed for electronic ear tags during the first year of the study, showing 100% readability and fulfilling the ICAR requirements.

With regard to transponders injected in the distal area of the forefeet, no difference in readability during the first year was detected between T1 and T2 (92.0 vs. 96.0%; $P = 0.268$), but their values were under the 98% required for ICAR approval. No breakages or electronic failures were registered at the end of the first year. Most losses of T1 and T2 (90.9%) occurred during the first 2 wk after injection, similarly to results indicated in lambs identified in the same body site with 12-mm transponders (Abecia et al., 2004). These early losses were mainly due to the backward movement of transponders through the channel of injection before the injection wound was totally healed, as observed in other species (Conill et al., 2000; Caja et al., 2005a). Furthermore, 98.4% of T1 and 100% of T2 losses were registered before 6 mo of injection.

3.4.4. Long-term readability of identification devices

Actual readability values of the different ID devices after the first year are shown in Table 3.3. Bolus losses decreased after the first year and steadied during yr 2 and 3. No difference between B2 and B3 was detected during the study, although B1 readability was less than that of B3 ($P < 0.05$). No difference between B2 and B3 was detected during the study, although B1 readability was lower than B3 ($P < 0.05$). As a consequence, only B3 fulfilled the requested ICAR value for official use.

With regard to ear tags, a total of 3 losses of E2 ear tags were registered after the first year; 2 of them during yr 2 and 1 during yr 3. One loss of E2 at yr 3 was directly observed in the head-locker of the milking parlor during milking, when the male-female mechanism of the ear tag unlocked. No electronic failures were observed for E1 and E2 during the entire study.

Table 3.3. Long-term performance of identification devices[1] in kids (n = 97) and adult dairy goats (n = 29) during a 3-yr period study.

Item	Visual ear tags[2]		Electronic boluses			Electronic ear tags[3]		Injectable transponders	
	V1	V2	B1[4]	B2[5]	B3[6]	E1	E2[4]	T1	T2
Birth to 5 mo of age									
Administered, n	41	50	91	19	—	46	45	75	100
Readable, n	35	49	72	19	—	46	45	69	97
Readability, %[7]	$85.4^{ac,x}$	$98.0^{bc,y}$	79.1^{a}	100	—	100	100	92.0^{cd}	97.0^{bd}
6 to 12 mo of age									
Previous, n	41	50	91	19	29	46	45	75	100
Administered, n	0	0	0	7	4	0	0	0	0
Readable, n	34	47	65	22	33	46	45	69	96
Readability, %[7]	82.9^{ab}	94.0^{ac}	71.4^{b}	84.6^{ab}	100	100	100	92.0^{ac}	96.0^{c}
1 to 2 yr of age									
Previous, n	—	—	66	22	32	33	33	66	50
Administered, n	—	—	0	2	1	0	0	0	0
Readable, n	—	—	44	20	32	33	31	60	48
Readability, %[7]	—	—	66.7^{a}	$83.3^{ab,x}$	97.0^{b}	100	93.9^{b}	90.9^{b}	$96.0^{b,y}$
2 to 3 yr of age									
Previous, n	—	—	23	8	28	10	13	42	—
Administered, n	—	—	0	0	0	0	0	0	—
Readable, n	—	—	16	7	27	10	12	39	—
Readability, %[7]	—	—	69.6^{a}	87.5^{ab}	96.4^{b}	100	92.3^{ab}	92.9^{b}	—

[a-d]Within a row, values with different superscripts differ ($P < 0.05$). [x,y]Within a row, values with different superscripts differ ($P < 0.10$).
[1]Abbreviations: V1, 'tip-tag' ear tag; V2, 'official' tamper-proof ear tag; B1, mini-bolus 13.7 g and 51.0 × 10.5 mm (Rumitag, Esplugues de LLobregat, Spain); B2, mini-bolus 20.1 g and 56.4 × 10.5 mm; B3, standard bolus 75 g and 68.2 × 21.0 mm; E1, ear tag made of plastic button male piece and electronic button female piece; E2, ear tag made of plastic flag male piece and electronic button female piece; T1, injectable transponder 15 × 2.1 mm; T2, injectable transponder 12 × 2.1 mm. [2]Applied on the left ear at 1 d of age, and removed in yearlings. [3]Applied on the right ear just after B1 administration. [4]One goat kid died at 79 d of age because of pneumonia. [5]Administered after detecting a B1 being lost (n = 28). [6]Administered after detecting a B2 being lost (n = 5) as well as in adult goats (n = 29). [7]Readability of ear tags included retention and reading (visual or electronic).

During the measurement of the external features of the F button pieces of E1 and E2, which were supposed to be all the same, small differences in the internal surface of the coupling orifice were observed between devices. Measurement results showed 2 types of button F pieces: 34% with beveled orifices of 6.7 ± 0.1 mm, and 64% of straight orifices of 6.4 ± 0.0 mm ($P < 0.001$). The beveled ear tags were able to be manually unlocked by pulling out the male piece (strength required for opening, 9.9 ± 1.0 kg) but not in the straight ones (male pin broke at 30.2 ± 0.7 kg), the difference being significant ($P < 0.001$). According to ICAR (2007), ear tags unfastening force should be greater than 280 ± 20 N (approximately 28.5 ± 2 kg). In addition, a slight difference in the outside diameter of the pin tip of the male piece was also observed in our study, E2 (flag) being greater than E1 (button) (7.6 ± 0.01 vs. 7.5 ± 0.01 mm, respectively; $P < 0.001$). A negative relationship was established between opening strength of ear tags and the diameter of the orifice of F piece (r = – 0.73; $P < 0.001$).

Because no split ears were observed for E2 losses, we concluded that losses occurred by unlocking the E2 ear tags. Moreover, 3 E2 flag pieces (9.1%) showed biting damage. Similar damage was also found in 2 E2 eventually lost. The use of E1 (button-button) ear tags prevented losses and nibbling.

Only 1 more loss of T1 was registered after the first year, the injectable transponders showing a readability in the range of 90.9 to 96.0% (Table 3.3). No differences were detected between T1 and T2, both values being inadequate for official use according to the ICAR requirement.

Apart from losses, the main limitation observed for injection in the metacarpal area was the lack of room for larger transponders; the use of small transponders results in smaller reading distances which compromises the efficiency of the recording and monitoring practices. Suitably designed transponders should permit implementation of farm automation; for example, high throughput inventorying, sorting for group or individual treatments, performance recording (weighting, milk recording), feeding according to production. Efficient electronic reading in semi-automated milk recording has proved to reduce labor costs and improve data accuracy in dairy goats (Ait-Saidi et al., 2008). Moreover, another issue when small-sized injectable transponders are used is the difficulty of ensuring that all transponders are removed from carcasses at slaughter.

Table 3.4. Readability of identification devices in goats, estimated by Kaplan-Meier non-parametric survival analysis at the end of the study.[1]

	Visual ear tags		Electronic boluses			Electronic ear tags		Injectable transponders	
Item	V1	V2	B1	B2	B3	E1	E2	T1	T2
Devices, n	45	52	92	28	34	46	46	75	100
Time, yr	1	1	3	3	3	3	3	3	2
Censored data, n[2]	38	49	64	23	33	46	43	68	96
Events, n[3]	7	3	28	5	1	0	3	7	4
Estimated readability, %	83.1	94.0	66.3[c]	81.4[cd]	96.8[ab]	100[a]	79.8[bd]	90.4[bd]	96.0

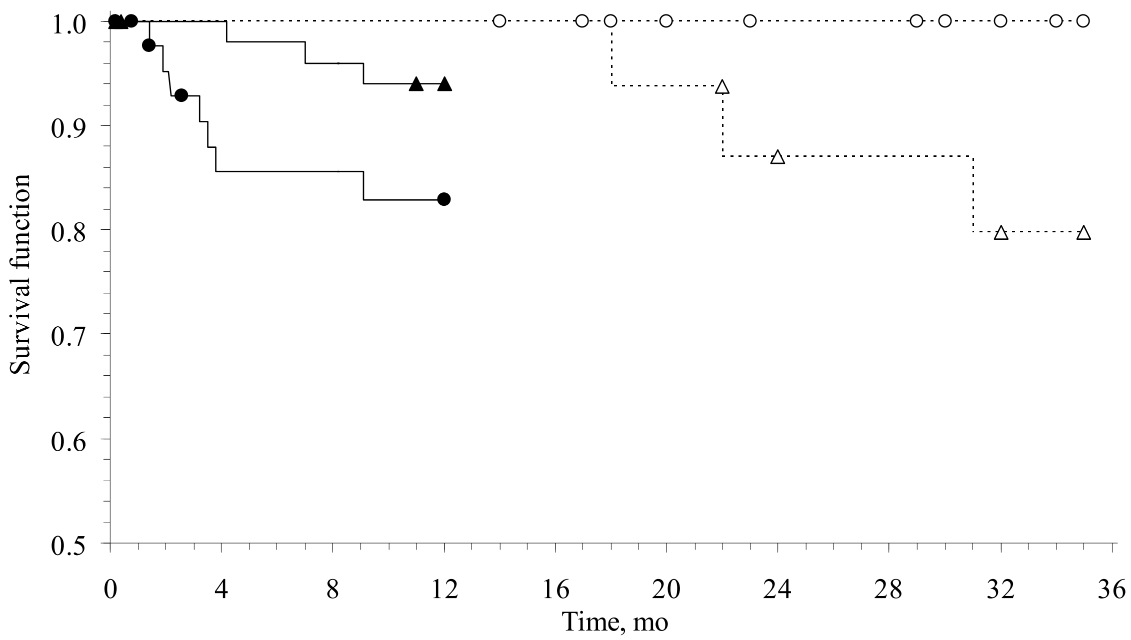
[a-d]Only for devices monitored until yr 3, values with different superscripts within a row differ ($P < 0.05$).

[1]Abbreviations: V1, ‘tip-tag’ ear tag; V2, ‘official’ tamper-proof ear tag; B1, mini-bolus 13.7 g and 51.0 × 10.5 mm; B2, mini-bolus 20.1 g and 56.4 × 10.5 mm; B3, standard bolus 75 g and 68.2 × 21.0 mm; E1, ear tag made of plastic button male piece and electronic button female piece; E2, ear tag made of plastic flag male piece and electronic button female piece; T1, injectable transponder 15 × 2.1 mm; T2, injectable transponder 12 × 2.1 mm.

[2]Devices in which the event was not observed during the study or which left the study earlier than yr 3.

[3]Devices unreadable.

Figure 3.2. Kaplan-Meier survival distribution functions for visual (—) and electronic ear tags (····) in dairy goats; censored data: V1 (●), V2 (▲), E1 (○), and E2 (Δ). Abbreviations: V1, "tip-tag" ear tag; V2, "official" tamper-proof ear tag; E1, ear tag made of plastic button male piece and electronic button female piece; and E2, ear tag made of plastic flag male piece and electronic button female piece.



Long-term readability values estimated by using the Kaplan-Meier non-parametric survival analysis are shown in Figures 3.2 and 3.3, and their values summarized in Table 3.4. Kaplan-Meier's estimated readabilities were in general lower than actual values, as a consequence of the late losses of ID devices. We considered the Kaplan-Meier's estimates as better indicators of readability because they avoided the bias produced by the low number of animals monitored at long-term (i.e., readability at yr 3 greater than at yr 2). The differences between actual and estimated values at yr 3 averaged 4.1%, ranging between 0 and 6.1%, except in E2, for which the estimated readability was 12.5% lower than actual. Fosgate et al. (2006) also carried out a 2-yr survival analysis for ear tag retention in water buffalo showing that long term retention (21.7% on average) was accurately estimated for both ears by the Kaplan-Meier's method.

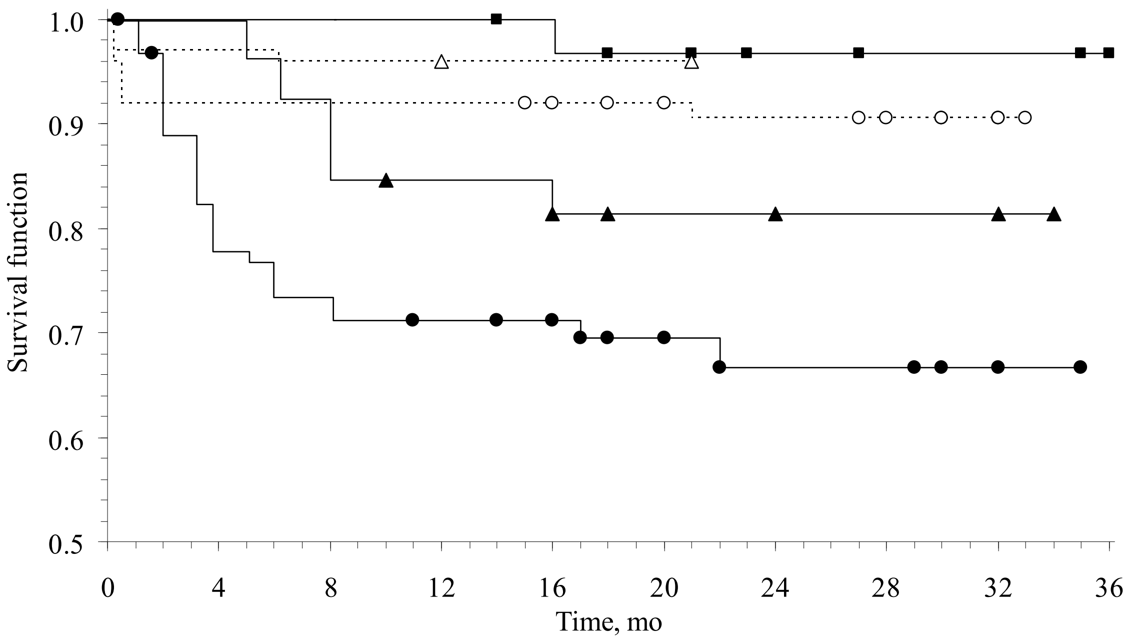
At the end of the study, B3 estimated readability (96.8%) was greater ($P < 0.05$) than B1 (66.3%) and B2 (81.4%) estimates, whereas no difference was detected between B1 and B2 ($P = 0.126$). Our results agreed with early reports (JRC, 2003; Capote et al., 2005;

Pinna et al., 2006) and support the importance of the features of electronic boluses on their readability into the reticulum-rumen, not only in cattle and sheep (Caja et al., 1999a; Fallon, 2001; Ghirardi et al, 2006) but also in goats (Carné et al., 2007).

The E1 electronic ear tag showed 100% estimated readability at the end of the 3-yr study, which differed (*P* = 0.022) from E2 estimated readability (79.8%). Observed E2 late losses as a consequence of aging deterioration is an aspect to be taken into account when comparing the long-term readability of ear tags and some other devices applied internally to the body (ruminal bolus and injectable transponders).

Apart from E1 ear tags (100%), devices with greater readability estimates at the end of the study were the B3 bolus (96.8%) and T2 transponders (96.0%), and no differences could be established (*P* > 0.05) between them. The lower readability was estimated for B1 (66.3%), followed by E2 (79.8%), B2 (81.4%) and T1 (90.4%), the latter 3 ones not differing (*P* > 0.05).

Figure 3.3. Kaplan-Meier survival distribution functions for electronic ruminal boluses (—) and transponders injected in the forefeet (····) in dairy goats; censored data: B1 (●), B2 (▲), B3 (■), T1 (○), and T2 (Δ). Abbreviations: B1, mini-bolus 13.7 g and 51.0 × 10.5 mm; B2, mini-bolus 20.1 g and 56.4 × 10.5 mm; B3, standard bolus 75 g and 68.2 × 21.0 mm; T1, injectable transponder 15 × 2.1 mm; and T2, injectable transponder 12 × 2.1 mm



3.5. CONCLUSIONS

According to our results, electronic ear tags (E1 and E2) and the standard bolus (B3) were the only ID devices which had readabilities greater than 98% at 12 mo after application, as recommended by the International Committee for Animal Recording (ICAR, 2007) and the Spanish Committee for Animal Electronic Identification (MAPA, 2007). The use of injectable transponders in the metacarpal area is not recommended in practice due to losses. Physical features of electronic ruminal boluses dramatically affect their retention, and therefore their readability. No differences in bolus retention were detected according to rearing management and feeding. Improvement of electronic bolus retention in goats needs to be achieved before generalizing its use. In contrast to the rest of devices tested, button-button electronic ear tags of appropriate design and technology have proved to be efficient devices for goat identification, although because of the small number of animals and devices used in this experiment, we recommend the confirmation of the results on a larger scale.

CHAPTER 4

Experiment 2: Visual ear tags and rumen boluses for goat identification under semi-extensive conditions

CHAPTER 4

Experiment 2: Extended field test on the use of visual ear tags and electronic boluses for the identification of different goat breeds under semi-extensive conditions in the United States

4.1. ABSTRACT

A total of 295 goats from 4 breeds (Alpine, n = 74; Angora, n = 75; Boer-cross, n = 73; Spanish, n = 73) were used to assess the retention of 3 types of electronic ruminal boluses (B1, 20 g, n = 95; B2, 75 g, n = 100; and B3, 82 g, n = 100) according to breed and feeding conditions. Boluses were administered with adapted balling guns. Time for bolus administration, reading with a handheld reader, and animal data recording (goat ID, breed, and bolus type) were registered. Each goat was also identified with 1 flag-button plastic ear tag (4.6 g, 51 × 41 mm). Retention of boluses and ear tags was regularly monitored for 1 yr. Ruminal fluid in 5 goats from each breed and management group was obtained with an oro-ruminal probe at 2 h after feeding. Ruminal pH was measured at 24 h, and at wk 1, 2, 3 and 4, and used as an indicator of feeding conditions on rumen environment. Time for bolus administration differed by bolus type (B1, 14 ± 2 s; B2, 24 ± 2 s; B3, 27 ± 2 s; $P < 0.05$) and goat breed (Alpine, 34 ± 3 s; Angora, 17 ± 2 s; Boer-cross, 16 ± 1 s; Spanish, 19 ± 2 s; $P < 0.05$), although differences were due to greater times for B2 and B3 in Alpine goats. Time for bolus administration averaged 22 ± 1 s, and overall time for □lousing, reading, and data typing was 49 ± 1 s on average. Ruminal pH differed according to breed and feeding management (lactating Alpine, 6.50 ± 0.07; yearling Alpine, 6.73 ± 0.07; Angora, 6.34 ± 0.06; Boer-cross, 6.62 ± 0.04; Spanish, 6.32 ± 0.08; $P < 0.05$) but no early bolus losses occurred; rumen pH did not differ according to bolus type (B1, 6.45 ± 0.05; B2, 6.39 ± 0.07; B3, 6.49 ± 0.05; $P > 0.05$). At 6 mo, electronic boluses showed greater retention than ear tags (99.7% vs. 97.2%; $P < 0.05$). At 12 mo, bolus retention was 96.3, 100 and 97.8% for B1, B2 and B3, respectively, not differing between B1 and B3 ($P = 0.562$). No effect of breed and bolus type on bolus retention was detected. No goat losing at the same time both bolus and ear tag was observed. Ear tag retention (91.7%) was lower ($P < 0.05$) than all types of bolus (98.1%) on average. Ear tag retention in Boer-cross (98.6%) and Alpine (96.9%) goats was greater ($P < 0.05$) than in Spanish (88.7%) and Angora (82.9%), and tended to differ ($P = 0.095$) between Spanish and Alpine. In conclusion, unlike flag-button visual ear tags and mini-boluses used here, properly designed boluses (e.g. standard bolus) met ICAR and NAIS retention requirements for goat identification under US conditions, and are recommended in practice.

4.2. INTRODUCTION

Permanent and reliable animal identification (**ID**) is a primary goal for the implementation of animal traceability systems. Electronic identification (**e-ID**) by using radio frequency (**RFID**) passive transponders improves traceability due to faster monitoring of livestock and easier management of databases for inventory and movements between premises.

Different e-ID devices have been tested in domestic ruminants, including injected transponders, electronic ear tags and rumen boluses (Conill et al., 2000; Carné et al., 2009; JRC, 2003). Properly designed boluses have shown a retention rate greater than 99% in sheep and cattle (Caja et al., 1999a; Ghirardi et al., 2006). In fact, boluses have been used for sheep and goat ID in Spain since January 2006 (Real Decreto 947/2005), in accordance with the current European regulations (EC 21/2004; EC 1560/2007). However, available boluses have shown a wide retention range in goats (88.7 to 99.6%) (JRC, 2003; Pinna et al., 2006; MAPA, 2007), which might be influenced by breed and feeding management (MAPA, 2002; Capote et al., 2005).

In the United States, goat ID is widely implemented under the National Scrapie Eradication Program, with a variety of ID methods in use (CFR, 2008). To harmonize the ID methodology, visual ear tags have been chosen as the de facto standard devices for the current deployment of the National Animal Identification System (NAIS); the use of electronic ear tags is optional (USDA, 2008a). Conversely, injected transponders are the recommended devices for Camelid ID (USDA, 2008c) and are also being suggested for goats where poor performance of ear tags occurs (USDA, 2006b). Little information is available on the use of boluses for the e-ID of goats in the United States.

The objective of this work was aimed at assessing the long-term performance of 3 types of ruminal bolus compared to a visual ear tag in different goat breeds under US conditions; the effect of breed and feeding management on early losses were also investigated.

4.3. MATERIALS AND METHODS

4.3.1. Animals and management

The experimental procedures and animal care conditions were approved by the Langston University Animal Care Committee. A total of 295 goats from 4 breeds (Alpine, dairy purpose, n = 74; Angora, fiber purpose, n = 75; Boer-cross, meat purpose, n = 73;

and Spanish, meat purpose, n = 73) belonging to the Research Farm of the E. (kika) de la Garza American Institute for Goat Research of Langston University, Langston (OK) were used. All the animals were adult goats, except for the Alpines, where 2 balanced groups of lactating does (n = 38) and yearlings (n = 36) were established to evaluate the different feeding conditions dependent on physiological stage. Boer-cross goats were 1/4 cross-bred with Spanish breed.

The Angora, Boer-cross and Spanish goats remained allocated to different outdoor paddocks according to breed, and rotationally grazed on Oklahoma native grass and Bermuda (*Cynodon spp.*) pastures. Paddocks were over-seeded in the fall with pasture-mix (50% wheat, 40% rye, and 10% vetch) at a seeding rate of 135 kg/ha with a fertilization (18-46-0) rate of 225kg/ha. The Angora, Boer and Spanish goats were also supplemented with commercial low protein pellets (CP, 13.3%) during spring-summer, and with high protein pellets (CP, 20.3%) during fall-winter (Stillwater Milling Inc., Stillwater, Oklahoma), offered at approximately 0.25 kg per animal. Alpine goats were fed good quality alfalfa hay; during lactation Alpine does were milked twice a day (0600 and 1700) and provided concentrate (CP, 15.6%; ME 2.7 Mcal/kg; Ca, 1.5%; P, 1.0%) in the paddock prior to the p.m. milking. Goats in the study had free access to round bales of prairie, Bermuda and wheat hay placed in raised, portable metal half round feeders, as well as to mineral blocks and fresh water.

Each goat was dewormed (Prohibit, Agri Laboratories, St. Joseph, MO) twice a year in October and December; Angora and Spanish goats were also dewormed and deloused with a pour-on insecticide (Ectrin, Fermenta Animal Health Company, Kansas City, MO) prior to shearing in late February and after shearing in March. Boer does were deloused (Atroban, Coopers Animal Health, Kansas City, MO) in April.

Goats were given a booster vaccination for enterotoxaemia and tetanus prophylaxis (Vision CD-T & Spur, Intervet, Millsboro, DE) in February, and Spanish goats received an additional vaccination (Covexin, Intervet, Upper Hutt, New Zealand) in mid April.

Breeding was scheduled from mid October to early January and kidding season started in mid March and ended in early June.

4.3.2. Administration and monitoring of identification devices

Each goat was visually identified with 1 standard flag-button plastic ear tag (4.6 g, 50.8 × 41.3 mm [flag dimensions]; Allflex USA, Dallas, TX) with opened locking system and a 3- to 5-digit animal ID code printed for farm management purposes.

Goats were also electronically identified with cylindrical ruminal boluses (Rumitag, Esplugues de Llobregat, Barcelona, Spain) made of atoxic and highly dense ceramic materials, according to the patents of the European Community et al. (1998) and Caja et al. (2005b). Three types of bolus were used, with the following features (material, weight, length × o.d. and specific gravity): **B1** (zirconia, 20.1 g, 56.4 × 11.2 mm and 3.9; n = 95), **B2** (alumina, 75.0 g, 68.2 × 21.0 mm and 3.4; n = 100), and **B3** (alumina, 82.1 g, 69.1 × 21.2 mm and 3.6; n = 100). Distribution of boluses according to goat breed and bolus type is shown in Table 4.1.

