Departament de Ciència Animal i dels Aliments

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Implementación de la identificación electrónica para el control de producciones en granjas de ovino y caprino

Implementing electronic identification for performance recording in sheep and goat farms

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Adel Ait Saidi

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Implementing electronic identification for performance recording in sheep and goat farms

Thesis presented by Adel Ait Saidi, under the advice of Dr. Gerardo Caja López from Departament de Ciència Animal i dels Aliments of the Universitat Autònoma de Barcelona

Fdo: G. Caja

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“It is better to light some candles than to curse the darkness”

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LIST OF ABREVIATIONS

a.m.	Ante meridiem
ANOVA	Analyze of variance
AT	Monthly milk records at the am or pm milkings (alternate)
AU	Automatic
A4	Monthly milk records at the am and pm milkings
BEP	Break-even point
BW	Body weight
cm	Centimeter
CP	Crude protein
d	Day
DIM	Days in milking
DRE	Dynamic reading efficiency
e-ET	Electronic ear-tag
e-ID	Electronic identification
e-IT	Electronic injectable transponder
e-LT	Electronic leg-tag
e-RB	Electronic ruminal bolus
ET	Ear-tag
EU	European union
Exp	Experiment
FEOGA	European Fund For Direction and Agrarian Guaranties
FDX	Full duplex
g	Grams
GLM	General linear model
h	Hour
HDX	Half duplex
HHR	Handheld reader
ICAR	International Committee for Animal Recording
ID	Identification
ISO	International Organization for Standardization
kPa	Kilo Pascal
L	Liter
LC	Lacaune breed
LSM	Least square means
LT	Leg tag
M	Manual
m	Meter
Mcal	Mega calorie
MD	Movement document
min	Minutes
mL	Milliliter
mm	Millimeter
MN	Manchega breed

mo	Month
NE_L	Net energy of lactation
PDA	Personal digital assistant
PDIFF	*P* difference
p.m.	Post meridiem
r^2	Coefficient of determination of a linear regression
RS232	Recommended standard 232
RI	Ripollesa breed
ROR	Rate of return
s	Second
SA	Semi-automatic
SAS	Statistical analysis software
SAS-ISO	Smart antenna stick-iso
s.c.	Subcutaneous
SE	Standard error
SEM	Standard error of the mean
S.G.	Specific gravity
UAB	Universitat Autónoma de Barcelona
Vs.	Versus
v-ET	Visual ear tag
v-LT	Visual leg tag
×1	Once daily milking
×2	Twice daily milking

SUMMARY

European legislation made mandatory the use of electronic identification (e-ID) for sheep and goats which cost is questioned in practice. This thesis aimed to quantify the costs and derived benefits of using e-ID at farm level. Thus, 4 experiments (Exp.) were carried out to assess the performance and the cost-benefit of manual (M; visual ear tags and paper forms) or semi-automated (SA; e-ID boluses and automated data downloading) systems implemented for performance recording.

In Exp.1, 24 dairy goats were used to compare M and SA (standard boluses) for milk recording under once daily milking (×1). No difference in milk recording time was observed but SA was 75% faster in uploading data into a computer than M. Use of SA instead of M saved 8 s/goat in total time of milk recording. Although, no difference in data error was detected between M and SA at milk recording, 1.1% of errors occurred only at M data uploading. Reduction in labor time cost varied by herd size and accounted 40% of e-ID implementation costs. Results highlighted the need of operator training in SA system.

In Exp.2, a flock of 48 dairy ewes was used to compare M and SA (HHR, handheld reader and small-boluses; PDA, personal digital assistant and v-ID) milk recording systems under ×1 or twice- (×2) daily milkings. No interaction between system×test-day was observed, agreeing with the operator expertise. Data transfer was markedly faster for both SA systems than in M. Consequently, total milk recording was faster for both ×1 and ×2 in SA systems than for M, saving 7 and 15 s/ewe, respectively. Data errors averaged 3.6% in M, whereas no errors were found in SA. Results demonstrated the time-affectivity of HHR and PDA systems for milk recording in dairy ewes.

In Exp.3, Data recording at lambing by M and HHR systems were compared using 73 dairy and 80 meat ewes. Time for lambing recording was greater in dairy than in meat ewes, due to the lower operator experience and ear tag dirtiness. Overall time for lambing recording was greater in M than HHR for both dairy and meat flocks, saving 36 and 48 s/ewe, respectively. Data uploading errors only occurred in M (4.9%).