Table 4.1. Electronic boluses used for the long-term (1 yr) identification of goats, according to goat breed and bolus type

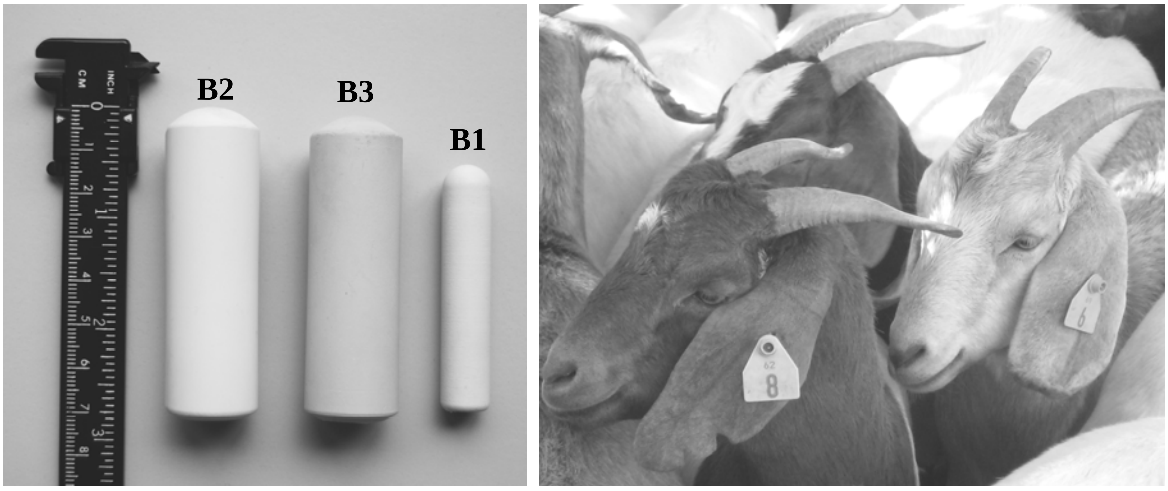
Breed	Bolus type[1]			Overall
	B1	B2	B3	
Alpine	25	24	26	75
Angora	24	25	26	75
Boer-cross	23	26	24	73
Spanish	23	25	25	73
Overall	95	100	100	295

[1] Abbreviations: B1, mini-bolus 20.1 g and 56.4 × 11.2 mm; B2, standard sized bolus 75.0 g and 68.2 × 21.0 mm; B3, standard sized bolus 82.1 g and 69.1 × 21.2 mm.

The B1 bolus was a small-sized type specially designed for early administration in lambs and kids. The B2 and B3 types were standard dimensioned boluses for administration in replacement sheep and goats of more than 3 mo of age. Each bolus contained a half-duplex (**HDX**), read-only, glass encapsulated transponder of 32 × 3.8 mm (Ri-Trp-RR2B-06, Tiris, Almelo, The Netherlands). Serial numbers of transponders included the manufacturer code (Rumitag, 964) and a 12-digit serial number, in accordance with both the list of manufacturer codes of the International Committee for Animal Recording (ICAR, 2008) and the **ISO** (International Organization for

Standardization) 11784 standard on animal electronic ID (ISO, 1996a). Transponders worked at a frequency of 134.2 kHz, in agreement with the ISO 11785 standard (ISO, 1996b).

Figure 4.1. Electronic rumen boluses and visual ear tags used.



Boluses were administered by trained operators using balling guns adapted to each bolus type (Rumitag). For administration, 1 assistant restrained each goat between their legs, holding the goat's head to maintain it in a natural position. Subsequently, one operator held the goat's jaw by the region without teeth (diastema) and introduced the balling gun laterally into the mouth through this same region. The balling gun was then centered to frontally reach the bottom of the oropharyngeal cavity (base of the tongue) and the bolus was released with a slight backward movement, stimulating the reflex of deglution similarly as indicated by Caja et al. (1999a). After administration, each bolus was read in static conditions (animals restrained) by using a full-ISO RFID handheld transceiver (reader) (Ges2s, Rumitag). For the readings, a directional caudo-cranial sweep in the abdomen region was performed to ensure that the bolus suitably reached its final location in the reticulorumen. Time required for bolus administration with the goats previously restrained, and for reading and data typing (ear tag animal ID, goat breed and bolus type) on the transceiver were recorded for each goat; breed and bolus type data were entered into the reader from a previously configured drop down menu. Administration difficulties were monitored by registering the number of bolus administration attempts; an administration attempt was registered when the bolus was not swallowed but expelled immediately after being released into the animal's mouth. Attempts rate was expressed as follows: no. administration attempts / no. boluses administered.

Any additional incidence during bolusing was also registered. After administration, all boluses were read in static conditions at d 1, wk 1, 2, 3 and 4, mo 2, and thereafter every 2 mo until 1 yr. Retention of ear tags was monitored with the same schedule as boluses.

Retention of both ear tags and boluses was expressed as follows:

Retention rate (%) = (no. retained devices / no. monitored devices) × 100

All goats that were culled, slaughtered or died during the study were monitored and boluses recovered.

Figure 4.2. Administration and static reading of electronic boluses in adult goats.

4.3.3. Ruminal pH measurements

In order to evaluate the influence of feeding management on the event of bolus early losses (1 mo), ruminal pH was used as an indicator of ruminal conditions. For this purpose, ruminal fluid samples (approximately 50 mL) were collected 2 h after morning feeding (0700 to 0900 depending on breed and paddock) in 5 goats from each breed and feeding management (lactating and yearling Alpines) chosen at random the day after bolusing and thereafter at wk 1, 2, 3 and 4. Thus, a total of 125 ruminal fluid samples from different animals were collected.

A plastic oro-ruminal probe (150 × 12 mm) and a manually managed suction pump were used for the ruminal fluid extraction. A toothguard was used to prevent goats from biting the probe. In order to lessen the effect of saliva contamination on pH values, probing was performed as quickly as possible by an experienced operator and both the toothguard and the probe were rinsed after each ruminal extraction. The pH measurements were performed immediately after collection by using a portable pH meter (Accumet 1003, Fisher Scientific, Pittsburgh, PEN).

4.3.4. Statistical analyses

Least squares means of time for bolus administration, reading and animal data recording, as well as for administration attempts, were obtained with the GLM procedure of SAS (v. 9.1, SAS Inst. Inc., Cary, NC). Factors considered were type of bolus, goat breed, interaction, and the residual error. Ruminal pH measurements were also analyzed by using the GLM procedure of SAS (SAS Inst. Inc.), and factors considered were goat breed, feeding management (Alpine yearling and lactating does), sampling date, their one-way interactions, and the residual error.

Retention of ID devices was analyzed with the CATMOD procedure of SAS (SAS Inst. Inc.) on the basis of the categorical nature of these variables. A Logit model with an estimation method of maximum likelihood (Cox, 1970) was used, evaluating the effects of type of ID device, goat breed, and their interaction. Significance was declared at $P < 0.05$ and factors that were not significant ($P > 0.20$) were removed from the final model.

In addition to the Logit model, a Kaplan-Meier non-parametric survival analyses and log-rank tests of equality across strata was performed for the ID devices with the LIFETEST procedure of SAS (SAS Inst. Inc.), as previously done by Fosgate et al. (2006) and Carné et al. (2009). These analyses allowed the retention of ID devices to be compared throughout the entire period of study without excluding right censored data (animals that left the study before a device was lost). Survival monitoring started at device administration and, as continuous goat monitoring was not possible, time of animals leaving the study was registered as interval-censored data.

4.4. RESULTS AND DISCUSSION

At the end of the 1-yr study, 265 (89.8%) of the initially identified animals remained monitored. A total of 10 goats were culled and 20 goat deaths were registered. No casualties were related to bolus administration, and annual mortality rate averaged 6.8%. This value is within the range of 3.6 to 9.7% observed at the Research Farm in the different goat breeds from august 2006 to August 2008 (E. Loetz and J. Hayes, E. (Kika) de la Garza American Institute for Goat Research, Langston University, Langston, OK, personal communication).

4.4.1. Bolus administration and animal data recording

Bolus administration records are shown in Table 4.2. Time for bolus administration differed ($P < 0.05$) by bolus type and goat breed. Nevertheless, no differences ($P > 0.05$) were observed among Angora, Boer-cross and Spanish goats. Thus, differences were mainly due to administration records in Alpine goats, where times for B2 and B3 administration were greater ($P < 0.05$) than in the other 3 breeds. Alpine goats in our study were bolused just after being fed and in many cases some feed was still in their mouths. This seemed to complicate the administration of standard sized boluses and thereby increased the time for bolus administration. To our knowledge, this observation has never before been reported when administering ruminal electronic boluses. In addition, Alpine goats were dehorned, which made restraining the head more difficult prior to bolusing.

Difficulties for administration of standard sized boluses (B2 and B3) in Alpines is also supported by the attempts rate, which was lower ($P < 0.05$) for B1 mini-bolus (1.12) than for B3 (1.60), and tended to be lower ($P = 0.089$) than for B2 (1.50). Similar to what was observed for bolus administration time, overall attempts rate value for B1 (1.06) was lower ($P < 0.05$) than for standard sized boluses (B2, 1.20; B3, 1.21) (Table 4.2); therefore, the use of small-dimensioned B1 bolus prevented administration difficulties like those observed with standard sized boluses in Alpine goats. On the contrary, no differences in attempts rate ($P > 0.05$) among boluses were observed for the other 3 breeds, averaging 1.04, 1.12 and 1.08 for B1, B2, and B3, respectively. As might be expected according to the aforementioned results, average attempts rate for bolus administration was greater ($P < 0.05$) in Alpines (1.40) than in the other 3 breeds (1.03 to 1.12).

Table 4.2. Administration and reading records of electronic boluses according to bolus type and goat breed

Item	Bolus type[1]			Overall
	B1	B2	B3	
Administration time[2,8], s				
Alpine	17 ± 4[ax]	40 ± 5[bx]	49 ± 5[bx]	34 ± 3[x]
Angora	12 ± 2[ax]	19 ± 4[ay]	20 ± 3[ay]	17 ± 2[y]
Boer-cross	9 ± 1[ax]	17 ± 2[ay]	21 ± 3[ay]	16 ± 1[y]
Spanish	17 ± 5[ax]	22 ± 3[axy]	17 ± 2[ay]	19 ± 2[y]
Overall	14 ± 2[a]	24 ± 2[b]	27 ± 2[b]	22 ± 1
Overall ID time[2,3,4,8], s				
Alpine	38 ± 5[ax]	69 ± 5[bx]	77 ± 6[bx]	61 ± 4[x]
Angora	38 ± 3[ax]	43 ± 4[ay]	46 ± 4[ay]	43 ± 2[y]
Boer-cross	35 ± 2[ax]	48 ± 3[ax]	50 ± 3[ay]	45 ± 2[y]
Spanish	49 ± 5[ax]	49 ± 4[ax]	45 ± 3[ay]	48 ± 2[y]
Overall	39 ± 2[a]	52 ± 2[b]	55 ± 2[b]	49 ± 1
Attempts/goat[5,6,8]	1.06 ± 0.03[a]	1.20 ± 0.05[b]	1.21 ± 0.06[b]	1.16 ± 0.03
Incidences	0	0	1[7]	—

[a,b]Within a row, values with different superscripts differ ($P < 0.05$).
[x,y]For the administration time and overall identification time, values with different superscripts within a column differ ($P < 0.05$).
[1]Abbreviations: B1, mini-bolus 20.1 g and 56.4 × 11.2 mm; B2, standard sized bolus 75.0 g and 68.2 × 21.0 mm; B3, standard sized bolus 82.1 g and 69.1 × 21.2 mm.
[2]Time recorded with animals restrained.
[3]Time for administration, reading and data typing on a handheld transceiver.
[4]Data recorded: Animal ID (3- to 5-digit code printed in the ear tag), goat breed, and bolus type (breed and bolus type from a drop down menu previously configured).
[5]Attempts rate = no. administration attempts / no. administered.
[6]Attempt: when a bolus is expelled without being swallowed just after being released into the animal's mouth.
[7]One B3 bolus broke after felling out and hitting on the concrete ground in an indoors paddock when administered to an Alpine goat.
[8]Significant breed × bolus type interaction ($P < 0.05$).

No differences in time for B1 administration were observed among goat breeds, being lower ($P < 0.05$) than for B2 and B3 (Table 4.2). In addition to these results, an interaction ($P < 0.05$) between breed and bolus type was detected for both administration time and attempts rate. Overall time for bolus administration averaged 22 s (Table 4.2), which was deemed suitable for the implementation of this e-ID methodology in practice. Using similar sized boluses, Caja et al. (1999a) indicated times of 24 and 26 s for their administration in sheep and goats, respectively.

No apparent health disturbances or injuries to the goats were observed due to administration of the 3 bolus types at bolusing and in the subsequent reading controls, agreeing with the fact that this kind of boluses can be safely administered by trained operators to yearling goats and sheep with BW greater than 20 and 25 kg, respectively (Caja et al., 1999a). Apart from administration attempts, the only incidence registered during bolusing was the breakage of 1 B3 bolus, which was expelled by an Alpine goat and broke when it fell to the concrete flooring. The bolus was discarded and a new one was administered to the same goat. Despite the small format of the Angora goats no specific difficulties for bolus administration were reported.

As might be expected, time for reading and data typing (ear tag ID code, breed and bolus type) on the handheld reader did not differ ($P > 0.05$) among breed and bolus type, being 27 ± 1 s on average.

Overall time registered for bolus administration, reading and data typing only differed ($P < 0.05$) for Alpine goats, and between B1 and the other 2 bolus types (B2 and B3), similar to observations for bolus administration. On average, time for completed ID of goats with rumen boluses averaged 49 s (Table 4.2). By using mini-boluses, Ghirardi et al. (2007) reported average time for ID of lambs (8 to 10 kg BW) of 35 s. Similar mini-boluses were used by Carné et al. (2009), who indicated average times for goat kids (7 kg BW) ID ranging from 26 to 28 s, but without taking into account time for restraining. The time observed in our results for the administration of standard sized boluses, reading and data typing on the reader (53 ± 2 s) was lower than that reported by Caja et al. (2003) using similar boluses in yearling and adult sheep (71 s) in the United States; but in that study time for animal restraining was included (G. Caja, personal communication).

4.4.2. Ruminal pH and short-term retention of identification devices

Ruminal pH differed ($P < 0.05$) according to both goat breed and feeding management (lactating vs. yearling Alpine), and was 6.49 ± 0.03 on average. The lower values were observed in Angora (6.34 ± 0.06) and Spanish (6.32 ± 0.04) goats, which differed ($P < 0.05$) from those in yearling Alpines (6.73 ± 0.07), Boer-cross (6.62 ± 0.04) and lactating Alpines (6.50 ± 0.07). Differences were also detected ($P < 0.05$) between lactating Alpines and the rest of breeds under study. Moreover, an interaction ($P < 0.05$) between goat breed and sampling date was observed. Although ruminal fluid collection by using an oro-ruminal probe may cause overestimation of pH values due to saliva contamination (Geishauser and Gitzel, 1996), results obtained remained within a normal physiological range.

On the contrary, no differences on the ruminal pH according to bolus type were observed (B1, 6.45 ± 0.05; B2, 6.39 ± 0.07; B3, 6.49 ± 0.05; $P > 0.05$) and no interaction with bolus type was detected either for breed or sampling date. According to our results, standard sized boluses did not affect rumen environment when compared to mini-boluses. Earlier studies reported no adverse effects of different types of ruminal boluses on feed intake, digestibility, reticulorumen anatomophysiology and production performance (Caja et al., 1999a; Garín et al., 2005; Antonini et al., 2006; Ghirardi et al., 2007).

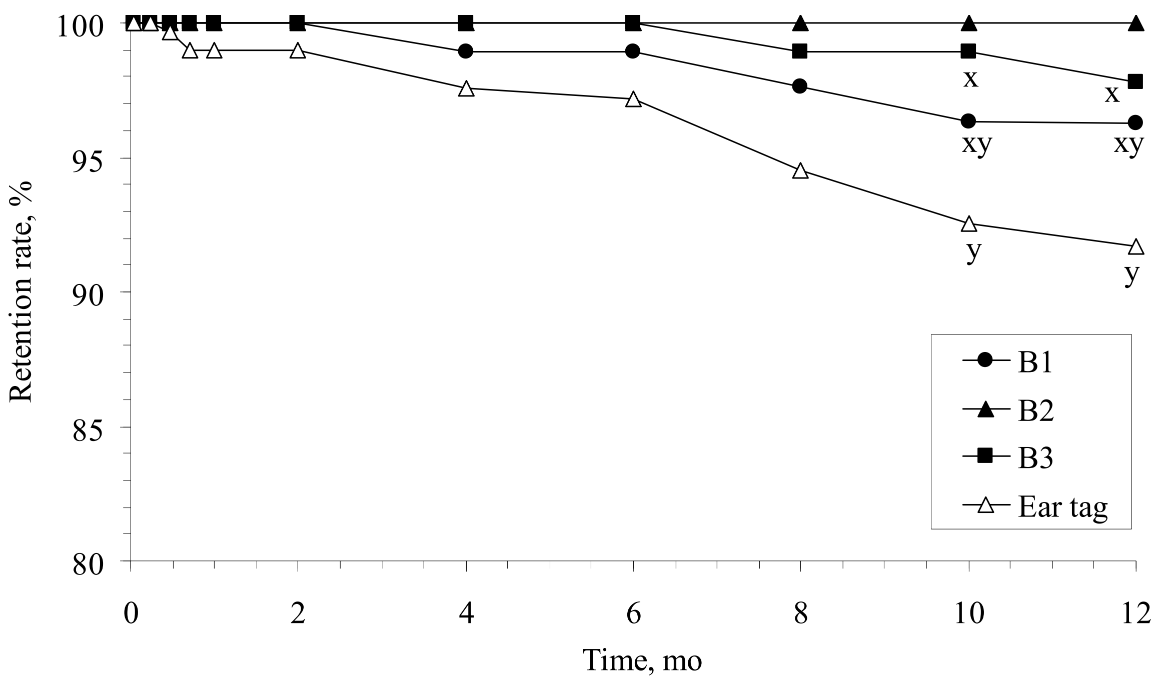
Losses of unsuitably designed boluses are mainly caused by regurgitation (Caja et al., 1999a; Fallon, 2001; Garín et al., 2005), although passage of small sized boluses through the reticulo-omasal orifice is not discarded (Ghirardi et al., 2007; Carné et al., 2009). As long as no early losses occurred in our study, no relationship between ruminal conditions and bolus retention could be established. It must be highlighted that the majority of bolus losses in goats in Europe have been reported in dairy breeds managed in highly intensified conditions (JRC, 2003; MAPA, 2002), with concentrate-based diets. With this regard, goat herds in the United States are essentially managed under extensive or semi-intensive conditions, which might be a factor of major relevance for the retention of rumen boluses.

4.4.3. Long-term retention of identification devices

Long-term retention of the different ID devices until 1 yr and the contrasts between devices obtained with the Logit model are shown in Figure 4.3. In this case, devices with no registered losses (100% retention rate) could not be statistically analyzed. With regard to boluses, only the loss of 1 B1 in a Boer goat was registered until 4 mo, which occurred by regurgitation when having the animal sedated and inverted on an operating table during a laparoscopic surgery; influence of this management on bolus losses remains a topic for further research. On the other hand, 7 losses of ear tags were registered at that time, and retention of boluses (99.7%) and ear tags (97.6%) tended to differ ($P = 0.067$). Ear tags did not meet the 98% retention in the year following tagging required for official ID by the

International Committee for Animal Recording (ICAR, 2007), although retention remained over the 95% minimum retention required by the USDA for ID of sheep and goats within the NAIS (USDA, 2008b). At 6 mo, no additional losses occurred except for 1 more ear tag, and the difference between bolus and ear tag retention (2.5%; $P < 0.05$) was similar to that observed at 4 mo (2.1%; $P < 0.07$). At 1 yr, 4 more bolus losses occurred, 3 of them (2 B1 and 1 B3) in Angora goats and 1 (1 B3) in a Boer goat, thereby resulting in an overall bolus retention of 98.1%.

Figure 4.3. Retention of 3 electronic bolus types and 1 visual ear tag in goats throughout 1 yr of study. Abbreviations: B1, mini-bolus 20.1 g; B2, standard sized bolus 75 g; B3, standard size bolus 82.1 g. Ear tag: flag-button, 4.6 g, and 50.8 × 41.3 mm (flag dimensions). [x,y]For each reading control, devices with different superscripts tended to differ ($P < 0.1$). No statistical contrasts were done when retention rate values were 100%.



With regard to ear tags, retention at 8 mo (94.5%) already fell under the NAIS requirements (USDA, 2008b). Likewise, a total of 22 ear tag losses were registered at 1 yr leading to a final retention rate of 91.7%. At 1 yr, ear tag retention continued to be lower ($P < 0.05$) than bolus retention.

As anticipated, the mini-bolus (B1) showed the lowest retention (96.3%) at 12 mo, although not different ($P = 0.562$) from the retention rate for B3 (97.8%); the retention of

B2 was 100%. Although low losses did not allow differences to be established, lower retention of the heavier bolus (B3) with respect to standard B2 was unexpected as the increment of weight and specific gravity of boluses have been demonstrated to improve their retention in the reticulorumen of cattle, sheep and goats (Fallon, 2001; Ghirardi et al., 2006; Carné et al., 2007). When considering mini-bolus (B1) and standard sized boluses (B2 and B3) as 2 separate groups of devices, retention tended to be greater for the standard sized boluses (99.5% vs. 96.3%; P = 0.093) at 10 mo, but no difference could be established at the end of the study (standard sized boluses, 98.9% vs. B1, 96.3%; P = 0.175).

Retention of ear tags tended to be lower (P = 0.063) than B3, whereas no difference (P = 0.173) was observed with respect to B1. Due to lack of losses, no contrast between B2 and ear tags could be carried out with the Logit model, although a difference (P < 0.05) between ear tags and overall standard sized boluses (B2 and B3) was detected.

Table 4.3. Estimated retention of identification devices with Kaplan-Meier non-parametric survival analysis and log-rank tests between devices in goats at 1 yr of study

	Electronic boluses[1]				Ear tags[2]
Item	B1	B2	B3	Overall	
Devices, No.	95	100	100	295	295
Censored data, No.[3]	92	100	98	290	273
Events, No.[4]	3	0	2	5	22
Estimated readability, %	96.7^{abx}	100^{ay}	97.9^{a}	98.2^{a}	92.2^{b}

^{a,b}Within a row, values with different superscripts differ (P < 0.05).
^{x,y}Within a row, values with different superscripts differ (P < 0.1).
[1]Abbreviations: B1, mini-bolus 20.1 g and 56.4 × 11.2 mm; B2, standard sized bolus 75.0 g and 68.2 × 21.0 mm; B3, standard sized bolus 82.1 g and 69.1 × 21.2 mm.
[2]Visual flag-button plastic ear tag, 4.6 g, and 50.8 × 41.3 mm (flag dimensions).
[3]Devices in which the event was not observed or which left the study before 1 yr after application.
[4]Devices lost.

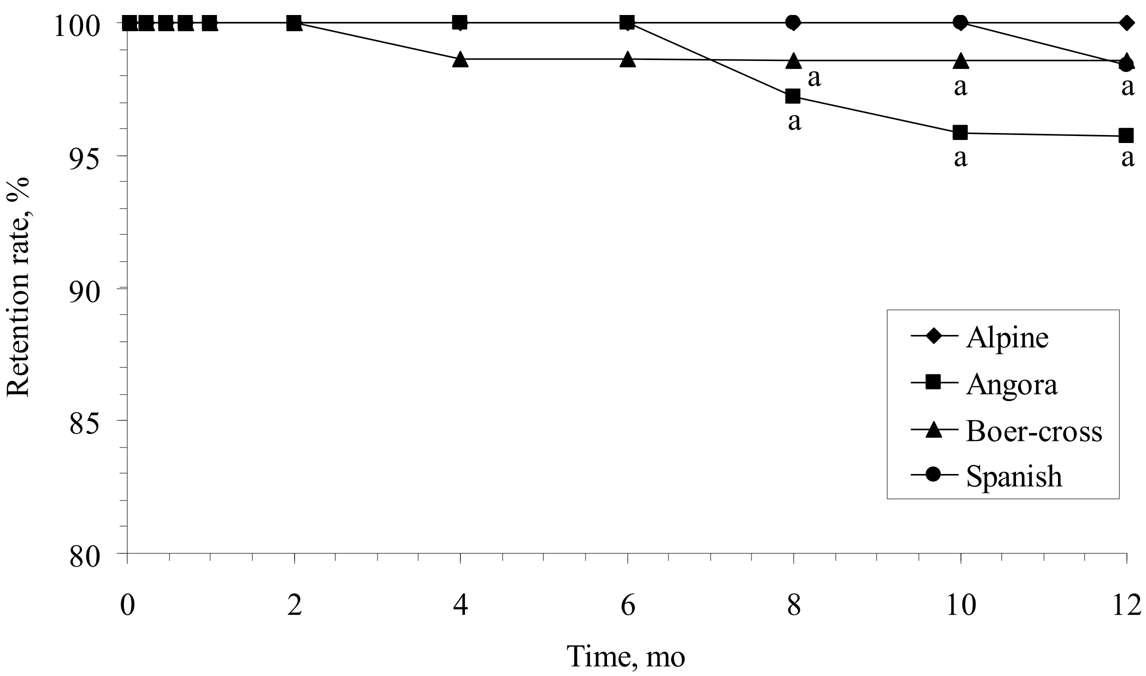
Results obtained with the Kaplan-Meier non-parametric survival analyses are shown in Table 4.3. The Kaplan-Meier estimated values of retention were slightly greater (0.2% on average) than actual values, which was expected according to the low number of censored data before the end of the 1-yr study. Estimated retention of standard sized boluses (B2 and B3) were greater ($P < 0.05$) than ear tags; moreover, B2 estimated retention tended to be greater ($P = 0.07$) than B1.

According to our results, retention of B1 did not fulfill ICAR requirements (>98%) from mo 8, and neither did B3 at 1 yr. Different authors have reported unsuitable retention of mini-boluses in different goat breeds (MAPA, 2007; Carné et al., 2009). Conversely, the use of properly designed standard sized boluses has shown suitable retention results in most European goat breeds (JRC, 2003; Pinna et al., 2006), except for the case of some Spanish goat breeds where bolus retention has turned out to be highly variable (Capote et al., 2005; JRC, 2003; MAPA, 2007). Unlike in goats, properly designed mini- and standard sized boluses have shown retention rates greater than 98% in different sheep breeds in the United States (Caja et al., 2003) and Europe (Ghirardi et al., 2006; MAPA, 2007).

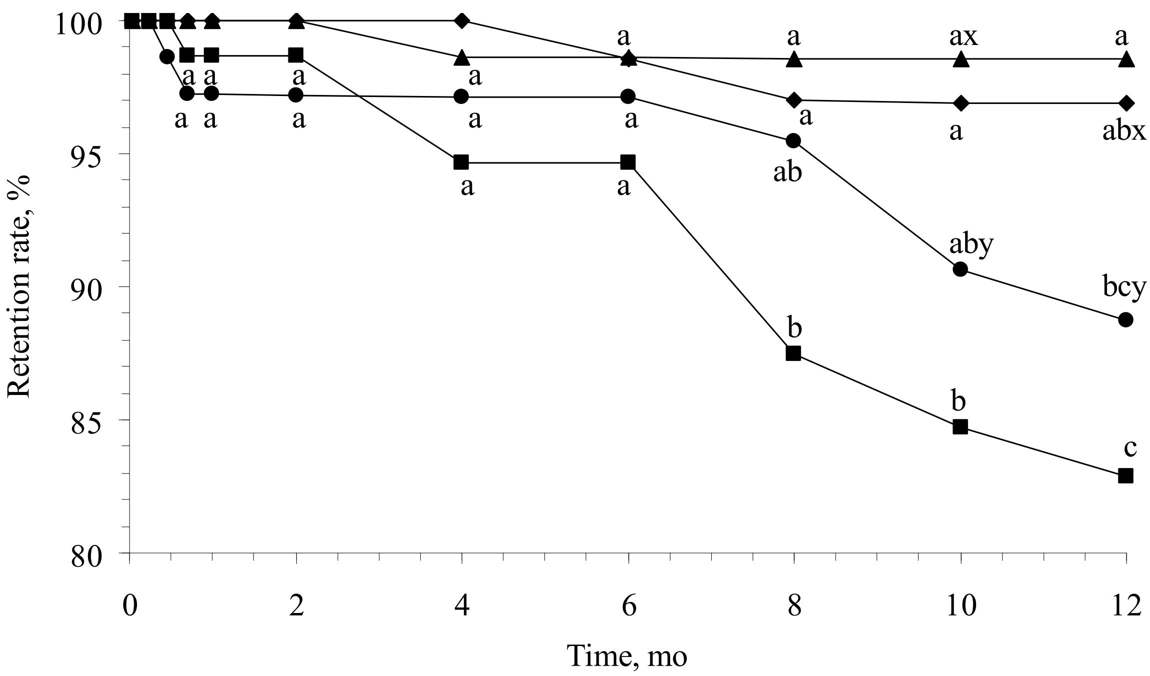
Retention of boluses and ear tags according to goat breed throughout the 1-yr study are shown in Figure 4.4, as well as the contrasts between breeds obtained with the Logit model. Retention of boluses in Angora (97.2%) fell under ICAR requirements at 8 mo after administration. At 12 mo, retention in Alpine was 100%, whereas no differences ($P > 0.05$) were observed among Boer-cross (98.5%), Spanish (98.4%) and Angora (95.8%). The majority (60%) of bolus losses occurred in the latter breed, whose size and BW is markedly lower than in the other 3 breeds under study; no losses occurred in the larger breed (Alpine). Thus, in addition to a possible breed and management effect, the BW of the goats (not determined in the current study) might affect the retention of boluses. Angora goats in our study were sheared between the 6 and 8 mo reading measurements, during which time 2 of the 3 bolus losses occurred. Though no in situ loss was observed during shearing, possible effects of this kind of specific management on bolus losses needs to be studied in thorough detail. At the end of the study, only bolus retention in Angora goats did not meet the ICAR requirements. This was mainly due to mini-bolus performance for standard sized boluses (B2 and B3) retention was 98%. Even so, all boluses tested met the retention requirements for official ID within the NAIS (USDA, 2008b).

Figure 4.4. Retention of electronic boluses (Panel a) and visual flag-button ear tags (Panel b) throughout 1 yr of study according to goat breed. For each reading control, goat breeds with different superscripts differ: $^{x,y}P < 0.1$, $^{a,b}P < 0.05$. No statistical contrasts were done when retention rate values were 100%.

a) Electronic boluses



b) Visual ear tags



In the case of ear tags, no differences in retention according to breed were detected until mo 8, when retention of ear tags in Alpine (97.0%) and Boer-cross (98.6%) was greater ($P < 0.05$) than in Angora (87.5%). Importance of ear tag losses in Angora goats by accidentally cutting off the ear tag during shearing has been remarked by the NAIS Goat Working Group (USDA, 2006b). Despite observing the greater increment of ear tag losses (7.2%) at the subsequent reading after shearing (mo 8), the specific cause of losses was not monitored.

At the end of the 1-yr study, ear tag retention in Boer-cross (98.6%) and Alpine (96.9%) were greater than in Spanish (88.7%) and Angora (82.9%); moreover, retention in Alpine and Spanish tended to differ ($P = 0.095$). Only the retention rate of ear tags in Boer-cross goats met ICAR requirements (> 98%). Ear differences between breeds seem to be mainly responsible for the retention variability of the ear tags used, although different management and pens allocation may have contributed to ear tag loss as well. As indicated for the boluses, materials and proper design of ear tags are key factors to optimize their retention rate. In this regard, the button-flag ear tags used here proved not to be efficient devices for goat ID. To our knowledge, no bibliographical references on the retention of visual ear tags in goats are currently available. Carné et al. (2009) tested flag-button and button-button electronic ear tags in Murciano-Granadina dairy goats in Spain and reported an optimum long-term performance of the latter. In the US, the NAIS Goat Working Group has pointed out a high incidence of ear tag losses, as well as drawbacks when dealing with goat breeds where small ear size does not permit the suitable application of ear tags (USDA, 2006b). Within this framework, the use of alternative ID devices such as injectable transponders is under consideration. In fact, injectable transponders of small size (12 mm in length) have been recommended instead of ear tags for the deployment of the NAIS in camelids, although proper site for injection remains under study (USDA, 2006a; USDA, 2008c). Performance of injectable transponders highly depends on their size and the injection site (Conill et al., 2000; Carné et al., 2009), which may bring about high levels of early losses before the injection site heals, as well as subcutaneous migration and the impossibility of efficient removal from carcasses (Klindtworth et al., 1999; Conill et al., 2000). Moreover, the use of small transponders dramatically diminishes their reading distance and causes poor dynamic reading efficiency.

Supplementary to retention rate and reading performance, guaranteeing the certainty of available animal ID data is another relevant issue, regardless of whether mandatory or voluntary ID programs are deployed. Only tamper evident devices are accepted under NAIS provisions (e.g. ear tags). Nevertheless, internally applied devices (e.g. ruminal boluses and transponders injected i.m. or i.p.) may be satisfactory because they are extremely hard to remove. However, the main drawback of internally applied e-ID devices is the need for additional visual ID for routine management whenever RFID readers are not broadly available. In this regard, it must be underlined that no goat without both bolus and ear tag was observed, which supports the idea of implementing dual ID systems with devices from different ID methodologies in order to optimize animal traceability.

4.5. CONCLUSIONS

Because of poor retention, the mini-boluses used in this study can not be recommended for general administration for the e-ID of goats under US conditions, although further research with a greater number of animals is warranted to assess the influence of goat breed on bolus performance. Standard sized boluses with suitable weight and specific gravity have proven to be easily and safely administered and to offer suitable retention according to ICAR and USDA requirements, irrespective of goat breed. The visual flag-button plastic ear tags used in this work did not fulfill the official ID requirements, and their performance strongly depended on goat breed. Larger scale experiments comparing the performance of different ID devices in goats should be done to advice farmers on the single or dual ID system which best works for both the specific goals of the NAIS and the preferences of US goat industry. The results presented in this study confirm previous reports in the European Union on the use of ear tags and boluses for goat identification and registration.

CHAPTER 5

Experiment 3: Leg tags vs. rumen boluses and electronic ear tags for dairy goat identification in the milking parlor

CHAPTER 5

Experiment 3: Readability of visual and electronic leg tags versus rumen boluses and electronic ear tags for the permanent identification of dairy goats

5.1. ABSTRACT

Murciano-Granadina dairy goats (n = 220) were used to assess the performance of leg tags compared to different visual and electronic identification (ID) devices: 1) leg tags (LT) in the shank of the right hind leg (metatarsus), consisting of plastic bands (181 × 39 mm, 21 g; n = 220) 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). All transponders used half-duplex technology. Shank circumference of 47 replacement kids (5 to 6 mo of age) and 103 adult goats were measured to evaluate the appropriate circumference of fastened LT. Goats had been identified with rumen boluses and ear tags prior to the start of the experiment. Total time for leg tagging (LT application and transponder attachment), reading and data recording with a handheld transceiver was measured. Readability [(read/readable) × 100] was monitored for 1 yr with goats restrained in the milking parlor. Reading time and errors for RB and ET2 in the milking parlor using the handheld transceiver were also recorded. Shank circumference of kids (70 ± 1 mm) was 79.5% of those in adult goats (88 ± 1 mm), thus, LT (107 ± 1 mm inner circumference) were only applied to adult goats, as were considered inadequate for 5-mo kids. Time for leg tagging and data recording was 53 ± 3 s. At 1 yr, readability of RB was 96.5%. No losses of LT occurred, although 3 (1.5%) had to be removed due to limping, being LT visual readability 98.5%. Moreover, 7 (3.6%) LT were found open and electronically unreadable due to loss or breakage of the button tag. Readability of button transponders, excluding removed LT, was 93.9% for ET1, and 98.3% for ET2. For ear tags, readability was 95.7 and 97.0% in EE and VE, respectively. Only LT and ET1 readabilities differed. Reading time in the milking parlor was greater for RB (61.2 s) than for ET1 (45.9 s), as well as reading errors (0.3 vs. 0%). In conclusion, leg tags were not adequate for the identification of goat kids < 6 mo of age although, if adequately sized and fastened, this may be an efficient method for adult goats under intensive conditions. Only leg tags with ET2 transponders met the ICAR requirements for official ID of adult goats (readability > 98%) under the conditions of this experiment.

5.2. INTRODUCTION

The European regulation CE 21/2004 on 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 the Member States where total sheep and goat population surpasses 600,000 animals, as well as in goats where the total number is greater than 160,000.

According to this regulation, RFID has been officially deployable since 2005 although its compulsory implementation has been adopted from January 2010 (CE 1560/2007). Regulation CE 21/2004 has already enforced in Spain, where RFID rumen boluses have been in use since 2006 (Real Decreto 947/2005).

Nevertheless, bolus retention in goats has proved to be highly variable (Caja et al., 1999; Pinna et al., 2006; Carné et al., 2009a,b). As a consequence, the use of subcutaneous small size transponders (i.e., 10 to 15 mm) in the fore- (metacarpus) or hind-leg (metatarsus) of goats was also approved to be used in goat herds with poor bolus retention. However, transponders injected in the leg have also shown a wide range of losses and reading performance of small transponders is low (MAPA, 2007; Carné et al., 2009a). Moreover, injection in the hind-leg of dairy goats has proven more difficult than in the fore-leg (MAPA, 2007).

Recently, European Regulation CE 21/2004 has been amended by Regulation CE 933/2008, which specifies the mandatory use of 1 visual and 1 electronic ID device simultaneously. Rumen boluses and ear tags have eventually been established as the authorized RFID devices whenever RFID is compulsory; visual ear tags and visual pastern tags are accepted as the second ID device. Additionally, identification in the pastern by using electronic marks (electronic leg tags) and injectable transponders has also been accepted in sheep and goats whose first means of ID is a visual ear tag and only when not leaving the Member State of origin (CE 933/2008). Although visual tags on the metatarsus are common for goat ID in the milking parlor (Balvay, 2007), extremely scarce information is available on the use in practice of leg tags for the long-term visual and electronic readability. Thus, this work aimed at evaluating 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 comparisons.

5.3. 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, as well as the guidelines of the ICAR (2007) and the Spanish Committee on Animal Electronic Identification (MAPA, 2007).

5.3.1. Animals, management, and identification devices

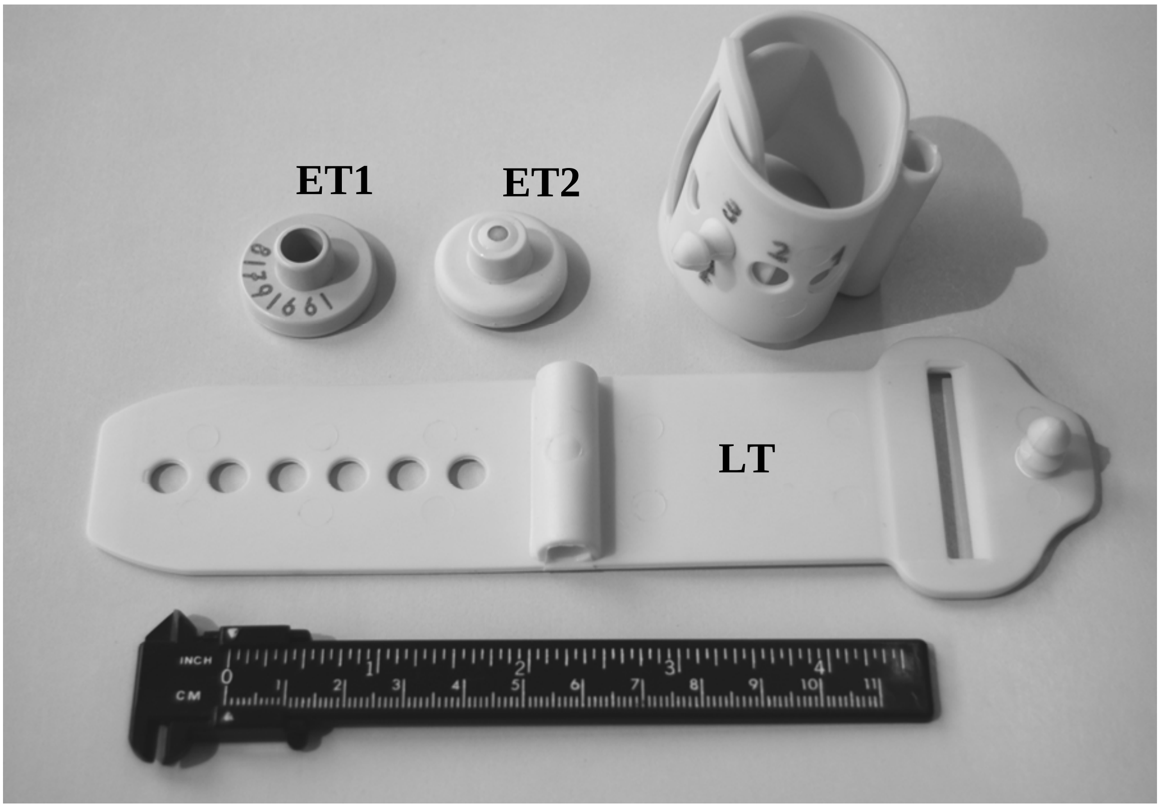
A total of 220 adult Murciana-Granadina dairy goats from a commercial farm (Ramaderia Huguet, Girona, Spain; n = 170) and from the experimental farm of the Universitat Autònoma de Barcelona (S1GCE, Barcelona, Spain; n = 50) were used. All goats were born before 2005 and were not subject to the new European Regulation EC 21/2004 on goat ID. Goats were fed indoors with dehydrated ryegrass hay ad libitum (12% CP; as fed), 0.5 kg/d of alfalfa pellets (17% CP; as fed), and 0.5 to 1.0 kg/d of commercial concentrate (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).

All goats were visually identified with a leg tag (**LT**) consisting of a yellow plastic band (weight, 21 g; length and width, 181 × 39 mm; and thickness, 2.2 mm; Animalcomfort, Jumilla, Murcia, Spain; Figure 5.1) with an adjustable buckle-like closure system, specially designed for goat ID. Each leg tag had a 3-digit animal ID code printed for farm management purposes. The buckle's pin of the leg tags was specially designed to be coupled with female ear tag pieces by using adapted tagger pliers supplied by the leg tag manufacturer. Two types of button half-duplex (**HDX**) transponders were used (Figure 5.1): **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 agreement with the International Organization for Standardization (**ISO**) 11784 and 11785 standards on animal electronic ID (ISO, 1996a,b).

As European regulations lay down that animals must be officially identified no later than 6 mo of age, the metatarsus' circumference of 103 adult and 47 replacement (5 to 6 mo of age) goats were measured to decide on the suitable inner circumference of leg tags to be used. Subsequently, the inner circumference of 50 closed leg tags with the chosen closing adjustment for adult goats was also measured to compare with leg circumferences obtained.

Prior to the start of this study, goats were also identified with standard size cylindrical boluses (**RB**; n = 220; weight, 75.0 g; length × o.d., 68 × 21 mm; and specific gravity, 3.4; Rumitag) made of atoxic, nonporous and dense ceramic materials. These boluses were considered as control devices as they had already been tested in previous studies (Pinna et al., 2006; MAPA, 2007; Carné et al., 2009a,b). Each bolus contained an ISO HDX, 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 agreement with corresponding ISO standards (ISO, 1996a,b). Boluses were administered by trained operators as described by Caja et al. (1999a) and Carné et al. (2009b). Boluses of these characteristics have been used since 2006 as the official RFID device for sheep and goats in Spain (Real Decreto 947/2005).

Figure 5.1. Leg tags and attached transponders for the visual and electronic identification of dairy goats in the hind leg. Abbreviations: LT = plastic-made leg tag with a 3-digit code printed for individual visual identification (weight, 21 g; length × width, 18 × 4 cm; and 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) to be attached to LT; ET2 = half-duplex closed button transponder; weight, 5.5 g; o.d., 25 mm; Rumitag, Esplugues de Llobregat, Barcelona, Spain) to be attached to LT.



As the use of button RFID ear tags has recently been regulated in Spain (Real Decreto 1486/2009), 47 goats were also tagged with 1 button-button HDX 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 manufacturer (Universal Total Tagger, Allflex Europe). Transponders included the manufacturer code (Allflex, 982) and agreed to the ISO standards therein (ISO, 1996a,b). Additionally, all goats wore 1 polyurethane visual ear tag (**VE**; flag-button; weight, 4.2 g; flag piece dimensions, 38 × 40 mm; n = 220; Azasa-Allflex, Madrid, Spain) on the right ear, with the button piece located on the inner side of the ear. Both pieces of the tag had printed a 6-digit alphanumeric code aimed at compulsory official ID; these ear tags were applied by Veterinary Service Officers.

5.3.2. Measurements and readings of identification devices

Electronic devices were read in the milking parlor with ISO handheld transceivers (Ges 2S, Rumitag) able to read ISO transponders at a minimum distance of 12 and 20 cm for ear tags and boluses, respectively, as established by the 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 their 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 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 thereafter every mo until 1 yr. For VE, only 1 reading at the end of the study was conducted.

Performance of ID devices was expressed as readability (visual or electronic), being:

Readability = (no. read devices / no. readable devices) × 100

Breakage or damage of ear and leg tags was also recorded, as well as 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 Limited, Slinfold, United Kingdom) was used, and fastened LT pieces were pulled at a constant displacement rate of 500 mm/min until breakage or unfastening as indicated for ear tags by the ICAR (2007).

Reading performance of ET2 and RB was evaluated in static conditions in the milking parlor. For this purpose, time for reading 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, check readings were performed to ensure that all devices to be read 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, therefore corresponding to 720 readings for each type of device. Reading failures, and crossed readings (reading devices from adjacent goats) were registered as well. Some crossed readings with the bolus of the adjacent goat to the left might occur when boluses were not located in the reticulorumen but in the rumen. Considering the potential crossed reading and 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 transponders not read (from the contiguous goat to the right). 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.

Dynamic reading efficiency of RB and ET2 attached to LT was also evaluated by using a frame antenna (94 × 52 cm; Tiris, Almelo, The Netherlands) connected to a portable stationary transceiver (model F-210, Rumitag) in groups of 22 to 35 goats passing through a runway (width, 50 cm). None of these goats were identified with additional RFID devices. Three antenna locations with respect to goat passage were tested: vertical on the left side, longitudinal on the floor, and vertical with goats passing through it. Dynamic reading efficiency was expressed as: (no. read devices /no. readable devices) × 100.

5.3.3. Statistical Analyses

Data on the shank and LT circumferences, and 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 a categorical fixed effect with 3 categories (kid goats, adult goats, and leg tags), 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 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-Meyer non-parametric survival analysis and log-rank test of equality across strata (ID devices) was 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 time of LT and RB in static conditions in the milking parlor was analyzed with the PROC GLM, and the model included the device type (ET2 and RB) as fixed effect, and the residual error. The PROC CATMOD was used for the evaluation of reading failures and false readings in the milking parlor, considering 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 the 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 also analyzed with the PROC GLM, according to the antenna position.

5.4. RESULTS AND DISCUSSION

5.4.1. Application performance of leg tags

The metatarsal circumference of replacement Murciano-Granadina kid goats (< 6 mo) was 79.5% of that in adult goats (88 ± 1 mm), being the inner circumference of the fastened LT 107 ± 1 mm. It should be mentioned that Murciano-Granadina breed is described as a medium frame dairy goat (bucks, 50 to 70 kg; does, 40 to 55 kg BW; ACRIMUR, 2010). According to results, the metatarsal circumference of the replacement goats was considered not appropriate for the application of LT as permanent ID at this age, as tamper-evident LT fitting the shank size of goat kids might eventually cause leg constriction in adult goats. As a consequence, only adult goats were eventually included in the study of ID devices. In fact, 3 (1.5%) LT in adult goats had to be removed because of limping. In one case the leg tag caused constriction of the metatarsus of an inflamed leg, this inflammation not being related to the leg tag application. In the other 2 cases the leg tag was too loose-fitting and slid down under the sesamoid bones, getting blocked between the sesamoid bones and the hoof.

Abecia and Torras (2009) recently reported previous results on the suitability of Patuflex leg tag (IRW Reyflex, 2010) application in Murciano-Granadina goat kids of 5 mo of age. The authors also measured the metatarsal circumference of kids (76 mm, on average), which was slightly greater than the value in the current study, and corresponded to correspond to 86.7% of the circumference of adult goats (88 mm, on average). The inner circumference of fastened leg tags ranged from 106 to 127 mm depending on the fastening adjustment. In the same study, displacement of leg tags under the sesamoid bones was reported in a total of 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 leg tags 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 leg tags for tagging at early ages seems critical to prevent both the displacement of devices in young goats, and the 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, on average. This value is within the range of average time obtained with standard rumen boluses used in adult goats of different breeds (52 to 55 s; Carné et al., 2009b).

5.4.2. Long-term readability of identification 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 a herd, these events not being related to the experimental procedures. Readability of ID devices in the milking parlor is shown in Table 5.1 and Figure 5.2; no readability progress of VE ear tags throughout the study is shown in Figure 5.2 as only one control at the end of the study was carried out. Apart from the 3 LT that had to be removed because of limping, no losses or breakages occurred during the experimental period. However, 1 (0.5%) LT had the end of the band partially unfastened although button transponder was functional and properly fastened. It can not be anticipated if the loose end of the LT in such an event might lead to additional losses due to biting or to getting caught on the premises.

Figure 5.2. Murciano-Granadina dairy goats wearing RFID leg tags in the left hind leg

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). However, most LT had to be manually cleaned to allow visual readability of the printed codes. Bolus readability remained within 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).

Regarding the button transponders, those corresponding to the LT that had to be removed were not included in the Logit model analyses. At the end of the study no electronic failures for ET1 and ET2 were detected. On the other hand, losses of ET1 were numerically greater than those of ET2 (6.4 vs. 1.7%, respectively; *P* = 0.110), thereby resulting in an average button transponder readability of 96.4%; as a consequence of button transponder losses, 3.6% LT appeared open and electronically unreadable.

Unfastening force of LT by using ET1button 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 (2007) for the unfastening or breakage of ear tags used for official animal ID. Therefore, observed losses of ET1and ET2 are likely to be preceded by the button breakage; in fact, in 2 (1.7%) ET2 losses we observed parts of the button still attached to the LT.

On the other hand, as the design of LT did not prevent their movements around the metatarsus, the influence of the location of the attached transponder (lateral, medial, front, or rear) on their breakage remains a topic for further research. The design of the LT used in our study also allows encasing a glass-encapsulated transponder as alternative to the button transponder; readability performance by using this sort of transponder should be thoroughly evaluated as well. Leg tag designs with the transponder encased in the plastic body of the device are recently available (Hilpert et al., 2009; ITW Reyflex, 2009; ICAR, 2010). One report is available, to our knowledge, regarding the use of these types of devices (Balvay, 2009). According to this study, losses after at least 6 mo at tagging ranged from 1 to 12% in adult goats in France, depending on the leg tag model. Moreover, 1.6 to 4.5% of devices were electronically unreadable. This same author reported similar losses of visual leg tags, although in this case visual readability was of 90%.

With regard to EE, only one goat left the study before its conclusion. 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. In fact, 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 conditions (Carné et al., 2009a). In an 8-mo large-scale study (n = 2,620), Schuiling et al. (2004) reported 5.1% average losses in adult goats identified with different types of RFID ear tags. Moreover, 1.6% electronic failures were registered, obtaining a final readability of 93.3%. In addition, remarkable variability of losses (0 to 7.1%) and electronic failures (0 to 2.9%) between herds was observed (Schuiling et al., 2004), being our data within the aforementioned ranges.

Table 5.1. Readability of leg tags, rumen boluses, and visual and electronic ear tags in adult dairy goats during a 1-yr study.[1]

		Button transponders				Ear tags	
Item	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 ($P < 0.05$).

[1]Devices: LT = plastic-made leg tag with a 3-digit code printed for individual visual identification (weight, 21 g; length × width, 181 × 39 mm; and 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-made rumen bolus (weight, 75 g; length × o.d., 68 × 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 × 40 mm; Azasa-Allflex).

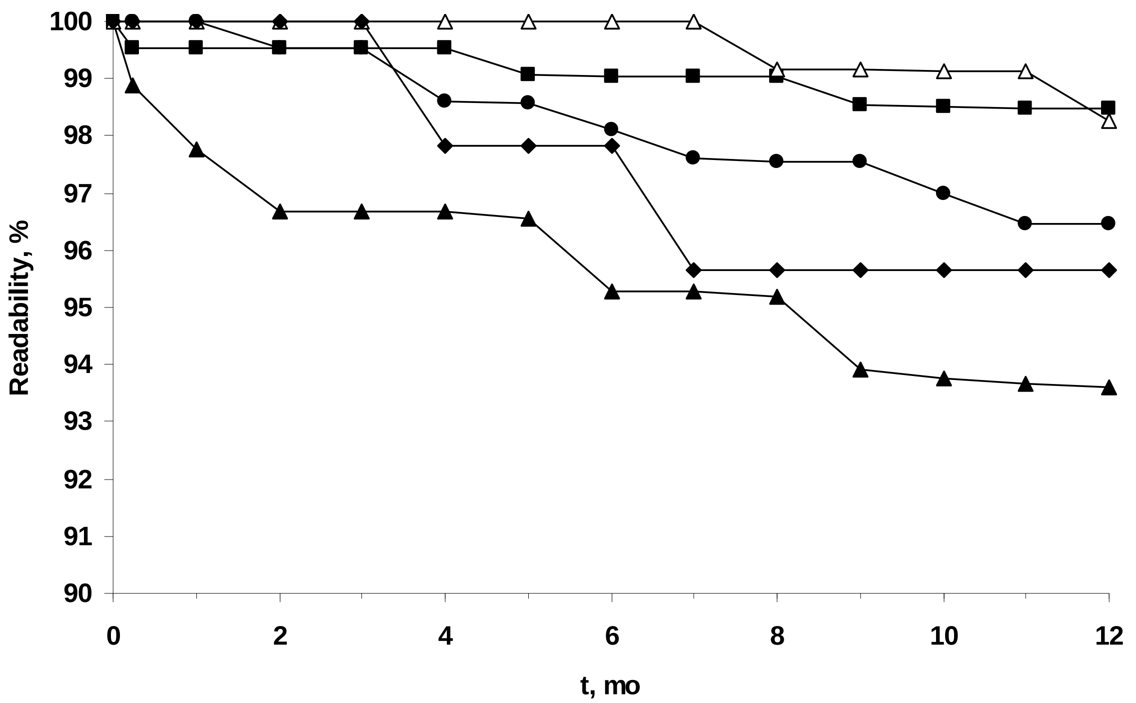
[2]Button transponders attached to the 3 leg tags removed were excluded from the Logit model analyses.

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

[4]Damaged devices were unreadable.

[5]Breakage 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 5.2. Evolution of readability of identification devices throughout 1-yr study in dairy goats: LT (■), RB (●), ET1 (▲), ET2 (Δ), and EE (♦). Abbreviations: LT = plastic-made leg tag with a 3-digit code printed for individual visual identification (weight, 21 g; length × width, 181 × 39 mm; and thickness, 2.2 mm; Animalcomfort); ET1 = half-duplex open button transponder (weight, 3.9 g; o.d., 26 mm; Azasa-Allflex) attached to LT; ET2 = half-duplex closed button transponder (weight, 5.5 g; o.d., 25 mm; Rumitag) 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).



Performance of compulsory official VE used in Spain at the time this work was carried out was also evaluated at the end of the experiment. A total of 6 VE losses were registered, thereby obtaining 97.0% retention. However, it must be stressed that damages in the flag piece were observed in 24.9% of cases, 22.8% corresponding to the breakage of the flag piece right by the base, making the VE appear as button-like devices. Nevertheless, only lost devices were usually replaced by the veterinary officials during the annual blood sampling. The high number of such findings might be related to an apparent good retention rate of these resulting devices, especially considering the relatively low incidence of annual losses. In sheep, retention of this same type of official ear tag averaged 96.7%, although no reference to damages was made (Ghirardi et al., 2006).

According to our results, only the visual readability of LT and electronic ET1 differed ($P < 0.05$) at the end of the study, corresponding to the highest and lower readability results obtained, respectively. Furthermore, only the LT visual readability and ET2 electronic readability were greater than 98%, as recommended by the ICAR for extended field tests lasting 1 yr (ICAR, 2007).

Results of estimated readability of ID devices, obtained with the Kaplan-Meyer survival analysis, are shown in Table 5.2. 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 factual and estimated readability were low, ranging from 0.1 to 0.5%; this was mainly due to the high number of devices being monitored until the end of the study. As previously observed for factual 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 similarly to factual data, no differences ($P > 0.1$) between LT, RB and EE were detected.

Table 5.2. Estimated readability of identification devices with Kaplan-Meier non-parametric survival analysis and log-rank tests between devices in dairy goats throughout 1-yr study[1]

		Button transponders				
Item	LT	ET1	ET2	Overall	RB	EE
Applied, n	220	90	130	220	220	47
Censored data, n[2]	23	12	14	26	23	1
Events, n[3]	3	5	2	7	7	2
Readability estimates, %	98.6[a]	94.1[bx]	98.4[aby]	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 ($P < 0.10$).
[1]Devices: LT = plastic-made leg tag with a 3-digit code printed for individual visual identification (weight, 21 g; length × width, 181 × 39 mm; and thickness, 2.2 mm; Animalcomfort); ET1 = half-duplex button transponder (weight, 3.9 g; o.d., 26 mm; Azasa-Allflex) attached to LT; ET2 = half-duplex button transponder (weight, 5.5 g; o.d., 25 mm; Rumitag) attached to LT; RB = ceramic-made rumen bolus (weight, 75 g; length × o.d., 68 × 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).
[2]Devices which left the study before 1 yr without an event being registered.
[3]Unreadable devices.

5.4.3. Static reading efficiency of leg tags and boluses in the milking parlor

Results referring to reading efficiency of leg tags with electronic transponders (ET2) and RB in static conditions from the pit side in the milking parlor are shown in Table 5.3. Because of 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 mainly due to an easier access to the ET2 from the rear position of the animal, as the operator was located in the pit of the milking parlor, allowing at the same time for a quicker transition between goats. In the case of RB, the stick antenna had to be positioned close to the cranial left-side abdominal area, as boluses have been described to remain mainly located in the reticulum of domestic ruminants (Garín et al., 2003; Castro et al., 2004; Antonini et al., 2006).

Table 5.3. Comparison of static reading efficiency of electronic leg tags (ET2 transponders) and rumen boluses in dairy goats in the milking parlor (values are least squares means ± SE), by using a handheld transceiver connected to a stick antenna[1]

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

[1]Smart Reader (Rumitag, Esplugues de Llobregat, Barcelona, Spain) connected to a 70-cm stick antenna.
[2]Devices: RB = ceramic-made 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.
[3]Number of read devices, carried out in groups of 24 goats in the milking parlor.
[4]Groups of 24 goats in a double-12 stall parallel (side by side) milking parlor.
[5]Reading of transponders from adjacent goats in the milking parlor.
[6]No statistical contrasts could be carried out when no reading incidences or 100% readability were registered.

The RB average unitary reading time (Table 5.3), obtained when reading the RB from the rear of the goats, was within the previously reported range (2.4 to 4.0 s) by Caja et al. (1996) for boluses administered to dairy sheep, and in a similar milking parlor. On the contrary, ET2 average unitary reading time was lower than that obtained for RB (P < 0.001; Table 5.3). Similarly, low unitary reading times of electronic ear tags (1.9 to 2.8 s) were reported in dairy sheep read from the front in the milking parlor, as the transponder was quickly localized by sight (Caja et al., 1996).

As previously explained, in the case of RB, potential crossed reading of the bolus in the adjacent goat to the left might occur when the boluses were not located in the reticulum but in the rumen. For this reason, readings were performed starting from the left side of each stall, in order to minimize the possibility of crossed readings with transponders not read (corresponding to the contiguous goat to the right). As already mentioned in the material and methods section, this detail is of major relevance as current commercial transceivers can be configured so that no duplicate readings are registered in a reading session; thus, if the goat to the left was wrongly read, the transceiver’s screen would display that the transponder had already been registered. In such an event, the operator would only have to perform a new reading attempt of the transponder expected to be registered. In this regard, 2 such cases were observed in our experiment, representing 0.3% of overall bolus readings. As anticipated, no crossed reading with goats to the right in the milking parlor occurred. Crossed readings might also occur if intending to read a goat which had lost the rumen bolus.

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) indicated 0.6% of reading errors in similar experimental conditions when carrying out semi-automated milk recordings, although the nature of these reading anomalies was not specified. In our work, the aforementioned reading methodology and transceiver configuration to avoid duplicate recording, prevented mistaken assignation of the transponder to a different goat; in such conditions, reading errors only caused an increment in the average reading time required per goat.

5.4.4. Dynamic reading efficiency of leg tags and rumen boluses

Results of dynamic reading performance of RB and ET2 in a runway, according to the position of the frame antenna, are shown in Table 5.4. The speed of passage of goats through the runway was lower ($P < 0.05$) when goats were forced to pass through the antenna, as goats tended to slow down just before crossing it. Nevertheless, the speed of passage was in all cases lower than 1 goat/s, which agrees with conditions for proper dynamic reading according to previous reports (JRC, 2003; Ghirardi et al., 2006b). Goats in our study wore both RB and ET2 transponders (estimated distance between transponders 30 cm), which led to the worst condition possibly faced when reading herds identified with several types of RFID devices. In such conditions, the incidence of reading collisions due to the presence of more than 1 transponder at a time inside the electromagnetic field generated by the transceiver were maximized; this fact was expected to cause an increment of transponder's reading failures.

Results of dynamic reading efficiency according to the position of the frame antenna in the runway (Table 5.4) showed that the greatest reading efficiency was obtained with RB read with the antenna located laterally to the left of the runway. The following 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. According to our results, no antenna location offered maximum reading performance for both types of devices. In fact, the best antenna position for ET2 reading was likewise the worst option for proper RB reading. These findings should be taken into account if dealing with goat herds where different RFID devices are in place, as allowed by current Europe regulations (EC 21/2004 and EC 933/2008).

As anticipated, the reading collision reported in our experiment reduced the reading efficiency of devices, when compared to 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., 2006b). Likewise, the only reference available, to our knowledge, on the dynamic reading efficiency of rumen boluses by using a frame antenna located on the floor of a runway (no details available on the transceiver technical features) yielded 74.2% (MAPA, 2007), which is higher than the value obtained in our study.

Table 5.4. Dynamic reading efficiency[1] (DRE) of electronic rumen boluses and button transponders attached to leg tags in dairy goats (values are least squares means ± SE), according to the position of the transceiver's antenna[2,3]

Antenna position	Passage speed, 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,b]Within a column, values with different superscripts differ ($P < 0.05$).
[1]Using a frame antenna (94 × 52 mm; Tiris, Almelo, The Netherlands) connected to an F-210 portable stationary transceiver (Rumitag, Esplugues de Llobregat, Barcelona, Spain), in goats passing through a runway (width, 50 cm); DRE = (no. read devices/no. readable devices) × 100.
[2]Devices: RB = ceramic-made 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.
[3]Reading sessions carried out in groups of 22 to 35 goats.

With regard to the performance of transponders attached to leg tags, no literature on their dynamic reading efficiency is available. Nevertheless, an average dynamic reading efficiency of 99.7% has been reported when using 15-mm transponders injected in the foreleg pastern of Murciano-Granadina adult goats and the tranceiver's antenna 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 on field conditions. This recommended minimum value allows > 99.7% readability of electronic devices 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.

5.5. CONCLUSIONS

Leg tags in the hind leg of adult goats offered a suitable (> 98%) visual and electronic readability, if adequate button transponders are used. Nevertheless, both design and inner circumference of fastened leg tags should be evaluated in thorough detail to avoid limping and prevent other derived damages. This is also the case of early leg tag application in replacement stock. In this study, standard-sized rumen boluses and electronic ear tags did not reach the recommended readability (> 98%) for official identification of goats as a consequence of losses, which should be reduced.

CHAPTER 6

Experiment 4: Modeling the retention of electronic rumen boluses in goats

CHAPTER 6

Experiment 4: Modeling the retention of rumen boluses for the electronic identification of dairy goats

6.1. ABSTRACT

A regression model of the retention of rumen boluses in the reticulorumen of goats was constructed. With this aim, 2,482 boluses were administered to goats from dairy (Murciano-Granadina, n = 1,326; Alpine, n = 381) and meat (Blanca de Rasquera, n = 532) breeds. A total of 19 bolus types made of different materials (ceramic, plastic tubes filled with concrete and silicone, and ballasts) were used, thereby obtaining a wide variation in bolus features: o.d. (9 to 22 mm), length (37 to 84 mm), weight (5 to 111 g), volume (2.5 to 26 mL), and specific gravity (SG; 1.0 to 5.5). Each bolus contained a half-duplex glass encapsulated transponder (32 × 3.8 mm), and was administered using adapted balling guns. Goats also wore 2 visual plastic ear tags: V1 (double flag, 5.1 g), and V2 (flag-button, 4.2 g). Bolus and ear tag retention (retained/monitored × 100) was recorded for at least 1 yr. Dynamic reading efficiency (dynamic reading/static reading × 100) was also evaluated from a total of 1,496 bolus readings. No administration incidents or apparent behaviour and performance alterations were observed for any bolus type. Static reading efficiency of retained boluses was 100%, except for the prototypes with metal ballasts, which yielded a 93.3% reading efficiency. Retention of metal-ballasted boluses was confirmed using x-ray equipment. Excluding ballasted boluses, a 99.5% dynamic reading efficiency was obtained. Ear tag losses were 6.5 for V1 and 3.7 % for V2, ranging from 3.2 to 7.8% depending on ear tag type and goat breed. Bolus retention varied (0 to 100%) according to their physical features. Obtained data allowed the fitting of a logistic model of bolus retention rate according to bolus volume and weight (R^2_{41} = 0.98); the SG was implicitly considered. Inclusion of literature data was discarded as it caused overestimation of retention values when compared to the original model. Estimated weight and SG to produce mini- (5 mL), medium- (15 mL) and standard-sized (22 mL) boluses for 99.95% retention rate in goats were 42.9, 73.0, and 94.1 g, and 8.58, 4.87, and 4.28, respectively. In conclusion, increase of specific gravity was fundamental to optimize bolus retention and reduce bolus size in goats. Mini-boluses are not recommended, as no available radio translucent materials reach the required SG. By contrast, medium-sized boluses (10 to 15 mL; SG 5.9 to 5.2) to be administered at early ages and efficiently retained in adult goats could be produced.

6.2. INTRODUCTION

During the last decades, a number of passive radiofrequency identification (**RFID**) devices have been tested to electronically identify domestic ruminants, including injectable transponders in different body locations (Fonseca et al., 1994; Lambooij et al., 1999), ear tags (Schuiling et al., 2004; Carné et al., 2009a), rumen boluses (Caja et al., 1999a; Fallon et al., 2002; JRC, 2003), and leg bands (Abecia et al., 2009; Carné et al., 2009c, 2010). In the case of rumen boluses, these have proved to be easily administered and show a suitable long-term retention when properly designed and administered in sheep and cattle (Hasker and Bassingthwaighte, 1996; Teyssier et al., 2003; Ghirardi et al., 2006a,b). In this sense, small-sized boluses (5 to 6.5 mL) have been successfully used to permanently identify lambs at early ages (Garín et al., 2005; Ghirardi et al., 2007).

A relationship between physical features of boluses and their retention rate in the reticulorumen has been pointed out by different authors (Ribó et al., 1994; Caja et al., 1999a; Fallon, 2001). More recently, the possibility of satisfactorily predicting the retention of boluses according to their physical features in both cattle and sheep has been described (Ghirardi et al., 2006ab).

In agreement with provisions of current European regulations on sheep and goat identification and registration (EC 21/2004; EC 1560/2007; EC 933/2008), RFID rumen boluses have been used in Spain since 2006 as the electronic device (Real Decreto 947/2005). Nevertheless, retention rate of boluses in Spanish goat breeds has come to be noticeably lower than in sheep, especially in the case of dairy breeds (JRC, 2003; MAPA, 2007; Carné et al., 2009a). It has been suggested that feed management, as well as goat mature size and breed, affect bolus retention rates (MAPA, 2002; Capote et al., 2005; Carné et al., 2009ab).

The objective of this study was to establish a regression model of the retention of rumen boluses in goats, mainly of dairy purpose, according to bolus physical features. Ultimately, results must enable the design of boluses which optimize their retention rate in any goat breed and under different production systems.

6.3. 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, and the guidelines of the Spanish Committee on Animal Electronic Identification (MAPA, 2007).

6.3.1. Animals and management

A total of 2,239 adult goats from 3 breeds (dairy purpose: Murciano-Granadina, n = 1326; and French Alpine, n = 381; meat purpose: Blanca de Rasquera, n = 532) were used. The Murciano-Granadina goats in Catalonia (Spain) belonged to 4 commercial farms (Tona, Barcelona, n = 274; St. Vicenç de Castellet, Barcelona, n = 291; Juneda, Lleida, n = 410; and Terradelles, Girona, n = 239) and 1 experimental farm (S1GCE, Serveis de Granges i Camps Experimentals, Universitat Autònoma de Barcelona, Bellaterra, Barcelona, n = 112). The Murciano-Granadina goats from the commercial farms were managed under intensive conditions, being kept indoors and fed hay and concentrate. In the case of the S1GCE experimental farm, goats additionally grazed 5 h a day (1000 to 1500 h) on cultivated Italian ryegrass pasture. In all cases, does were milked once daily in the morning (0700 to 1100 h). The Alpine goats belonged to one commercial farm (Villarcayo, Burgos, Spain) managed similarly to the Murciano-Granadina commercial farms, although in this case does were milked twice daily (0630 and 1730 h).

The Blanca de Rasquera goats, a local Catalan breed highly rustic and intended for meat production (Carné et al., 2007), belonged to 1 commercial farm (Horta de Sant Joan, Tarragona, Spain), and were managed in a semi-extensive production system, grazing 8 h/d (1000 to 1800 h) on Mediterranean forest range lands. Kidding does were supplemented with alfalfa hay and concentrate in the shelters.

All goats from the S1GCE experimental farm that died or were culled during the experiment were sent to the Pathology Service of the Universitat Autònoma de Barcelona for necropsy.

6.3.2. Visual ear tags

The Murciano-Granadina goats were individually identified with either 2 types of official plastic ear tags: **V1**, double flag type (weight, 5.1 g; flag piece dimensions, 37 × 39 mm; Rumitag, Esplugues de Llobregat, Barcelona, Spain), and **V2**, flag-button type (weight, 4.2 g; flag piece dimensions, 38 × 40 mm; Azasa-Allflex, Madrid, Spain). All goats born after July 2005 wore V1 in the right ear, according to currently deployable European regulations in this regard. For goats born before July 2005, V2 were applied in the right ear, in agreement with the former European and Spanish regulations on livestock

ID (Directive 92/102/EEC; Real Decreto 205/1996), placing the button piece in the inner face of the ear. The Blanca de Rasquera goats were visually identified with either V1 or V2 official ear tag types in a similar way to that detailed for the Murciano-Granadina goats.

The Alpine goats had been brought from different French farms 2 yr before and maintained their official ID consisting of 1 official flag-flag plastic ear tag in each ear.

6.3.3. Rumen boluses and administration procedures

A total of 2,482 boluses, belonging to 19 different prototypes and commercial devices, and varying in their physical features (length, o.d., volume, weight, and specific gravity [**SG**]) were used (Table 6.1). Administration of boluses with extremely different physical features was expected to result in a wide range of retention rate values, thereby allowing the build up of a regression model of bolus retention in the reticulorumen of goats according to bolus features.

Eleven bolus types were cylindrical devices made of non-porous dense ceramic materials, of which 3 were commercial devices for ruminant electronic identification, and the remaining 8 were specially made prototypes. Four more boluses consisted of cylindrical capsules made of plastic tubes that contained small sized boluses, filling materials (silicon, concrete, or metal ballasts), and were eventually sealed with epoxy resin. The remaining 4 bolus types consisted of ceramic prototypes with stainless steel ballasts attached to one end in order to increase the SG.

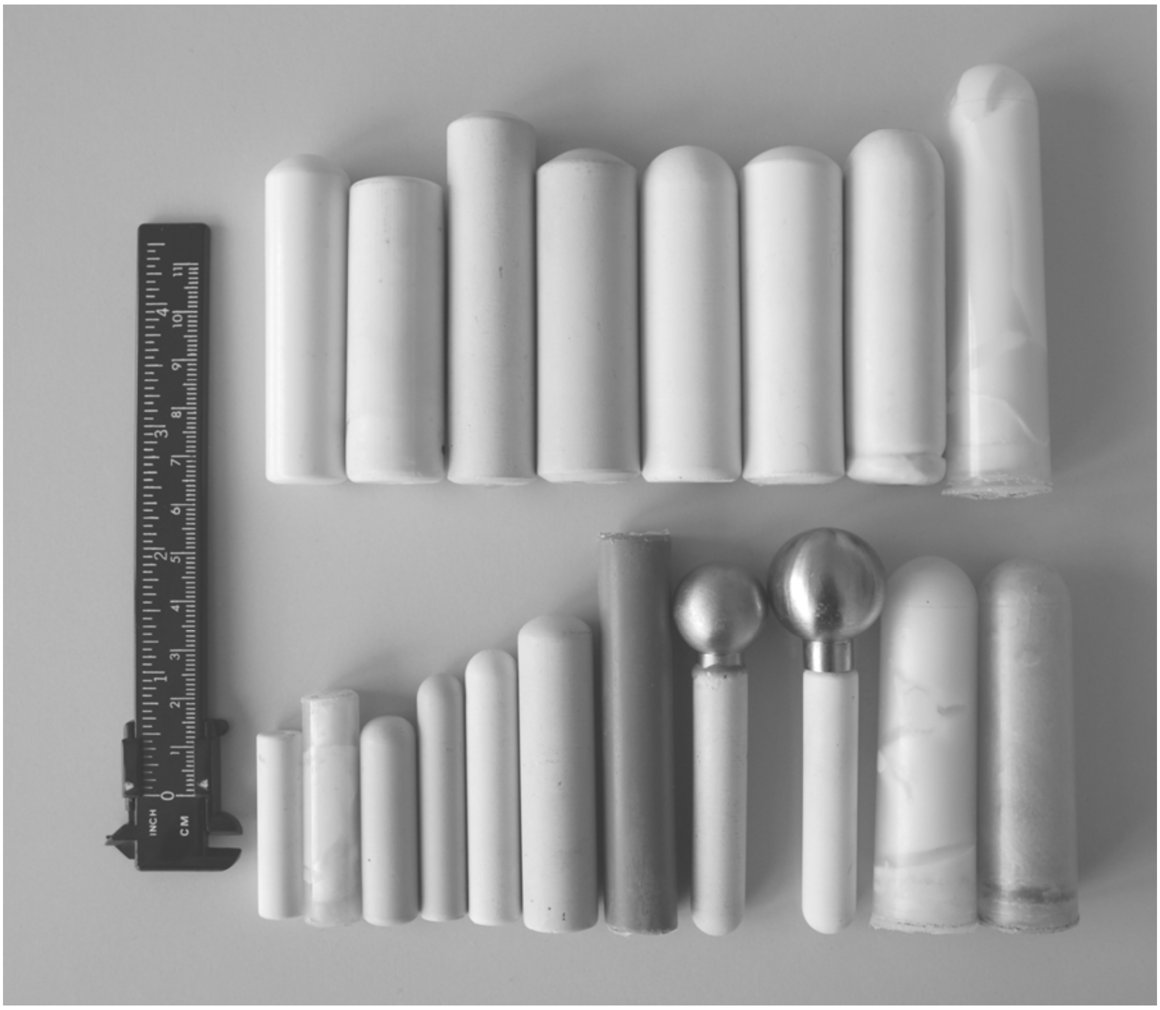
A random sample of 10 boluses of each type (n = 190) was collected to measure their physical features under laboratory conditions using a precision weighing scale (accuracy, 0.01 g; BP 3100 P, Sartorius AG, Goettingen, Germany) and an electronic digital calliper (accuracy, 0.03 mm; Shaodong Feiyue Hardware Tools Factory, Yiwu, China).

The SG (density rate of a given substance with respect to density of water at 1 atm of pressure and 4 ºC of temperature) of each bolus was measured according to the Archimedes principle by contrasting the weight of the bolus with the weight of its volume of distilled water, similarly to the method described by Ghirardi et al. (2006a).

Each bolus contained a half-duplex glass encapsulated transponder of 32 × 3.8 mm (length × o.d.), which worked at a frequency of 134.2 kHz in agreement with the International Organization for Standardization (**ISO**) 11785 standard on animal electronic

ID (ISO, 1996a). In goats born after July 2005, transponder codes included the country (Spain, 0724), re-tagging counter (00), species (sheep and goat, 04), and a 12-digit serial number in which the autonomous community (Catalonia, 09) was included, according to the current Spanish (Real Decreto 947/2005) and European (EC 21/2004; 2006/968/EC) regulations. For the rest of the goats, ISO transponders with the ICAR (2010) manufacturer codes (Allflex, 982; Innoceramics, 957; Rumitag, 964) and a 12-digit serial number were used, in agreement with ISO 11784 standard (ISO, 1996b).

Figure 6.1. Electronic rumen boluses tested to model the bolus retention in goats.



All boluses were administered using balling guns adapted to each bolus type. Administration was done as previously described by Caja et al. (1999a) and Carné et al. (2009b). To check for possible electronic failures during administration procedures, each bolus was read immediately before and after administration by using full-ISO radio frequency handheld transceivers (Ges2S, Rumitag) able to read boluses at a minimum distance of 20 cm, as specified in the European regulation in this regard (EC 933/2008). For the post-administration readings, a directional caudo-cranial sweep in the abdomen region was performed with a handheld transceiver to ensure the proper descent of the bolus into the reticulorumen. Subsequently, bolus type and goat ID data (goat breed, and ear tag and farm codes) were typed and stored into the reader.

6.3.4. Monitoring of identification devices

Boluses were read in static conditions (animals restrained) with the handheld reader at wk 1 and mo 1 after administration to register early losses, and thereafter every 2 mo until 12 to 18 mo depending on the bolus type. From the overall 309 goats that lost the bolus, 243 were reidentified with a different bolus type. Boluses that could not be monitored for at least 1 yr of study were excluded from calculations as 1 yr is the minimum time frame indicated by the ICAR to carry out long-term performance tests on the use of livestock ID devices (ICAR, 2007). Additionally, performance of ear tags in Murciano-Granadina (V1, n = 168; V2, n = 502) and Blanca de Rasquera (V1, n = 218; V2, n = 276) goats was registered at 1 yr.

The retention of the ID devices was expressed as:

Retention rate (%) = (no. retained devices / no. monitored devices) × 100

As bolus failures are extremely rare, unreadable boluses were deemed as lost.

Additionally, dynamic reading controls were carried out in 3 farms of Murciano-Granadina goats, as well as in the 2 farms of Alpine and Blanca de Rasquera goats. For the readings, goats passed through a portable runway (width, 40 cm; length, 200 to 300 cm) with a left-side-installed frame antenna (94 × 52 cm; Rumitag) in vertical position, and connected to a stationary transceiver F-210 (Rumitag). Minimum reading distance obtained was 50 cm, as laid down in the European regulation in this regard (EC 933/2008). A handheld transceiver was used to confirm bolus readability in static conditions (bolus retention) whenever an unread bolus was detected; bolus losses were not included in the dynamic reading efficiency data. Bolus prototypes with metal ballasts were also excluded, as electric conductivity of metal strongly interfered with radio frequency electromagnetic fields and dramatically reduced the reading distance achieved. Dynamic reading efficiency (%) was calculated as: (no. read devices/no. readable devices) × 100.

6.3.5. Statistical analyses

Bolus retention data were analyzed with a nonlinear least squares regression model, using the NLIN procedure of SAS v.9.1 (SAS Inst. Inc., Cary, NC) and assuming a logistic distribution, as previously carried out in beef cattle and sheep (Ghirardi et al., 2006ab). The final model included the weight (**W**) and volume (**V**) of boluses as independent covariates:

$$y = \frac{A}{1 + b_0 \cdot e^{-(b_1 \cdot W + b_2 \cdot V)}}$$

being: y, the bolus retention rate (response variable); b_0, b_1, and b_2, the regression coefficients; and A, the maximum value of bolus retention rate expressed as a percentage (A = 100). The WEIGHT statement of SAS was used to allow for a weighted regression according to the number of boluses of each type evaluated.

Retention rate of ear tags was analyzed with the CATMOD procedure of SAS, and a Logit model with an estimation method of maximum likelihood (Cox, 1970) was used. Effects evaluated were breed (Murciano-Granadina and Blanca de Rasquera) and ear tag type (V1 and V2). The CATMOD procedure was also used to analyze the bolus dynamic reading efficiency, evaluating the effects of bolus type, goat breed, and herd.

In all cases, significance was declared at $P < 0.05$ and variables that were not significant ($P > 0.20$) were removed from the final models.

6.4. RESULTS AND DISCUSSION

6.4.1. Features of boluses, and administration and reading performances

Features of each bolus type are detailed in Table 6.1. For practical purposes, boluses used in this study were divided into 3 categories according to their volume: small-sized (2.7 to 7.2 mL), medium-sized (11.6 to 15.4 mL) and standard-sized boluses (18.1 to 26.0 mL). With regard to their dimensions, boluses ranged from 37.4 to 83.8 mm in length and 9.3 to 22.1 mm in o.d. Boluses also varied in weight, ranging from 5.3 to 110.8 g, as well as SG, ranging from 1.0 to 5.5. Prototypes with attached stainless steel ballasts were not cylindrical, as the ballast was a ball and had a larger o.d. than the body of the bolus. A total of 7 bolus types in our study (#2, 3, 4, 9, 12, 14 and 15; Table 6.1) have already been tested in fattening lambs and adult sheep (Teyssier et al., 2003; Garín et al., 2005; Ghirardi et al., 2006b, 2007).

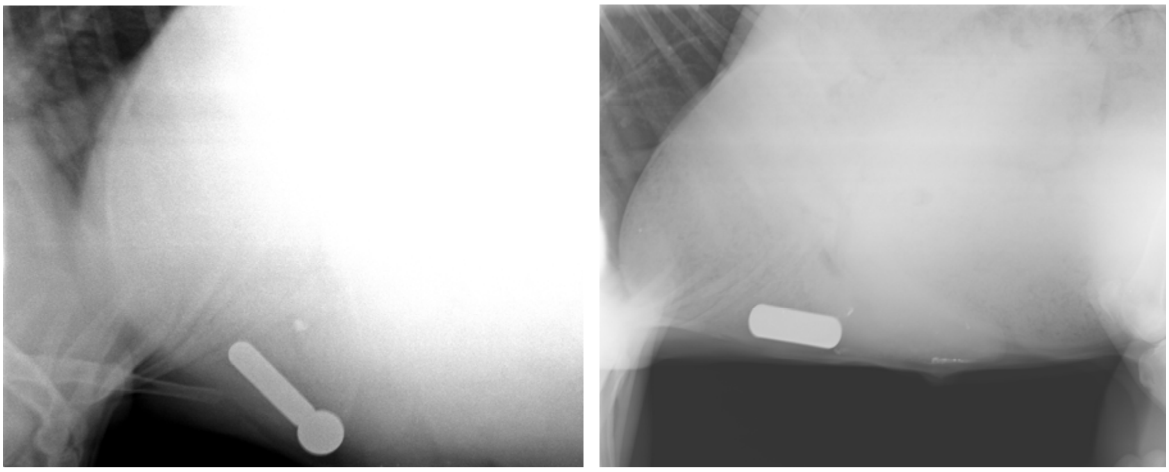
No incidences at bolus administration were reported for any of the bolus types. Moreover, an extra large bolus prototype (#10, 26 mL), which had never been tested in small ruminants, was easily and safely administered to goats in our experiment. These findings confirm earlier results in sheep and goats where 22-mL boluses were safely administered by trained operators to adult sheep and goats (Caja et al., 1999a; Ghirardi et al., 2006a; Carné et al., 2009b) as well as to replacement sheep and goats with BW greater than 30 and 25 kg, respectively (Caja et al., 1999a). No casualties registered during the study appeared to be related to bolus administration or their long-term location in the reticulorumen; moreover, no necropsy reports of dead goats from the experimental farm indicated any damage caused by the bolus, and in all cases the bolus was properly located in the reticulorumen.

Retained boluses could be easily read in static conditions in the shelters and the milking parlor by using handheld readers, except for the prototypes with metal ballasts. In these last cases, several reading attempts were frequently necessary probably due to interferences in the signal emitted by the transponder. In fact, proper retention of 8 of these ballasted boluses had to be confirmed at the end of the study by using portable X-ray equipment (Model X803G, MinXray Inc., Northbrook, IL, USA).

Nedap Agri, from The Netherlands, developed RFID boluses made of plastic with steel ballasts attached to one end; these ballasts increased the SG and allowed a swift submersion through the rumen content (Fallon, 2001). Nevertheless, the body of the bolus encased larger transponders to compensate for poor reading performance due to interferences caused by the metal ballast. The use of this sort of device, with SG up to 2.75, has been described in sheep (Caja et al., 1996) and cattle (Lambooij et al., 1999; Fallon et al., 2002).

With respect to dynamic reading efficiency, boluses with attached metal ballasts were not taken into account as unsuitable reading performance was anticipated. A total of 1,496 bolus readings were carried out, with the goats passing in front of the frame antenna at a speed of up to 2 goats/s. At the end of the study, 8 reading failures were registered, thereby obtaining a reading efficiency under dynamic conditions of 99.5%. Moreover, no differences according to bolus type, goat breed or herd could be established. Similarly, Pinna et al. (2006) reported bolus dynamic reading efficiency greater than 99.7% in Sarda goats, using similar HDX transponders. Readabilities greater than 99.5% were also described by using both mini- (3 to 5 mL) and standard-sized (22 mL) boluses in different meat and dairy sheep breeds (Ghirardi et al., 2006b). No bolus or herd effect were detected either in this case.

Figure 6.2. X-ray images of ballasted and ceramic standard-sized boluses located in the reticulorumen of adult Murciano-Granadina dairy goats.



6.4.2. Bolus retention and regression model

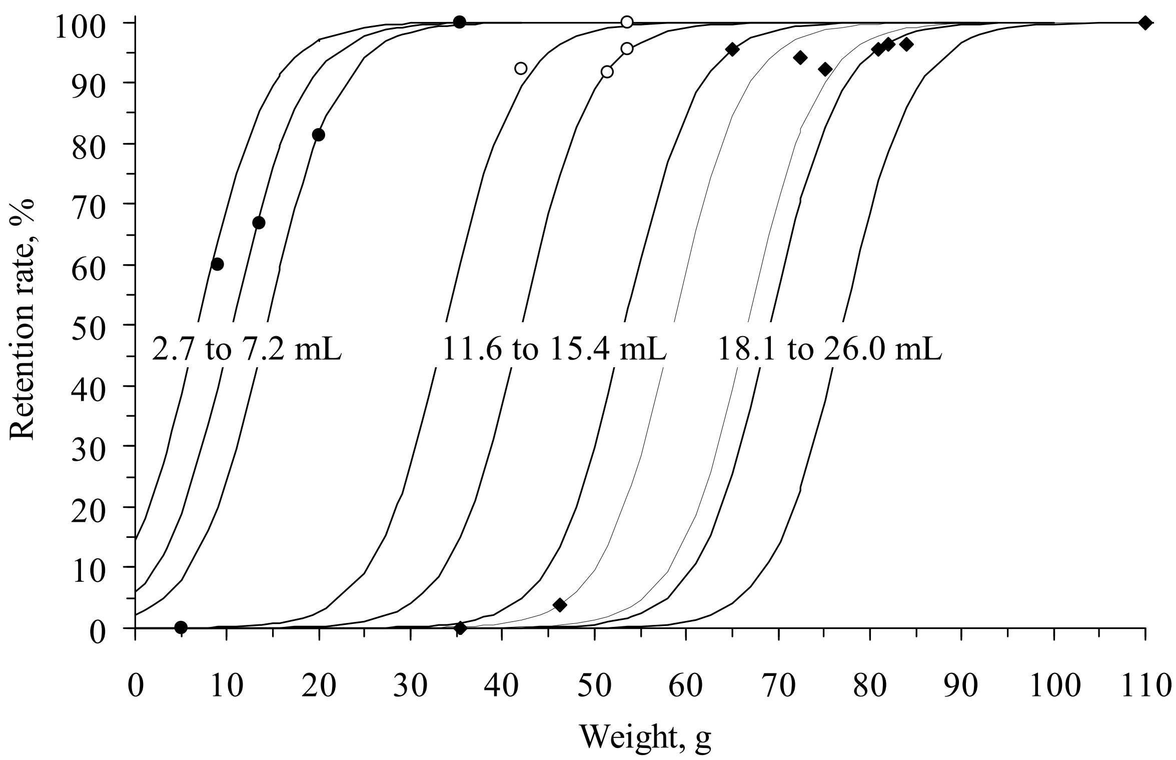
Retention of the different bolus types is shown in Table 6.1. Retention rates ranged from 0 to 100% ($P < 0.001$) as anticipated according to the variety of bolus features, and previous research in sheep and cattle (Ghirardi et al., 2006a,b). The lowest retention rates (< 3.8%) were obtained for the bolus types #1, 5 and 8, which varied in weight (5.3 to 46.2 g) and volume (5.2 to 22.2 mL), but with SG < 2.2. On the contrary, the greatest retention rate values (100%) were observed with bolus types #6, 10, 18 and 19, which corresponded to a wide range of weights (35.5 to 110.8 g) and volumes (7.2 to 26.0 mL), although with SG > 4.1. Thus, SG appeared to be of major relevance for bolus performance according to retention results. Only the 4 bolus types where no losses occurred were above the ICAR retention requirement for animal ID (> 98% at 1 yr after administration; ICAR, 2007).

At the end of the study, 2,299 boluses (92.6%) had been monitored for at least 1 yr, which corresponded to 1,398 (60.8%) Murciano-Granadina, 394 (17.1%) Alpine, and 507

(22.1%) Blanca de Rasquera goats; these boluses made up the dataset utilized to assess the regression model. Different parameters (weight, volume, SG, length, and o.d.) were evaluated to properly estimate bolus retention rate according to their physical features. Results obtained proved that a logistic model taking the weight and volume of boluses as covariates offered the greatest adjustment (R^2 = 0.98; $P < 0.001$), as similarly indicated previously by using analogous models for sheep and beef cattle (Ghirardi et al., 2006ab). It bears mentioning that when considering weight and volume, SG was being implicitly considered as well. The equation of the model estimating the percentage of retention rate in goats according to bolus weight and volume was as follows:

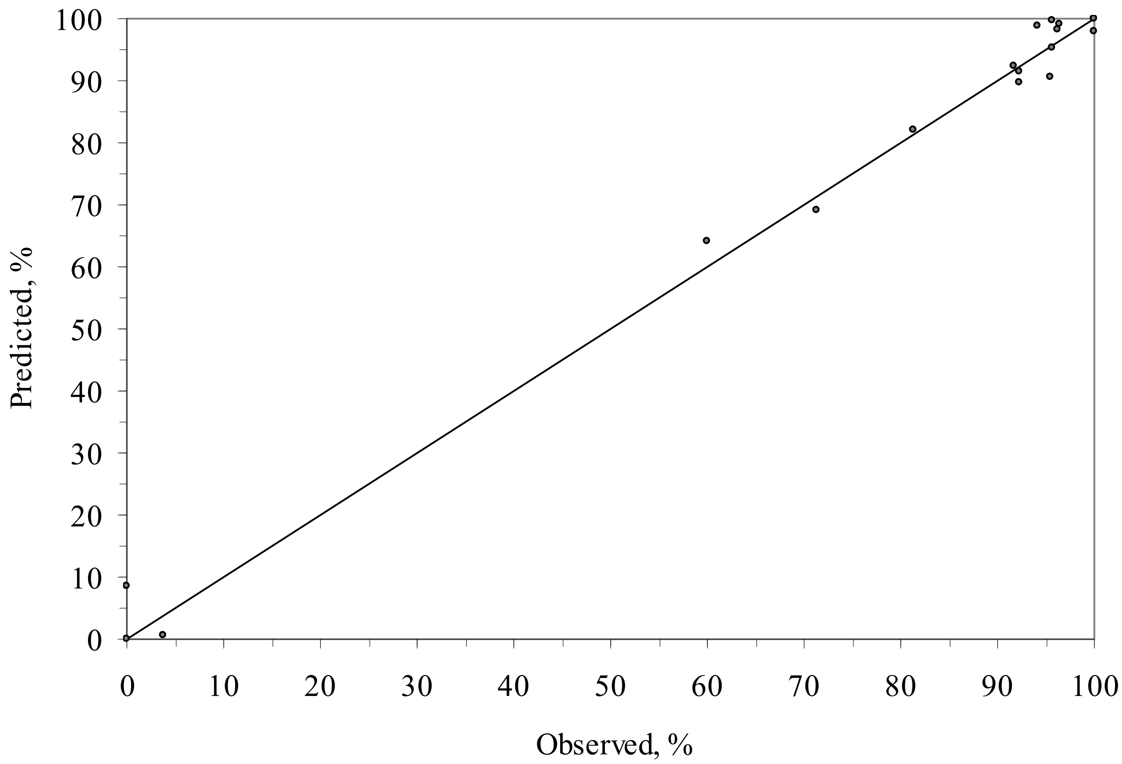
$$\text{Retention rate (\%)} = \frac{100}{1 + 0.734 \cdot e^{0.788 \cdot V - 0.262 \cdot W}} \quad (1)$$

Figure 6.3. Bolus retention rates (%) according to their weight (W, g) and volume (V, mL) in goats under on-farm conditions (●, small size boluses: 2.7 to 7.2 mL; ○, medium size boluses: 11.6 to 15.4 mL; ♦, standard and large size boluses: 18.1 to 26.0 mL). Lines are the estimated retention rates for different bolus volumes according to the logistic regression (equation 1 aforementioned).



Factual retention data and estimated retention curves according to the different bolus volumes are shown in Figure 6.3. As can be observed, for any given bolus volume, retention rate increased when weight and SG increased. In contrast, increasing the bolus weight while maintaining the SG invariable, only offered a moderate improvement of the retention rate. It was also confirmed that suitable retention of small boluses is feasible if appropriately designed; as previously indicated in sheep and cattle, a reduction in bolus size not affecting the retention performance can be accomplished by increasing the SG (Garín et al., 2005; Ghirardi et al., 2006ab).

Figure 6.4. Comparison of observed and estimated values of bolus retention rate in goats (SEM = 2.4)



Error of the estimated retention averaged 2.4 units of percentage (Figure 6.4), being greater than those reported in sheep (1.3) and cattle (1.5) by Ghirardi et al. (2006ab). Greater error in our study may be explained by the larger number of boluses tested and the lower bolus types with 100% retention rate with respect to the aforementioned works. In addition, and unlike other goat breeds, some Spanish dairy breeds have shown a great variability in bolus retention rates (MAPA, 2002, 2007; Carné et al., 2009a). In fact, it has been suggested that breed and management conditions affect bolus retention in goats

(JRC, 2003; Capote et al., 2005; Carné et al., 2009ab).Taking into account this variability, the construction of the model was aimed at obtaining devices with optimum retention rates irrespective of breed and management, rather than estimating the most representative mean retention in the goat species. For this reason, more than 60% of boluses included in the model belonged to Murciano-Granadina Spanish dairy goat, which has been indicated to show a wide range of retention values, generally being poorer than in other breeds evaluated (MAPA, 2002, 2007; Capote et al., 2005; Pinna et al., 2006); concentrate-based and small particle sized total mixed rations commonly used in Murciano-Granadina goats have been suggested to affect bolus retention (Carné et al., 2009a).

In a subsequent step of our study, available literature referred to the medium and long-term (> 8 mo) bolus retention in goats was joined to the model (Caja et al., 1999a; JRC, 2003; Capote et al., 2005; San Miguel et al., 2005; Pinna et al., 2006; MAPA, 2007; Carné et al., 2009a,b). In this case, the regression coefficients obtained were: $b_0 = 0.832$, $b_1 = 0.255$, and $b_2 = -0.715$. Results with our observed data tended to be more conservative than those obtained when including literature data, that is, estimation curves with our data were displaced to the right, thereby indicating that greater weight and specific gravity are required to reach the desired bolus retention.

Hereinafter, to facilitate the presentation of results and their subsequent discussion, reference will be made to the volumes of 5, 15 and 22 mL, which were chosen as representative of commercially available mini-, medium-, and standard-sized boluses, respectively. In this sense, differences between the 2 produced models were greater when dealing with large volumes. Thus, average differences of estimated retentions including or not including the literature data were 1.7, 4.3 and 6.3% for 5, 15 and 22 mL volumes, respectively. Nevertheless, when focusing on critical retention > 98% indicated by the ICAR (2007), these differences were reduced to 0, 0.3 and 0.6% for the same volumes considered. In view of the low variability between the 2 models for retention rates close to 100%, and the more strict requirements of our data to design boluses with optimum retention, it was concluded that the model obtained with our observed data was more suitable for the purpose of this work.

In the present study, taking into consideration the unfavorable scenario of bolus losses previously reported in goats, we decided to evaluate results for a retention rate of 99.95%, thereby being even more stringent with bolus requirements. Hence, the previous equation

(1) was rearranged and 2 new equations were obtained, which allowed the assessment of the estimated weight, volume and SG of boluses for their optimum retention in goats:

$$W = 27.83 + 3.01 \cdot V \qquad (2)$$

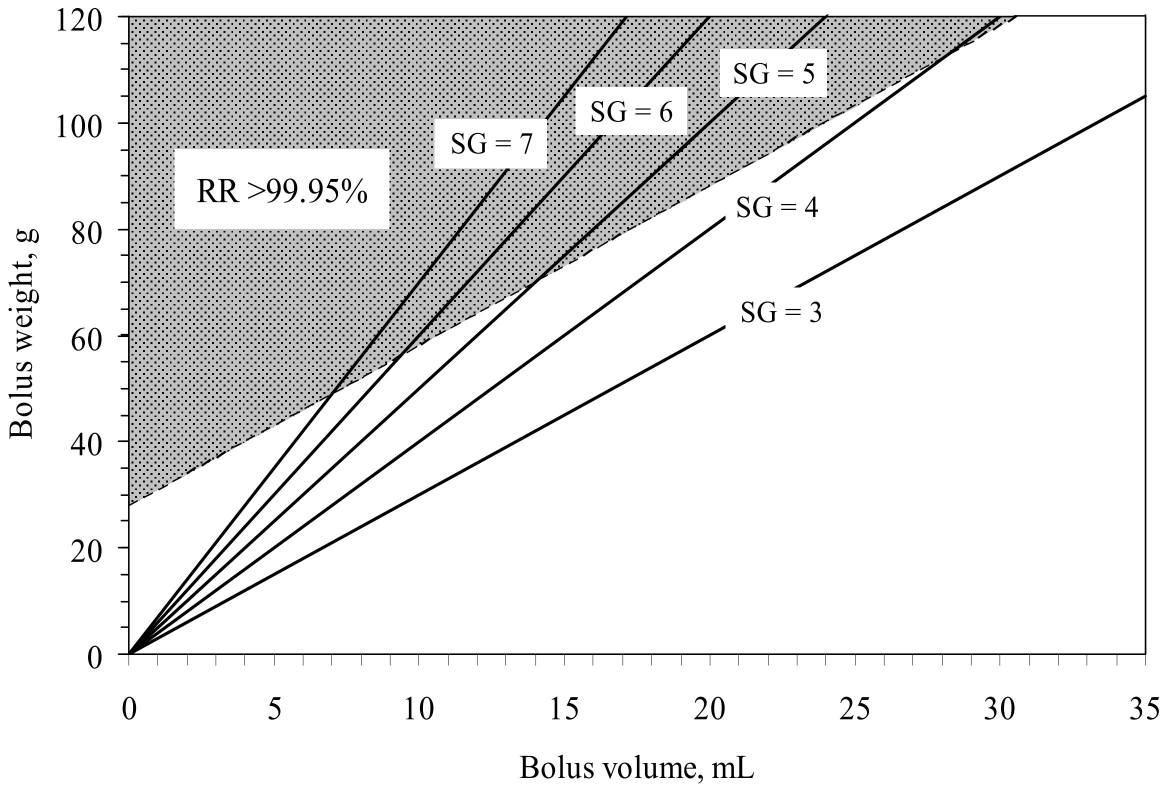
$$SG = 27.83 / V + 3.01 \qquad (3)$$

According to these equations, the minimum weight and SG to obtain the desired retention of small (5 mL), medium (15 mL), and standard size (22 mL) boluses were: 42.9 g (SG = 8.58), 73.0 g (SG = 4.87) and 94.1 g (SG = 4.28), respectively. Before comparing our results with those obtained in the sheep and beef cattle models (Ghirardi et al., 2006ab), it should be pointed out that volume and weight coefficients in the published equation of the sheep model (Ghirardi et al., 2006b) were interchanged.

For an estimated retention of 99.95%, minimum bolus weight and SG in sheep were: 22.9 g (SG 4.57) for 5-mL boluses, 38.0 g (SG 2.53) for 15-mL boluses, and 48.6 g (SG 2.20) for 22-mL boluses. In the case of cattle, estimated weight and SG for the same volumes were 58.1 g (SG 11.6), 74.8 g (SG 4.99), and 86.5 g (SG 3.93), respectively. It is remarkable that values in goats approximately doubled those in sheep, which makes evident the differences between species regarding the retention performance of boluses. On the contrary, differences between goats and cattle were much lesser, although they varied considerably depending on the dimensions of the bolus.

Figure 6.5 summarizes the results obtained in our study, showing the variety of combinations of weight, volume and SG that would allow producing boluses with an optimum retention rate (99.95%). From a view of designing boluses for an optimum retention and also of allowing the administration at early ages, the use of high dense boluses with reduced volume is required (Garín et al., 2005; Fallon, 2001; Ghirardi et al., 2006ab). As radio frequency translucent materials are necessary, dense ceramic materials are being used at present for this purpose, and boluses with SG up to 4.1 have been produced. Yet, estimated SG for mini-boluses (e.g. 5 mL of volume) to be retained in goats is greater than 8.5. Therefore, as long as currently utilized materials do not allow such high SG values to be reached, the use of mini-boluses for goat ID should be discarded. Unsuitability of mini-boluses for goat ID has already been pointed out in earlier reports (Carné et al., 2009ab); this is a major difference between sheep and goats as mini-boluses with SG greater than 3.5, and more than 15 g of weight, have been successfully used (retention > 98%) for permanent sheep ID (Teyssier et al., 2003; Ghirardi et al., 2006b, 2007; MAPA, 2007). Results of the present work indicate the need for a SG between 4.9 and 5.8 to produce medium sized boluses (e.g. 10 to 15 mL of volume) which can be properly retained in goats; available radio translucent materials could be successfully used nowadays to obtain boluses with such required physical features.

Figure 6.5. Bolus weight and volume combinations that allow a retention rate (RR) greater than 99.95% (grey zone) according to bolus specific gravity (SG) in goats on farm conditions.



6.4.3. Ear tag retention

Performance of visual plastic ear tags is shown in Table 6.2. Damages by biting and breakage of the flag pieces were greater ($P < 0.05$) in V2 than in V1 ear tags, and a breed effect was also observed in V2. Most damages registered in this last ear tag type were due to the breakage of the flag piece, thus obtaining button-like ear tags; the breakage of flag pieces in V2 seemed to be caused by a too weak insertion of the flag piece to the ear tag body. As only lost devices were replaced by the veterinary officials during the annual blood sampling campaigns (Carné et al., 2010), yearly incidence of such breakages was not established. These findings may be of relevance for V2 retention as button-button

RFID ear tags have been indicated to offer greater long-term retention rates than flag types (Carné et al., 2009a). Retention rate varied among herds (92.2 to 98.0%), although only a tendency of difference (*P* < 0.1) was detected for the V2. Moreover, retention of V2 was numerically greater than V1 in the 2 goat breeds evaluated, even though only the retention of V1 in Blanca de Rasquera and V2 in Murciano-Granadina goats differed (92.2 vs. 96.8%, respectively; *P* < 0.05). Despite the fact that literature in this regard is limited, losses in our study remained within the wide range of 1.4 to 17.1% reported in different goat breeds (Carné et al., 2009ab). Yet, visual ear tag retention values in our results did not meet the ICAR recommendations (> 98%) for official animal ID (ICAR, 2007).

Table 6.2. Performance of visual plastic ear tags in Murciano-Granadina (dairy) and Blanca de Rasquera (meat) goat breeds at 1 yr of study.[1]

	Murciano-Granadina		Blanca de Rasquera		Overall	
Item	V1	V2	V1	V2	V1	V2
Ear tags, No.	168	502	218	276	386	778
Damaged[2], %	3.0^{a}	13.7^{b}	4.1^{a}	21.7^{cx}	3.6^{a}	16.6^{bcy}
Lost, %	4.8	3.2	7.8	4.7	6.5	3.7
Retention rate, %	95.2^{ab}	96.8^{b}	92.2^{a}	95.3^{ab}	93.5^{a}	96.3^{b}

[a,b]Within a row, values with different superscripts differ (*P* < 0.05).
[x,y]Within a row, values with different superscripts tended to differ (*P* < 0.1).
[1]Abbreviations: V1, double flag type, 5.1 g, 37 × 39 mm flag dimensions (Rumitag, Esplugues de Llobregat, Spain); V2, flag-button type, 4.2 g, 38 × 40 mm flag dimensions with the button piece placed on the inner side of the ear (Azasa-Allflex, Madrid, Spain).
[2]Ear tags with apparent signs of damage caused by biting or breakage of the flag pieces but still readable.

6.5. CONCLUSIONS

Features of boluses affect their retention in the reticulorumen of goats. Moreover, boluses need to be heavier and with greater SG than in sheep and cattle. Mini-boluses similar to those used in sheep are not recommended in goats. On the other hand, medium size boluses (10 to 15 mL) with SG of 4.9 to 5.8 could be successfully produced with radio translucent materials for their efficient retention in the reticulorumen of goats, thereby giving response to the current problem of using proper boluses for goat identification.

Table 6.1. Features and retention rates of electronic rumen boluses for the permanent identification of goats.

Serial number	Bolus type	Bolus features[1]				Goats, n				Retention rate, %
		length × o.d., mm	Weight, g	Volume, mL	SG[10]	Applied	Not recorded[11]	Lost	Retained	
#1	Plastic tube[2]	48.1 × 12.1	5.32 ± 0.16	5.15 ± 0.14	1.03 ± 0.02	25	0	25	0	0
#2	Ceramic[3]	37.4 × 9.3	9.00 ± 0.04	2.65 ± 0.01	3.40 ± 0.01	45	10	14	21	60.0
#3	Ceramic[3]	51.0 × 10.5	13.66 ± 0.03	3.91 ± 0.01	3.49 ± 0.01	92	1	26	65	71.4
#4	Ceramic[3]	56.4 × 11.2	20.14 ± 0.21	5.16 ± 0.01	3.90 ± 0.01	636	51	109	476	81.4
#5	Plastic tube[4]	76.4 × 20.2	35.38 ± 0.21	21.88 ± 0.13	1.62 ± 0.01	30	1	29	0	0
#6	Ceramic + ballast[5]	72.7 × 15.1	35.45 ± 0.08	7.20 ± 0.04	4.92 ± 0.03	33	3	0	30	100
#7	Ceramic[3]	64.1 × 15.5	42.10 ± 0.14	11.63 ± 0.08	3.62 ± 0.01	42	3	3	36	92.3
#8	Plastic tube[4]	76.6 × 20.2	46.21 ± 0.27	22.23 ± 0.11	2.08 ± 0.01	28	1	26	1	3.7
#9	Ceramic[6]	67.7 × 16.9	51.56 ± 0.09	14.37 ± 0.03	3.59 ± 0.01	56	8	4	44	91.7
#10	Ceramic + ballast[5]	79.1 × 19.9	52.92 ± 0.09	9.67 ± 0.06	5.47 ± 0.03	31	2	0	29	100
#11	Plastic tube[4]	83.8 × 15.3	53.75 ± 0.54	15.41 ± 0.13	3.49 ± 0.04	24	2	1	21	95.5
#12	Ceramic[7]	62.3 × 19.8	64.87 ± 0.21	18.11 ± 0.06	3.58 ± 0.01	50	5	2	43	95.6
#13	Ceramic[3]	76.9 × 18.1	72.53 ± 0.20	18.92 ± 0.12	3.86 ± 0.01	258	19	14	225	94.1
#14	Ceramic[8]	68.2 × 21.0	75.04 ± 0.29	22.34 ± 0.07	3.36 ± 0.01	504	45	35	424	92.3
#15	Ceramic[3]	67.2 × 20.1	80.65 ± 0.23	19.85 ± 0.03	4.06 ± 0.01	150	13	6	131	95.6
#16	Ceramic[3]	69.1 × 21.2	82.13 ± 0.48	22.64 ± 0.08	3.63 ± 0.01	393	15	14	364	96.3
#17	Ceramic[3]	69.4 × 21.3	84.01 ± 0.09	22.46 ± 0.01	3.74 ± 0.02	30	2	1	27	96.4
#18	Ceramic + ballast[9]	73.8 × 20.9	97.93 ± 0.13	23.37 ± 0.05	4.19 ± 0.01	30	1	0	29	100
#19	Ceramic + ballast[9]	79.3 × 22.1	110.8 ± 0.16	26.01 ± 0.05	4.26 ± 0.01	25	1	0	24	100
—	Total, n	—	—	—	—	2,482	183	309	1,990	—

Corresponding footnotes are detailed in the following page.

[1]Each bolus contained a glass encapsulated half-duplex transponder (32 × 3.8 mm).

[2]Hand made prototype consisting of a plastic tube filled with silicone and sealed with epoxy resin.

[3]Specially made prototype.

[4]Hand made prototype consisting of a plastic tube containing a type 4 ceramic bolus, filled with silicone (type 5) or concrete (type 8) and sealed with epoxy resin.

[5]Hand made prototype consisting of a type 4 ceramic bolus with a stainless steel ballast (type 6: 16.7 g; type 10: 32.8 g) attached.

[6]Standard commercial bolus (Innoceramics, Teramo, Italy).

[7]Standard commercial bolus (Allflex, Vitré, France).

[8]Standard commercial bolus (Rumitag, Esplugues de Llobregat, Spain).

[9]Hand made prototype consisting of a type 15 bolus with a stainless steel ballast (30.5 g) attached, and a thermo-retractile plastic cover.

[10]SG = specific gravity.

[11]Animals which died or left the study before 1 yr after bolusing.

CHAPTER 7

Electronic identification of goats: State of the art

CHAPTER 7

Electronic identification of goats by using radio-frequency devices: State of the art

7.1. ABSTRACT

The use of passive radio frequency (RFID) technology for goat identification has become a key issue in recent years, especially in the European Union, where its compulsory use in sheep and goats is regulated. This paper reviews research carried out so far on the use of ear tags, injectable transponders, rumen boluses, and leg tags for goat identification, basing on their retention, readability, and retrieval easiness. The healing process of ear tags is conditioned by ear tag features and the biocompatibility of making materials. Moreover, ear tag retention is highly variable, in most cases not reaching the long-term (12 mo) readability of at least 98% required by the International Committee of Animal Recording. Button ear tags have been suggested to offer suitable readability, and are regarded for official use in different official programs. The subcutaneous injection of encapsulated transponders in different body locations has also been evaluated, mainly focusing on readability and migration results. Injection in the armpit offers the greatest readability in goats, although it is subjected to the greatest migration rates. Injection in the extremities has also been considered, although smaller transponders are used in this case, thereby compromising their reading distance. The main drawback of injectable transponders is their deficient retrieval at slaughter. The retention of rumen boluses has shown a remarkable variability in goats, and the influence of breed and feeding management on losses has been suggested. Most studies have indicated lower retention rates in goats than in other ruminant species. Even though, a regression model of bolus retention according to bolus weight and volume has been proposed, similarly to previous models established for sheep and cattle. According to this model, especially heavier and denser boluses are required in the case of goats to ensure that the device is permanently retained. Considering radio translucent materials currently available, suitable boluses for goat identification can be efficiently produced. Different RFID leg tags have also been proposed, especially for dairy goats in the milking parlor. The proper circumference of the leg band is recognized as a key aspect to be studied in this case as it seriously conditions the identification at early ages, while preventing the unlawful removal during the goat lifespan. Electronic readability of leg tags is greatly influenced by the type of transponder.

7.2. Introduction

The different episodes of animal disease outbreaks (Transmissible spongiform encephalopathies, scrapie, foot-and-mouth disease, swine flu, etc), food-borne diseases, as well as the detection of certain forbidden or improperly used substances in the food chain, have increased the public concern about the safety of products intended for human and livestock consumption (McKean, 2001; Pettitt, 2001). Moreover, these episodes made it evident that livestock identification (ID) and traceability, as well as the origin of their derived products, were seriously compromised by animal ID systems in place at that moment.

Regarding goats, these concerns have become an issue of particular interest since the publication of recent European regulations on the identification and registration of sheep and goats (EC 21/2004; EC 933/2008). These regulations lay down the compulsory use of a double ID system for replacement sheep and goats, consisting of 1 visual and 1 radio frequency identification (RFID) device. Ear tags, rumen boluses, and marks on the pastern (injects or leg bands) are the devices accepted for official use, each Member State being entitled to choose the ID device to be officially used. In the case of goats, the possibility of using such variety of ID methods is caused, to a great extent, by the greatly variable results obtained in the different experiments carried out up to present (Schuiling et al., 2004; Pinna et al., 2006; Carné et al., 2009a); this variability is even more remarkable in the case of boluses, as devices successfully used for sheep ID seem not to be adequate for the efficient ID of some goat breeds (JRC, 2003; Capote et al., 2005; MAPA, 2007).

In the United States, visual ear tags have been broadly used within the frame of goat health surveillance programs (CFR, 2008), although RFID ear tags are recommended for the current deployment of the National Animal Identification System (NAIS); even so, the use of alternative devices is also under study for the cases where poor performance of ear tags occurs (USDA, 2006c).

At this point, a general discussion on the performance of RFID devices used in goats needs to be addressed. To our knowledge, the only review on goat RFID was published more than 13 years ago (Caja et al., 1997), which justifies a re-evaluation of this topic. Thus, and taking into consideration the experience and improvements achieved in recent years, this work was aimed at presenting the state-of-the-art of radio frequency technology for the permanent and reliable identification of goats. As ear tags are still the ID method of reference, a brief allusion is also made to available research projects on the feasibility of visual ear tags in goats.

7.3. Visual ear tags

Available published data on the performance of visual ear tags in goats is summarized in Table 7.1. Most of available literature corresponds to ear tags used within official disease control and eradication programs of dairy goats managed in intensive conditions (Caja et al., 1999a,b; Carné et al., 2009a, 2010a,b), with retention and readability rates highly variable (80 to 97%). On the other hand, Pinna et al. (2008) and Carné et al. (2009b, 2010b) evaluated official and non-official ear tags in different goat breeds under semi-extensive and extensive conditions, likewise obtaining a wide variation in their retention rate (80.2 to 98.6%).

The performances of ear tags are mainly dependant on their losses, which are basically due to tag breakage or ear splitting; however, a wide range (2.5 to 21.7%) of ear tag damage has also been described (biting,…), which can seriously conditions the readability of the printed code in the remaining ear tags, as well as causing breakages that may lead to further losses (Carné et al., 2009a). Button devices have been suggested as being less subjected to losses in intensively managed dairy goats (Carné et al., 2009a), although the extent of influence of ear tag features on their performance remains to be thoroughly studied.

In conclusion, visual plastic ear tags showed a great variability in their readability rates, remaining in most cases under the 98% value recommended by the International Committee for Animal Recording (ICAR, 2007). If the need of tamper-proof or tamper-evident devices is also considered, the use of visual ear tags can not be recommended in practice as the unique system for the deployment of official ID programs. Therefore, the evaluation of alternative ID methods is required.

Table 7.1. Performance of visual ear tags in goats.

Reference	Breed	Production system	Devices applied, n	Type	Age, d	Trial duration, d	Lost, %	Damaged, %	Readability, %
Caja et al. (1999a)	Murciano-Granadina	Semi-intensive	16	Flag-button	120	360-1,080	6.3[1]	—	93.7[1]
			67	"	Does		6.0[1]	—	94.0[1]
Caja et al. (1999b)	Murciano-Granadina, Malagueña, & French Saanen	Intensive	2,160	Button-button	Does	1,080	20.0	—	80.0
Pinna et al. (2008)	Sarda	Extensive	210	—	90-150	Adults[2]	14.8	—[3]	85.2
Carné et al. (2009a)	Murciano-Granadina	Semi-intensive	41	Tip-tag	1	360	14.6	2.5	82.9
			50	"	1	360	0	6.0	94.0
Carné et al. (2009b)	Alpine	Semi-intensive	74	Flag-button	Does & yearlings	360	3.1	—	96.9
	Angora	Extensive	75	"			17.1	—	82.9
	Boer	Extensive	73	"			1.4	—	98.6
	Spanish	Extensive	73	"			11.3	—	88.7
	Overall		295	"			8.3	—	91.7
Carné et al. (2010a)	Murciano-Granadina	Intensive	220	Flag-button	Does	360	3.0	24.9	97.0
Carné et al. (2010b)	Blanca de Rasquera	Extensive	218	Flag-flag	Does	540	7.8	4.1	92.2
			276	"			4.7	21.7	95.3
	Murciano-Granadina	Intensive	168	Flag-button	Does		4.8	3.0	95.2
			502	"			3.2	13.7	96.8

[1]Damaged ear tags were included.
[2]Monitored at the milking parlor when becoming lactating does.
[3]Official ear tags from the ASL (Local Health Centre).

7.4. Electronic ear tags

Similarly to what may occur with visual ear tags (Johnston and Edwards, 1996; Edwards et al., 2001), evaluating the healing process of the tagging wound of RFID ear tags is of major relevance for their use in practice. Using design-improved devices in adult and goat kids, Schuiling et al. (2004) indicated that nearly 70% of tag wounds were healed after 2 mo in both kids and does. At 4 mo, close to 5% of ears in goat kids remained unhealed, as well as 8.5% in does. At the end of the 8-mo study, ears not fully recovered had been reduced to 1.7 and 2.7% for kids and does, respectively. No differences between tag types were reported, although a herd effect was shown. The same ear tags were also tested in sheep and the percentage of unhealed ears was 10 to 30% lower throughout the study, with a final value at 8 mo close to 1% (Schuiling et al., 2004).

In dairy Murciano-Granadina goat kids of 3 mo of age, Carné et al. (2009a) pointed out only 3.3% of infections by using flag-button and double button electronic ear tags. Moreover, 90.2% of wounds were totally healed within 2 mo after tagging. Caja et al. (1998a) indicated a high incidence of infections at the tagging point in sheep identified with similar ear tags.

Schuiling et al. (2004) also evaluated the incidence of severe damage caused by the tag pressing the ear, and at 1 mo after tagging they registered 4.0 and 23.6% of such cases in goat kids and adult goats, respectively. At 4 mo, pressure wounds had remitted in young goats whereas 6.3% of cases were still apparent in adult goats. Moreover, appearance of new pressure wounds was observed in ears previously registered as fully healed (Schuiling et al., 2004). Distance between coupled male and female pieces to allow the ear not to be pressed is, therefore, of key relevance to prevent such cases, as well as to allow air circulation and so favor wound healing (Bauer et al., 2009). This is mostly dependant on the length of the tag's tip to be inserted in the ear, and should be adequately fitted for the large variability of ear thickness according to goat age and breed. In this regard, Spanish regulations establish a minimum distance of 9.4 mm between the 2 pieces of fastened ear tags (Real Decreto 1486/2009).

Problems with ear tag biocompatibility have also been suggested. Thus, 6.5% of tissue reaction, irritation, and swelling, but without bleeding or pus, were registered in dairy Murciano-Granadina goat kids tagged with flag and button devices (Carné et al., 2009a); although observed signs remained apparent up to 3 months after tagging, wounds eventually healed and no relationship with subsequent retention performance could be established.

With respect to the readability of RFID ear tags in goats, current information is summarized in table 7.2. Schuiling et al. (2004) evaluated different ear tags (button and flag types) in both kids and adult goats. They indicated an increase of losses in adult goats (5.1%) compared to goat kids (1.5%), and an increase of electronic failures (1.6 vs. 0.5%), thereby obtaining a final readability of 93.3 and 98.0%, respectively. In addition to the influence of age, the authors registered a remarkable variability in losses (0 to 7.1%) between herds under study, with an average retention of 96.6%. Moreover, they indicated 0 to 2.9% electronic failures according to herd, thereby obtaining an overall mean readability of 95.5%.

Carné et al. (2009a) evaluated the readability of button-button and flag-button ear tags for a period of nearly 3 yr in Murciano-Granadina goat kids identified at 3 mo of age. No electronic failures were detected during the study, and at 1 yr of age no losses were registered, obtaining a 100% readability. At 2 yr, factual readability of flag-button ear tag was 93.9%. In this case, estimated readability by using a nonparametric survival analysis was also obtained to allow including data from goats leaving the study before its conclusion; estimated readability of flag-button tags was lower (79.8%) than factual value. All tag losses were caused by breakage or unfastening of the ear tag as no split ears were registered (Carné et al., 2009a). Moreover, 9.1% of ear tags showed biting damage, which might prevent proper visual readability. On the contrary, readability of button-button devices was 100%. Accordingly, button ear tags were recommended for long-term ID of goats from early ages (Carné et al., 2009a). A different type of button ear tag was also tested in this goat breed, and a readability of 95.7% was obtained at 1 yr (Carné et al., 2010a). Furthermore, 2.1% transponders occasionally failed, which might be caused by humidity filtration into the ear tag. No results on the performance of RFID ear tags at the slaughterhouse are available.

Although improvements on ear tag features have been undertaken to optimize their retention and readability, the need for considering alternative devices has been suggested in some goat breeds where size of the ear may prevent the proper insertion of ear tags, as well as in conditions where low retention is achieved (USDA, 2006b).

Table 7.2. Performance of radio-frequency ear tags for goat identification.

Reference	Breed	Production system	Devices applied, n	Type	Age, d	Trial duration, d	Losses, %	Failures, %	Readability, %
Schuiling et al. (2004)	—	Various	2,383	Various[1]	Does & kids	240	1.5	0.5	98.0
			2,620				5.1	1.6	93.3
Carné et al. (2009a)	Murciano-Granadina	Semi-intensive	46	Button-button	90	1,050	0	0	100
			46	Flag-button			20.2[2]	0	79.8[2]
Carné et al. (2010a)	Murciano-Granadina	Semi-intensive	47	Button-button	Does	240	4.3	2.1[3]	95.7

[1]Button (n = 2,495) and Flag (n = 2,508) types.
[2]Estimated by Kaplan-Meyer nonparametric survival analysis.
[3]Occasional failures were not included in the final readability.

In conclusion, information available on the use of RFID ear tag in goats makes evident the need for further research to validate their use for permanent official ID. From data currently available, it can be concluded that properly designed button devices might offer adequate readability performance if suitably designed. Moreover, low incidence of damages on button ear tags also ensures a suitable visual readability, although in this case the size of printed codes would invariably require animal restraining.

7.5. Injectable transponders

When considering the use of injectable transponders, several aspects must be taken into account. Firstly, easiness of application and the compliance with acceptable welfare practices. Secondly, the long-term readability of devices, which depends on their losses, breakages and electronic failures during the animal lifetime. Besides, attention must be paid to possible migration caused by tissue reaction to transponders, as well as appropriate retrieval at slaughter to ensure that no carcass contamination occurs. All these factors determine both the size of transponders to be used and the proper body location where injected.

A wide range of transponders injected in different body locations have been tested so far in cattle (Klindtworth et al., 1999; Lambooij et al., 1999; Conill et al., 2000), sheep (Hunt, 1994; Conill et al., 2002; Hogewerf et al., 2009) and swine (Lambooij et al., 1995; Stärk et al., 1998; Caja et al., 2005a). Conversely, available literature referred to their use in goats is scarce. Existing information on the features and readability of injectable transponders utilized for goat RFID is summarized in Table 7.3.

First results in goats were obtained by Fonseca et al. (1994a) in the frame of the European FEOGA Project (1993-94). They evaluated the performance of 32.5 × 3.8 mm transponders subcutaneously injected in 4 different body sites (under tail, ear base, groin, and armpit) in adult goats. After 1 yr, the lower readability rates were observed under the tail (89.1%) and in the ear base (92.7%); moreover, an incidence of 5.5 and 3.6% breakages was registered in these respective body locations. On the contrary, readabilities greater than 98% were obtained in the groin and armpit. The poor readability rates observed in the tail and ear base of goats are principally due to the limited room for allocating the transponder, which entails a shorter injection channel and an increase of early losses due to the transponder falling out through the injection site before it is totally healed.

Most losses have been observed within the first 2 wk in different species and injection sites (Lambooij et al., 1999; Babot et al., 2006; Carné et al., 2009a). In order to diminish these early losses, injections are performed whenever possible in an up down direction to avoid the effect of gravity on the displacement of transponders (Conill et al., 2002). Stärk et al. (1998) suggested the tension on the skin in too superficially injected transponders in swine as a cause of skin necrosis that could lead to additional losses of transponders. This fact can also occur in the event of necrosis due to infection and inflammation.

Likewise, transponder migration due to tissue reaction to the transponder may contribute to losses or the finding of the transponder out of the body region where it was injected. These findings may affect both the readability performance and the suitable retrieval of devices at slaughter (Caja et al., 1998; Klindthworth et al., 1999). In a desirably healing process, a fibrous conjunctive tissue capsule is produced outside the transponder, thereby getting the device fixed on the tissue close to the site where initially injected (Lambooij et al., 1992). These events have also been described in goats (Queiroga et al., 1994; Roquete et al., 1994), where there was less tissue reaction with transponders injected in the ear base and armpit.

With regard to migration distance, Fonseca et al. (1994a) found that the greatest mean migration values of 32-mm transponders at 1 yr after injection occurred in the groin (56 ± 1 mm), whereas lowest values were registered in the tail (27 ± 1 mm). Equally, Ribó et al. (1994a) observed the lowest migration values in the tail (26 mm) of Murciano-Granadina goats, whilst the greatest average migration was observed in the armpit (63 mm).

In view of readability and migration results, armpit was considered as the most appropriate site for injection of 32-mm transponders in adult goats (Fonseca et al., 1994a; Ribó et al., 1994a). In adult sheep, mean migrations in the same body regions turned out to be lower (< 43 mm) than in goats, although analogous lower readability rates in the tail and ear base were indicated (Caja et al., 1998b).

Table 7.3. Performance of radio-frequency transponders injected in different body locations in goats.

Reference	Breed	Devices applied, n	Injection site	L × o.d., mm	Age, d	Trial duration, d	Losses, %	Breakages, %	Readability, %
Fonseca et al. (1994a)	—	55	Ear base	32.5 × 3.8	Does	360	1.8	5.5	92.7
		63	Armpit	"			0	0	100
		55	Groin	"			1.8	0	98.2
		55	Tail	"			7.3	3.6	89.1
Caja et al. (1998a)	Murciano-Granadina	2,160	Armpit	32.5 × 3.8	Does	350	1.9	0.1	98.0
Pinna et al. (2005a)	Sarda	47	Intraperitoneal	32.5 × 3.8	1-4	28	0	—	100
MAPA (2007)	Murciano-Granadina	378	Metacarpus	12.0 × 2.1	Does	360	1.7[1]	—	98.3
		890	Metacarpus & metatarsus[2]	15.0 × 3.0		360	1.3[1, 2]	—	98.7[2]
		141	Perianal area	12.0 × 2.1		90	48.2[1]	—	51.9
		91	Perianal area	"		360	3.6[1]	—	96.4
Carné et al. (2009a)	Murciano-Granadina	100	Metacarpus	12.0 × 2.1	90	630	4.0	0	96.0
		75	Metacarpus	15.0 × 2.1	90	990	7.1	0	92.9

[1]No checking of transponder breakage was carried out.
[2]Results not expressed according to the 2 injections sites tested.

Based on these previous experiments, Caja et al. (1999b) evaluated the large scale readability of transponders injected in the armpit of dairy goats, with the objective of implementing a semi-automated milk recording system by using handheld transceivers in the milking parlor. During the 3 yr of study they indicated a readability of 98.0%, confirming the suitability of this injection site for the long-term identification of adult goats.

In recent years, the use of injects in the pastern has become of key importance as it is the only body region where injects are currently accepted for official RFID of sheep and goats in the European Union (EC 21/2004; EC 933/2008). This injection site is anticipated to prevent food contamination as transponders can be safely removed from the carcass by cutting out the distal part of legs; human consumption of animals injected is not allowed though. Moreover, migration in this area is deemed of no relevance for reading and retrieval efficiency. Nevertheless, no studies have been published in this regard.

In response to European regulations, different short and medium scale projects have been carried out to evaluate the performance of injects located in the rear metacarpal (fore-leg) and metatarsal (hind-leg) areas of adult goats (MAPA, 2007). Nevertheless, the use of large transponders was discarded in this region despite small transponders (with small antennas) offering lower reading distances. Two sizes of transponders were eventually evaluated (12 × 2.1 and 15 × 3.0 mm). Readabilities obtained were greater than 98%, although no specific results for the case of metatarsus were made available (MAPA, 2007). Likewise, no discrimination of losses, breakages or electronic failures was considered.

As goats within the European Union must be identified before 6 mo of age or when leaving the premises of origin, Carné et al. (2009a) evaluated the use of injects in the metacarpus applied to replacement goat kids of 3 mo of age. In this case, transponders of 3 mm o.d. were discarded, and only devices with 2.1 mm o.d. and varying in their length (12 and 15 mm) were tested. At the end of the first yr of age, readabilities were 96 and 92% for the 12- and 15-mm transponders, respectively. Moreover, most losses (90.9%) occurred during the first 2 wk after injection. Likewise, readabilities at 2 yr of age were 90.9 and 96.0%. On the other hand, and unexpectedly, no infection or inflammation was observed after injection. In addition, low incidences of bleeding (5.5%) and limping (<1%) were registered, and remitted within the following hours.

Metacarpal injection of 12-mm transponders had previously been evaluated in ewes and lambs of different ages (Abecia et al., 2004), reporting similar incidences of bleeding, infection, and limping than in goat kids. In this study, an overall readability of 2% was obtained at approximately 2 mo after injection, all losses being observed within the first wk after injection. However, approximately 8% of losses were observed in lambs identified at 1mo of age, whereas losses <2% were obtained in younger lambs, and in ewes (Abecia et al., 2004).

Although transponders placed in the distal areas of the legs may be expected to be greatly subjected to breakages, no such findings were registered for transponders injected in metacarpus and metatarsus (MAPA, 2007; Carné et al., 2009a). Similar results have been reported in lambs and ewes (Abecia et al., 2004). Final location of transponders close to the sesamoid bones is suggested as offering protection from damages (MAPA, 2007; Carné et al., 2009a); moreover, the use of small size transponders would additionally reduce the risk of breakages. According to readability values, injects in the legs (metacarpus and metatarsus) can be a valid alternative method for goat RFID (MAPA, 2007). Conversely, these injection sites are not recommended in goat kids due to losses observed and lower reading distance (Carné et al., 2009a). No data on the slaughter recovery of subcutaneous injects can be found in goats. Irrespective of the readability at slaughter, the main drawback observed in sheep and cattle was the time needed for the efficient manual recovery of transponders from the carcasses, which exceeded the slaughter line speed (Lambooij et al., 1999; Conill et al., 2000, 2002) and hindered the implementation of this methodology for the animal ID and traceability in practice.

The intraperitoneal injection has been recently proposed as an alternative method to subcutaneous injections in livestock, having first been evaluated in piglets (Caja et al., 2002). This method seems to offer relevant advantages as it allows the use of large size transponders at very early ages and minimizes the events of losses and breakages (Caja et al., 2005a, Babot et al., 2006). In the case of goats, Pinna et al. (2005a) tested the intraperitoneal injection in kids of 1-5 d of age and 1.5 to 3.4 kg BW. The authors obtained a readability of 100% at 28 d after injection, when kids were sent to slaughter (7 to 8 kg BW). Nonetheless, although all transponders were properly removed from the carcass, only 27.3% of them were found attached to the intestines; the rest of transponders were found loose in the abdomen cavity. Similar results were also reported in lambs (Pinna et al., 2005b). Although carcass contamination is prevented, the recovery of transponders not adhered to the omentus constitutes the main shortcoming to be solved in order to avoid risks of meat contamination, as many of these transponders are lost or fall onto the ground of the slaughterhouse during evisceration (Gosálvez et al., 2007). On the other hand, an automated recovery system is guaranteed, given that manual recovery of transponders adhered to the intestines omentus is a very time consuming process.

No data is available on the long-term performance of intraperitoneal injects in ruminants. In fattening pigs slaughtered at 6 to 7 mo of age and 100 kg of BW, readabilities greater than 98% have been registered (Caja et al., 2005a; Babot et al., 2006). On the contrary, readabilities of 69 to 92% have been reported in extensively managed Iberian pigs slaughtered at 15 mo of age and 150 kg BW (Gosálvez et al., 2007). Part of the unreadable transponders might correspond to losses due to passage through the urethra and rectum in the event of performing the injection in the bladder or the intestines, as well as readability failures in fattened Iberian pigs (Caja et al., 2005a; Gosálvez et al., 2007).

7.6. Rumen boluses

The use of RFID boluses allocated in the reticulorumen of ruminants was first patented by Hanton and Leach (1974), who described an active transponder that obtained the power source from an internally attached battery. Whereas the idea of using boluses as a means of ruminant identification was not further developed for 15 yr, the utilization of rumen boluses for the slow release of medicaments or nutrients was widely explored in cattle (Owens et al., 1980; Riner et al., 1982; Fallon, 2001). The interest for RFID boluses was subsequently resumed in the early 90s, by means of passive transponders (Ribó et al., 1994c). This technology allows the use of devices whose source of energy is obtained from an externally generated electromagnetic field (Artmann, 1999). Consequently, no internal energy source restricts the lifespan of transponders.

Existing information on the features and readability of rumen boluses intended for goat RFID are summarized in Tables 7.4 to 7.6. Data referring to trials of short duration have been included in these tables, although the obtained retention rates in these cases will not be considered for discussion. The first attempt to produce boluses encasing a passive transponder was carried out within the FEOGA Project (Caja et al., 1994; Ribó et al. (1994c) supported by The European Commission. The authors used solid plastic tubes that were drilled to make room for 32-mm transponders. Boluses of 32 g of weight and 60 × 20 mm in dimensions were obtained (Table 7.4), and applied to 14 adult goats and 168 adult sheep. Retention of boluses in goats at 24 h after administration was 50%, and only 7% remained in the reticulorumen at 3 mo. Occurrence of bolus losses in sheep appeared to be notably lower as, at 3 mo, 50% of boluses could still be properly read. According to results, authors pointed out the influence of devices' physical features on their retention rate in the reticulorumen. Moreover, retention efficiency seemed to be also conditioned by ruminant species.

Bolus losses have been shown to mainly occur due to regurgitation (Fallon, 2001; Garín et al., 2005). In these events, ruminal motility causes the bolus to reach the cardias, and it is subsequently carried into the oral cavity by antiperistaltic motility through the esophagus. Consequently, bolus weight and specific gravity are regarded as the main factors affecting their retention, as these features condition that boluses stay in the bottom of the reticulum or the rumen (Caja et al., 1999a; Fallon and Rogers, 2002). Actually, weight and specific gravity had already been shown to dramatically influence the retention of slow-release boluses of trace elements, growth promoters, antihelmintics and antibiotics in cattle (Riner et al., 1982; Fallon, 2001).

A heavier RFID bolus (61 g, 75 × 20 mm) also made up of plastic tubes was subsequently tested (Ribó et al., 1994c), and no losses at the end of the first mo after administration were observed (Table 7.4); it was concluded that weight increase was responsible for the improvement of bolus performance.

At this point it should be indicated that volume and dimensions (length × o.d.) of boluses are not deemed to be relevant for their retention. Nevertheless, attention must be given to these features as they dramatically affect the weight and age of animals at which boluses can be safely administered (Caja et al., 1999a; Garín et al., 2005; Ghirardi et al., 2007).

The importance of physical features on the retention of RFID boluses was confirmed in later studies, and new prototypes with heavier materials were tested from the middle 1990s for the identification of cattle (Fallon and Rogers, 1996; Hasker and Bassingthwaighe, 1996; Caja et al., 1998a; Ghirardi et al., 2006a), sheep (Caja et al., 1996; Ghirardi et al., 2006b) and goats (Caja et al., 1998a). Some prototypes consisted of a transponder encased in a plastic tube with a stainless steel weight attached (Fallon and Rogers, 1996; Fallon et al., 2002).

Table 7.4. Performance of different types of radio-frequency rumen boluses in goats (I).

Reference	Breed	Production system	Devices applied, n	Age, d	Trial duration, d	L × o.d., mm	Weight, g	Volume, mL	SG[1]	Readability, %
Ribó et al. (1994c)	Murciano-Granadina	Semi-intensive	15	Does	90	60 × 20	32.0	19[2]	1.7[3]	7.0
			14	“	30	75 × 20	61.0	24[2]	2.5[3]	100
Caja et al. (1999a)	Murciano-Granadina	Semi-intensive	67	Does	1,080	66 × 20	67.0	20[2]	3.3	98.5
			16	120						100
Gecele et al. (2004)	Saanen & Anglo-Nubian	Semi-intensive	48	Does & yearlings	30	68 × 21	75.0	22.4	3.4	100
			48			68 × 21	80.0	22.4	3.6	100
Martín et al. (2004)	Palmera, Majorera, & Tinerfeña	Semi-intensive	27	65	100	67 × 51	51.0	14.4	3.5	100
Castro et al. (2005)	Majorera	Semi-intensive	15	16	33	9 × 35	9.0	2.6	3.4	100
			15	34	63	12 × 46	15.0		2.9[2]	100
Capote et al. (2005)	Palmera	Extensive	310	Does	360	68 × 21	75.0	22.4	3.4	89.7
	“	“	275	“		68 × 21	80.0	22.4	3.6	98.2
	“	“	50	“		77 × 18	73.0	18.9	3.9	98.0
	Majorera	Semi-extensive	134	“		68 × 21	75.0	22.4	3.4	100
	Tinerfeña	Semi-extensive	54	“		68 × 21	75.0	22.4	3.4	100
	Florida	Semi-extensive	202	“		68 × 21	80.0	22.4	3.6	100
	Murciano-Granadina	Semi-intensive	440	“		68 × 21	80.0	22.4	3.6	99.8
	Blanca de Rasquera	Extensive	198	“		68 × 21	80.0	22.4	3.6	95.4
	“	“	94	“		68 × 21	75.0	22.4	3.4	95.7
	“	“	109	Yearlings		77 × 18	73.0	18.9	3.8	97.2

[1]SG = specific gravity; [2]Estimated according to dimensions; [3]Estimated according to weight and volume.

Nevertheless, the mainstream of manufacturers chose to increase the bolus weight by using atoxic dense ceramic materials (Caja et al., 1999; ICAR, 2010), which are translucent to the radio frequency electromagnetic fields.

With regard to the use of ceramic boluses for goat identification, Caja et al. (1998a; 1999a) indicated 98.5% readability in a 3-yr study where Murciano-Granadina dairy goats were administered 65-g standard-sized boluses with a SG of 3.4 (Table 7.4); a total of 882 sheep and lambs were also evaluated, and offered 100% readability. These results were in agreement with those indicated by Ribó et al. (1994c), where retention of boluses in goats was lower than in sheep.

In the view of the technological development and the gained experience, an evaluation of these devices at a larger scale was warranted. With this aim, 30,627 goats were identified with boluses in Spain, Italy and Portugal in the frame of the European IDEA Project (JRC, 2003). Ceramic boluses with similar features to those previously tested by Caja et al. (1998a) and patented by the European Community (European Community et al., 1998) were used.

Table 7.5. Results of the European large-scale IDEA Project: Readability of rumen boluses for the electronic identification of goats.[1]

Country	Breed	Devices applied, n	Readability, %
Spain	Guadarrama	7,365	93.5
	Murciano-Granadina	6,330	93.9
	Saanen	1,385	99.6
	Malagueña	451	91.1
	Crossbreeds	1,094	95.3
	Overall	16,625	94.2
Portugal and Italy	Serpentina, Alpine, ...	14,002	99.8

Source: MAPA (2002), JRC (2003), San Miguel et al. (2005)

[1]Bolus features: weight, 65 g; length × o.d., 66 × 20 mm; volume, 22 mL; specific gravity, 3.4; patent by the European Commission et al. (1998).

Bolus readabilities obtained are detailed in Table 7.5. Loss rate of boluses throughout the project was >3%, on average (JRC, 2003). However, losses varied dramatically when considering or not the results obtained in some Spanish breeds (JRC, 2003). Thus, losses in several Spanish breeds averaged 5.8% (MAPA, 2002; San Miguel et al., 2005). These results are of key importance taking into account that more than 45% of goats included in the IDEA project were from Spain.

When results were evaluated without considering data from Spain, bolus retention in goats was 99.8%, which is similar to the retention reported in sheep within this same project (JRC, 2003). It must be underlined that, differently to goats, bolus retention in sheep was similar between the different participant countries. Given the great variability of bolus performance in goats, it was concluded that this issue remained a topic for further research (MAPA, 2002; JRC, 2003; San Miguel et al., 2005).

Different studies have been carried out after the IDEA Project regarding the evaluation of different bolus types to suitably identify any goat breed, and under a variety of production systems. Capote et al. (2005) evaluated the performance of rumen boluses in 1,866 goats from several Spanish breeds for a period of 1 to 3 yr (Table 7.4). Two standard-sized boluses (22 mL) but differing in their weight (75 vs. 80 g) and SG (3.4 vs. 3.6) were used. Moreover, a new prototype of lighter (73 g) but denser (SG 3.9) bolus, with a more reduced o.d. (18.1 mm) for administration at lower body weight, was also evaluated. The authors confirmed that the heavier bolus improved average retention. The greatest losses were observed in 2 breeds (Palmera and Blanca de Rasquera) characterized by their rusticity and management in extensive conditions. Ethological particularities (frequent fights and jumping) of some extensively managed breeds were suggested to cause bolus displacement from the bottom of the reticulorumen and, thereby, to ease the occasional regurgitation (Capote et al., 2005). In addition, differences between herds were already pointed out.

It bears mentioning that a retention of 99.8% in Murciano-Granadina goats (var. Granadina) administered with the 80-g bolus prototype was reported (Capote et al., 2005). Although this heavier bolus seemed to improve previous results in this breed (MAPA, 2002; San Miguel et al., 2005), it was subsequently tested in other Murciano-Granadina herds and average retention rates of 92.6% were obtained (MAPA, 2007). Moreover, the 75-g bolus was also tested in this same breed and management conditions, observing retention values <97% (Carné et al., 2009a, 2010a).

Table 7.6. Performance of different types of radio-frequency rumen boluses in goats (II).

Reference	Breed	Production system	Devices applied, n	Age, d	Trial duration, d	L × o.d., mm	Weight, g	Volume, mL	SG[1]	Readability, %
Pinna et al. (2006)	Sarda	Extensive	1,411	Does & kids	210	70 × 21	75.0	22.4	3.4	99.6
MAPA (2007)	Murciano-Granadina	Intensive	365	Does	270	68 × 21	80.0	22.5	3.6	92.6
			199		360	68 × 21	80.0	22.5	3.6	92.6
Pinna et al. (2008)	Sarda	Extensive	210	Does[2]	90-150	70 × 21	75.0	22.4	>3.3	100
Carné et al. (2009a)	Murciano-Granadina	Semi-intensive	92	30	1,050	51 × 11	13.7	3.9	3.5	66.3[3]
			28	171	910	56 × 11	20.1	5.2	3.9	81.4[3]
			34	Does & yearlings	870	68 × 21	75.0	22.3	3.4	96.8[3]
Carné et al. (2009b)	Various[2]	Semi-extensive	95	Does & yearlings	360	56 × 11	20.1	5.2	3.9	96.3
			100			68 × 21	75.0	22.1	3.4	100
			100			69 × 21	82.1	22.8	3.6	97.8
Carné et al. (2010a)	Murciano-Granadina	Semi-intensive	220		360	68 × 21	75.0	22.1	3.4	96.5

[1]SG = specific gravity.
[2]Alpine (n = 74), Angora (n = 75), Boer-cross (n = 73), and Spanish (n = 73).
[3]Values estimated with a Kaplan-Meyer survival analysis.

Therefore, low bolus retention observed in the IDEA Project for some Spanish breeds and production systems was still apparent with improved heavier boluses. Management of goat herds under highly intensified conditions, with concentrate-based diets, has been suggested to have an effect on the observed poorer performance of RFID boluses (Carné et al., 2009a; 2010b).

Likewise, results from following experiments carried out with goat breeds from outside of Spain and identified with standard-sized boluses, yielded average retention rates >98%. In this regard, a large scale (n = 1,411) study on the retention of 75-g standard-sized boluses in extensively managed Italian Sarda dairy goat, yielded a retention rate of 99.6% at 210 d after administration (Pinna et al., 2006). Goat kids were also identified with 75-g boluses at 3 to 5 mo of age, obtaining 100% readability in the milking parlor when being adult does (Pinna et al., 2008).

In a following study, Carné et al. (2009b) evaluated the retention of 75-g and 82-g standard-sized boluses in 4 breeds managed in extensive (Angora, Boer-cross and Spanish) or semi-intensive (Alpine) conditions in the United States. At 1 year, the authors obtained average retentions of 100% and 97.8% for the 75 and 82-g boluses, respectively, and overall retention was 99.5% (Carné et al., 2009b). Furthermore, only the Angora breed showed a retention rate lower than the 98% required by the ICAR (2007).

It must be highlighted that the 75- and 80-g aforementioned bolus types have also been broadly tested in sheep (Caja et al., 1999a; Caja et al., 2003; Teyssier et al., 2003; Ghirardi et al., 2006b; MAPA, 2007), obtaining in all cases retention rates greater than 99%.

In addition to standard-sized boluses, research in recent years has also been focused on the use of small-sized boluses to be administered at early ages so as to improve the implementation of animal traceability systems. Considering the use of the so-called mini-boluses, the issue of losses due to the bolus reaching the abomasum by going through the reticulo-omasal orifice, and being eventually expelled by intestinal passage, has also arisen. This possibility has been proposed in both sheep and goat as the diameter of the reticulo-omasal orifice in adult sheep (22 to 23 mm; Ghirardi et al., 2006b), lambs (14 mm; Ghirardi et al., 2007) and goat kids (24 mm; Martín et al., 2004) was greater than the o.d. of currently used mini-boluses (10 to 12 mm). In the case of goats, the size of the reticulo-omasal orifice in kids was nearly twice the size in lambs, which might contribute to the greater losses observed in goats.

In this respect, Carné et al. (2009a) evaluated the long-term retention of 2 different prototypes of mini-boluses administered to suckling kids of Murciano-Granadina breed (Table 7.6). The 13.8-g mini-bolus (SG 3.5) was administered to kids of 6.8 kg BW. The second mini-bolus was larger (20 g and 5.2 mL) and with greater specific gravity (3.9), and was administered in the event of losses (n = 28) of the former mini-bolus. Readability of the lighter mini-bolus was 71.4% at 1 yr of age and 69.6% at the end of the 3-yr study. The heavier mini-bolus offered retentions of 84.6 and 81.4% at 1 and 3 yr of study, respectively. Moreover, no effect of extending the rearing period on the retention of the 13.8-g mini-boluses could be confirmed (Carné et al., 2009a).

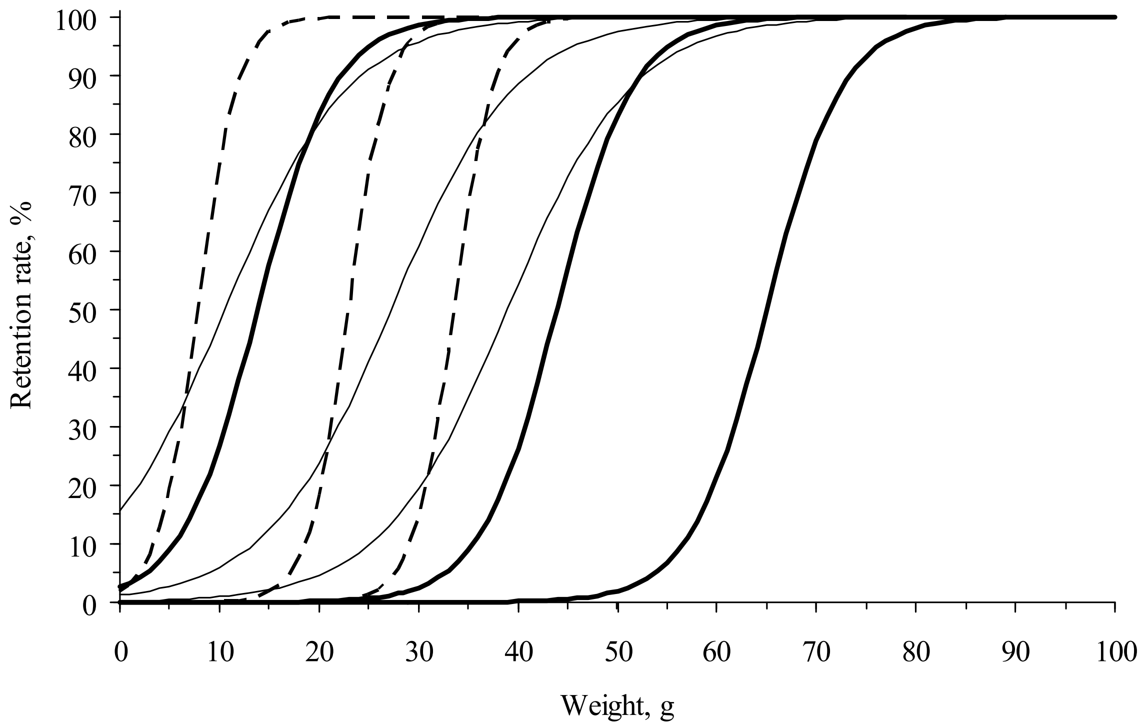
In a short-term study, Castro et al. (2005; 2010) also tested different mini-boluses in suckling kids, showing 100% retention at slaughter (10 kg BW); in this case, trial duration and pre-ruminant conditions of kids must be taken into account. Results in replacement goat kids contrast with those previously reported by using the same mini-boluses in fattening and replacement lambs (Ghirardi et al., 2007); in these cases, retention of the 13.8-g mini-bolus ranged from 97.3 to 100%, and was 100% for the 20-g mini-bolus.

The same 20-g mini-bolus has been tested in adult goats from different breeds managed in extensive (Angora, Boer, and Spanish) and semi-intensive (Alpine) conditions (Carné et al., 2009b); at 1-yr, an average retention of 96.3% was obtained, and a breed effect was not able to be detected. In a later study, mostly using dairy goats managed under intensive conditions, a long-term retention of 81.4% was observed (Carné et al., 2010b). All these studies concluded, therefore, that available mini-boluses were not recommendable for the permanent identification of goats.

More recently, the modeling of bolus retention in goats according to bolus features has been completed (Carné et al., 2010b), similarly to what previously done in cattle and sheep (Ghirardi et al., 2006a,b). The retention model in goats is of special interest given the poor and variable retention rates of RFID boluses in goats, as already detailed. Moreover, the model was shown to allow the assessing of the bolus features for an adequate retention, as well as optimizing the reduction in bolus size (Carné et al., 2010b). Bolus retention in cattle, sheep and goats fitted similar logistic regression models taking the weight and the volume of boluses as covariates (Ghirardi et al., 2006a,b; Carné et al., 2010b). To construct the goat model, 19 commercial and prototype boluses were evaluated; for this reason, retention results for each bolus type will not be detailed in this review, and only the obtained model will be next discussed.

The different curves corresponding to the estimated models of rumen bolus retention in goats, sheep, and cattle, according to bolus weight and volume are shown in Figure 7.1. Estimations are expressed for 3 different volumes (5, 15 and 22 mL), which are considered as representative of small-, medium-, and standard-sized boluses (Carné et al., 2010b).

Figure 7.1. Estimated retention rates for small-, medium-, and standard-sized rumen boluses of 5, 15, and 22 mL of volume in cattle (—), sheep (---), and goats (**—**) according to the weight (g) of boluses. Figures come from to the models published by Ghirardi et al. (2006a,b) and Carné et al. (2010b).

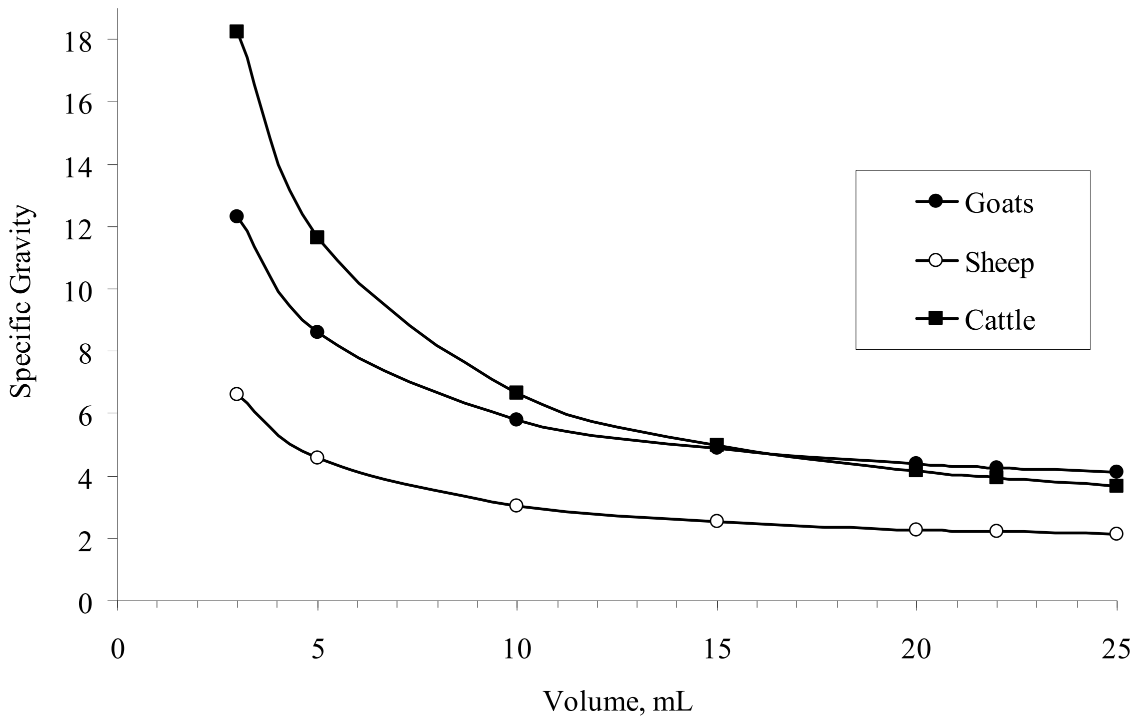


As can be observed, the curves corresponding to the goat model are noticeably displaced to the right, indicating that for a same given volume, a considerable increase of bolus weight is required; consequently, an increase in SG is necessary as well. In fact, estimated SG to produce a 5-mL mini-bolus to be adequately retained in goats was 8.6 (Carné et al., 2010b), which nearly doubles the 4.6 required in sheep (Ghirardi et al., 2006b). In the case of cattle, requirements for designing 5-mL boluses (SG 11.6; Ghirardi et al., 2006a) were even more stringent than for goats. An increase of boluses going through the reticulo-omasal orifice and subsequent intestinal passage might be an additional cause of mini-bolus losses in this species, although no data in this regard is available.

On the other hand, requirements for producing larger boluses for cattle are less strict, to the point that SG in medium- and standard-sized boluses are intermediary (3.9 to 5.0) in relation to those in sheep and goats. In any case, it is crucial to have confirmed that, similarly to what has already been observed in sheep and cattle, the increase of SG may allow reduced bolus volumes to be used in goats without causing a lower retention rate.

However, as radio-translucent materials are necessary to produce rumen boluses (Caja et al., 1999a; Garín, 2002; Fallon, 2001), the relatively low SG of these materials becomes the main limitation to optimize the reduction of bolus size (Ghirardi et al., 2006a,b; Carné et al., 2010b).

Figure 7.2. Volume (mL) and specific gravity of boluses for estimated retentions of 99.95% in goats, sheep and cattle calculated from models published by Ghirardi et al. (2006a,b) and Carné et al. (2010b).



Boluses currently available have SG no greater than 4.1 (Carné et al., 2010b; ICAR, 2010). Therefore, a compromise has to be reached between the volume to be achieved and the SG required for that purpose. Taking these aspects into consideration, and according to the aforementioned retention models, the SG and volume required for producing boluses with an optimum retention rate of 99.95% in goats, sheep, and cattle have been obtained, and are shown in Figure 7.2.

As can be observed, SG for producing boluses for cattle and goats dramatically increases when attempting to reduce the bolus size. Moreover, the difference of SG between sheep and goats is clearly noticeable, as this is steadily maintained at different bolus volumes. According to these new curves, it was possible to fit a potential regression model of the SG and volume in properly retained boluses. In the case of goats, the model was as follows ($R^2 = 0.983$; $P < 0.001$):

$$SG = 19.52\ (V) \cdot e^{(-\ 0.509)}$$

This last equation is of practical interest as it takes into account the 2 very main limitations encountered when designing new bolus types, namely, the manufacturing material available, and the size of the bolus so as to be administered at lower age and BW in the different ruminant species where utilized.

In addition to evaluating the retention rate of boluses, a number of studies have been aimed at studying the possible effects derived from their administration and the subsequent long-term retention in the reticulorumen of domestic ruminants (Hasker and Bassingthwaighte, 1996; Caja et al., 1999a; Martín et al., 2006). In the case of goats, studies have demonstrated that, if properly performed (Caja et al., 1999; Carné et al., 2009a,b), bolus administration can be safely done at a lower BW than in sheep (Caja et al., 1999a; Carné et al., 2009a; Castro et al. 2005, 2010); thus, 22-mL devices can be applied to young goats with >20 kg BW, and 4-mL mini-boluses can be administered to suckling kids of approximately 5 to 6 kg of BW (2 to 5 wk of age).

With regard to administration safety, less than 0.03% of deaths of goats due to bolus administration were registered in the IDEA Project; the Spanish working group indicated that >80% of casualties occurred during the first wk of the project deployment, thereby corresponding to goats identified by untrained operators (JRC, 2003). Similar incidence of administration problems were observed with sheep and cattle (JRC, 2003). Subsequently, a number of authors have reported no incidences related to bolus administration in goats (Ribó et al., 1994c; Caja et al., 1999a; Martín et al., 2006; Carné et al., 2009a,b; 2010a,b; Castro et al., 2010). According to Macrae et al. (2003), the importance of the neck position should be underlined to avoid incidences in the administration of boluses in Suffolk lambs.

On the other hand, no shortcomings related to alterations in the reticulorumen, food intake, digestibility, growth, and production efficiency have been reported in goats (Castro et al., 2005, 2010; Martín et al., 2006; Ait-Saidi et al., 2008). Similar conclusions have been obtained in sheep (Caja et al., 1999a; Garín et al., 2003; Ghirardi et al., 2007) and cattle (Hasker and Bassingthwaighte, 1996; Caja et al., 1999a; Antonini et al., 2006).

At slaughter, boluses are easily and quickly (8 s on average) recovered in the offal room (Caja et al., 1999a), thereby not being directly conditioned by the slaughter line speed. Similar results have been indicated in sheep and cattle (Caja et al., 1999a; Lambooij et al., 1999; Ghirardi et al., 2006b).

7.7. Leg tags

Leg tags (leg bands or leg marks) are broadly used in dairy goat herds (Balvay, 2007), either for individual ID or to mark animals for lot management. However, little attention has been paid on their use for official ID until the publication of European Regulation EC 933/2008, amending Regulation EC 21/2004 regarding the identification and registration of sheep and goats. Accordingly, visual and RFID leg marks can be used for official ID of sheep and goats if they do not leave the country of origin. Spanish (Real Decreto 1486/2009) and French (Arrêté du 24 décembre 2009) transpositions of European regulations already establish the official use of leg marks as visual devices.

Along with the possibility of using leg tags for visual ID, some RFID leg tags have also appeared recently (Hilpert et al., 2009; ITW Reyflex, 2009). In fact, an on-field study is being carried out in France since 2007 to evaluate the performance of visual (A. Raymond, A. Raymond; Capritag, Chevillot) and RFID leg tags (Patuflex, ITW Reyflex) in dairy goats. Results showed 12% of losses for a first model of Patuflex leg tag at 6 mo after tagging adult goats, which were subsequently reduced to <1% by using an improved model. Regarding electronic readability, 4.5 and 1.6% of devices unreadable for the first and second model of Patuflex leg tag were obtained at 16 and 6 mo after tagging, respectively (Balvay, 2009).

Unlike Patuflex leg tags, the A. Raymond leg bands were considered as suitable for application to young goats as the inner circumference of the tag can be enlarged when the goat grows; this leg tag yielded a retention close to 99%, although visual readability was 90%. Irrespective of the retention obtained, it appears clear to us that allowing the a posteriori modification of the inner circumference of leg tags prevent their use as tamper-proof devices as required in the EU (Regulations EC 21/2004 and EC 933/2008).

Abecia et al. (2009) tested the threshold age and BW for application of Patuflex leg tags in Murciano-Granadina dairy goats. The shank circumference of goat kids at 5 mo of age (76 mm) reached 86.7% of circumference in adult goats (88 mm) (Abecia et al., 2009); conversely, BW at that age only represented 35% of overall BW in adults. However, several cases of leg band displacement to the pastern were registered in 25% of goat kids. They concluded that a minimum age of 6 mo for leg tagging was appropriate to avoid unlawful removal, and to allow the permanent identification during the goat's lifespan without causing constriction in the leg of adult does. This study did not evaluate, however, losses and readability of devices in the subsequent months after tagging.

Carné et al. (2010a) evaluated the use of a new leg band of Spanish design (Animalcomfort) where the buckle to fasten the leg band had a pin that allowed the device to be closed with an ear tag button female piece, similarly to the closing systems of regular ear tags. In this study, RFID button pieces were used, thereby obtaining RFID leg tags. The shank circumference of adult goats (88 mm) was 79.5% of that in 5-mo kids (70 mm), and the inner circumference of fastened leg tags in adult goats was 107 mm. Authors concluded that early losses or removals, as well as constriction of the leg in grown goats could not be prevented if leg bands were applied at 5 mo of age. Long-term visual and RFID readability was also monitored during 1 yr. Visual readability was 98.5%, and the remaining 1.5% corresponded to tags removed because they caused limping (Carné et al., 2010a). Electronic readabilities were 93.6 and 98.3% for the 2 types of RFID button tags, respectively. It was therefore concluded that properly designed leg tags could be adequately used for permanent official identification of adult goats, whereas tagging at early ages remained a topic for further research (Carné et al., 2010a).

7.8. Dynamic reading efficiency

The application of radio frequency technology for livestock ID has supposed the possibility of widening the utilities of ID devices. Thus, in addition to ensuring the permanent, accurate and reliable ID of animals, RFID may be a valuable tool for the automation of farm management and data recording activities, thereby improving the production efficiency (Speicher, 1981; Ait-Saidi et al., 2007; Voulodimos et al., 2009). In this regard, efficient individual dynamic reading with livestock passing through a runway may facilitate lot-based management systems as well as quickly monitor great amounts of animals.

Existing information on the dynamic reading efficiency (**DRE**) of RFID devices in goats is summarized in Table 7.7. Although little information is found, the evaluation of RFID devices in animals going through a runway with the antenna placed in different locations has been tested by different authors. Thus, regarding ear tags Caja et al. (1998a) indicated poor DRE rates ranging from 61.2 to 72.5% in goats, which depended on the strength of the electromagnetic field generated by the transceiver; similar results (78.8%) have been indicated in sheep (Caja et al., 1998a). A greater range of values (53.4 to 99.9%) has been pointed out in cattle (Conill et al., 2000; Stewart et al., 2007; Wallace et al., 2008), which on one hand was a consequence of the variable performance in different body sites; on the contrary, the lower passage speed and greater distance between transponders in this species could reduce the occurrence of collisions between transponders (Ghirardi et al., 2006b).

With a frame antenna located on the left side of the runway, DRE > 99% have been obtained by using RFID rumen boluses (Caja et al., 1999a; Conill et al., 2000; Carné et al., 2010b). These high values are explained by the use of large transponders (32-mm), which show larger reading distances from the transceiver's antenna. Moreover, readings are optimized because rumen boluses are mostly located in the reticulum, at the very left side of the abdominal area (Caja et al., 1999a; Castro et al., 2005; Antonini et al., 2006). Similarly, results by using 32-mm transponders injected subcutaneously in the left armpit yielded DRE of 100% in goats (Caja et al., 1999b), and 99.9% in cattle (Conill et al., 2000).

Carné et al. (2010a) also evaluated the efficiency of boluses with the antenna placed in other positions (on the floor, and with goats passing through it), and with goats also being identified with RFID leg tags. In these conditions, where a remarkable increase of reading collisions was anticipated, bolus DRE was still greater than 95% (Carné et al., 2010a). Conversely, the lower bolus DRE was obtained with the antenna placed on the floor (Carné et al., 2010a), which additionally resulted to be the best position for the dynamic reading of leg tags (92.4%). The antenna on the floor was also indicated as the best position for the DRE of 15-mm transponders injected in the fore- or hind-legs (MAPA, 2007).

Table 7.7. Dynamic reading efficiency (DRE)[1] of different radio-frequency identification devices in goats.

Reference	Device type	Bdoy site[2]	Transponder size, mm	Antenna position	Readings, n	DRE, %
Caja et al. (1998a)	Ear tag	—	—[4]	Left lateral	276	61.2–72.5[6]
Caja et al. (1999a)	Rumen bolus	—	32.5 × 3.8[3]	Left lateral	332	100
Caja et al. (1999b)	Inject	Armpit	32.5 × 3.8[3]	Left lateral	2,160[5]	100
MAPA (2007)	Inject	Metacarpus	15.0 × 3.0	Floor	578	99.7
Carné et al. (2010a)	Rumen bolus	—	32.5 × 3.8[3]	Left lateral	495	95.2
				Floor	495	16.0
				Transversal	363	93.0
	Leg tag	Hind leg	—[4]	Left lateral	525	68.2
				Floor	525	92.4
				Transversal	385	83.4
Carné et al. (2010b)	Rumen bolus	—	32.5 × 3.8[3]	Left lateral	1,496	99.5

[1]DRE = no. devices read / no. devices readable and present.

[2]Devices applied to the left of the animal except for inject in the pastern.

[3]Ferrite coil.

[4]Air coil (button transponder).

[5]Goats identified throughout a 3-yr study.

[6]Depending on the strength of the transceiver's electromagnetic field (137 to 140 dbµV/m at 3 m).

It can be concluded that the reading efficiency strongly depends on the position of the antenna and the type of RFID device, which becomes an issue of major relevance when dealing with goat herds where different RFID methodologies are in use (Carné et al., 2010a).

7.9. CONCLUSIONS

The performance of electronic devices for the identification of goats has been studied by different authors in recent years. Obtained results showed that electronic identification devices perform better than visual devices in most cases.

Transponders injected in the armpit yielded adequate readabilities (>98%) as recommended by the ICAR (2007), although efficient retrieval at slaughter is a key shortcoming to be solved as it constitutes a public health issue. Small-sized transponders are necessary if intending to be injected in the pastern (metacarpus or metatarsus), although variable readability rates have been obtained when injected at early ages.

Readability of electronic ear tags was markedly variable, but adequately designed button-button ear tags showed a satisfactory retention and readability.

Leg bands with attached transponders were a valid alternative for the identification of adult goats, although thorough study of leg band designs is required to ensure their use for the identification of goats before 6 mo of age, as established in the EU regulations.

Rumen boluses currently used for sheep identification are not appropriately retained in some goat breeds and production systems, which is the case of many Spanish goats. Moreover, studies on the relationship between bolus features and their retention in the reticulorumen concluded that boluses with greater specific gravity are required in comparison to sheep. However, reduction in bolus size could be achieved by using materials with suitable minimum specific gravity. The use of small-sized boluses in goats is therefore conditioned by the availability of suitable radio translucent materials for bolus manufacturing.

CHAPTER 8

Conclusions

CHAPTER 8

CONCLUSIONS

Electronic identification at early ages

- Suitable electronic ear tags were easily applied to goat kids, the age at tagging not affecting the subsequent performance of these devices.
- The size of injectable transponders was the main limitation for their subcutaneous injection in the pastern of goat kids. Transponders larger than 15 mm were discarded.
- Appropriately dimensioned small-sized boluses were safely administered to goat kids. Moreover, the body weight for bolus administration was lower in goats than in sheep.
- No influence could be established between the suckling period and the early losses of small-sized rumen boluses in kids. Therefore, no increment of losses by regurgitation or intestinal passage could be attributed to the anatomical and physiological modifications that occur when the esophageal groove reflex is activated.

Visual and electronic ear tags

- Visual ear tags for the identification of replacement and adult goats showed long-term readabilities lower than the minimum 98% recommended by the ICAR (2007) for their official use in practice.
- Retention rate of visual ear tags varied according to goat breed, although no effect of production management (intensive vs. extensive) on ear tag performance could be established.

- Button electronic ear tags showed greater visual and electronic readability rates than flag types and, if adequately designed, may be a valid option for goat identification.

Visual and electronic marks on the pastern

- Long-term readability of injects varied according to their size, although in all cases was lower than 96%, and their use is not recommended.
- Leg tags attached to the hind-legs were not adequate for the identification of 5-mo goat kids due to the observed differences in shank circumference with respect to adult goats.
- Leg tags on the hind-leg of adult goats showed no losses, although some cases of limping were registered. As visual readability of leg tags remained over the 98% value, this type of device is a valid alternative for adult goat identification.
- Electronic readability of suitably designed button transponders attached to leg tags was >98%, complying with ICAR requirements.

Rumen boluses

- The low retention of small-sized boluses in goats from different breeds and management systems prevents their use in this species.
- Standard-sized boluses showed variable retention rates, although the greatest losses were observed in dairy herds managed under intensive conditions.
- A logistic regression of the retention of rumen boluses in the reticulorumen of goats was successfully constructed, taking the bolus weight and volume as covariates. A reduction in bolus size can be achieved by increasing the specific gravity, similarly to results previously reported in cattle and sheep.
- According to the regression model, medium-sized boluses (10-15 mL) with weights raging from 58 to 73 g and specific gravities between 4.9 and 5.8 can be successfully produced for the permanent identification of goats.

- Suitable medium- and standard-sized boluses for goat identification can be obtained with available radio translucent materials.
- Small-sized boluses are not recommended for goats, as no available radio translucent material reach the required estimated SG (>8).

CHAPTER 9

References

CHAPTER 9

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