Finally, in Exp.4, BW recording of 120 dairy and 120 meat ewes using an electronic scale was performed by M and AU (automatic using e-ID and stationary reader) systems. Mean BW recording and data uploading times, as well as overall BW recording time, were greater in M than in AU, saving on average 22 s/ewe. Uploading errors only occurred in M (8.8%). In conclusion, e-ID for SA and AU performance recording saved time and increased the reliability of the collected data.

Results of Exp.2, 3 and 4 were integrated into a whole cost-benefit study for typical meat (700 ewes; extensive or intensive) and dairy (400 ewes; ×1 or ×2 milk recording daily) farms. Benefits of using SA or AU mainly depended on sheep breed, test-days per yr, reader prices and flock size.

In conclusion, the use of e-ID in the optional scenario increased the cost of performance recording and partially paid the investment made (15 to 70%). For mandatory e-ID scenario or by using PDA, savings paid 100% of the extra-costs in all farm types, indicating their cost-effectiveness for sheep performance recording. In both scenarios, reader price was the most important extra-cost (40 to 90%) of e-ID implementation.

RESUMEN

Los costes de implementación de la identificación electrónica (e-ID) para cumplir la legislación europea preocupan el sector ovino y caprino. Con este motivo, a fin de cuantificar los beneficios secundarios del uso de la e-ID para el ganadero, se realizaron 4 experimentos (Exp.) para evaluar los resultados productivos, costes y beneficios de implementar un sistema manual (M; crotales visuales y anotación en papel) o semi-automatico (SA; bolos electrónicos y descarga automática de datos) para el registro de producciones in caprino y ovino.

En el Exp.1, se utilizaron 24 cabras lecheras para comparar el uso de M y SA en el control lechero realizado con 1 ordeño/d (×1) y en una sala 2×12. No se observaron diferencias en el tiempo de control lechero, pero SA fue 75% más rápido que M en la descarga de datos. El uso de SA ahorró 8 s/cabra en el tiempo total de control lechero. No se observaron diferencias entre M y SA en los errores de recogida de datos (0.6%), pero M produjo un 1.1% más de errores en la descarga de datos. La reducción del coste de trabajo con SA varió según el tamaño del rebaño (24−480 cabras) y se estimó en un 40% del coste de implementación de la e-ID.

En el Exp.2, se utilizó un rebaño de 48 ovejas lecheras para comparar los sistemas M y SA (HHR, e-ID con bolos; PDA, agenda electrónica e ID visual) en condiciones de ×1 o ×2 (2 ordeños/d) y una sala de 2×12. No se observó interacción entre día × sistema indicando que el operador tenía experiencia previa. La descarga de datos fue más rápida en los dos sistemas SA que en M. Como resultado, el control lechero, incluyendo la descarga de datos, fue más rápido en SA que en M, siendo el ahorro de 7 y 15 s/oveja para ×1 y ×2, respectivamente. Los errores en M fueron 3.6%, no detectándose en SA.

En el Exp.3 se compararon los sistemas M y SA para el control de paridera, utilizando un rebaño de 73 ovejas de leche y 80 de carne, durante 2 periodos distintos. El tiempo de control de paridera fue mayor en las ovejas de leche que en carne, debido a la menor experiencia del operador y la suciedad de los crotales. El tiempo total de control de paridera fue mayor en M que SA, tanto en las ovejas de leche como de carne, resultando en un ahorro de 36 y 48 s/oveja, respectivamente. Los errores de descarga de datos sólo ocurrieron en M (4.9%).

Finalmente, en la Exp.4, se compararon los sistemas M y automático (AU) para el registro de peso vivo (PV) utilizando una báscula electrónica en un rebaño de 120 ovejas de leche y 120 de carne. El tiempo medio de pesado, descarga de datos y el tiempo total, fueron mayores en M que AU, resultando con un ahorro de medio de 22 s/oveja. Los errores de descarga de datos sólo ocurrieron en M (8.8%).

Los resultados de los Exp.2, 3 y 4 se integraron en un estudio coste-beneficio para granjas tipo de ovino de carne (700 ovejas; sistema extensivo o intensivo) y de leche (400 ovejas; control lechero ×1 o ×2). Los beneficios por usar SA o AU variaron según la raza, el número de controles/año, el coste de lectores y el tamaño del rebaño.

Como conclusión, en el caso de la e-ID opcional, los costes del control de producciones cubrieron parcialmente la inversión inicial (15−70%). En el caso de e-ID obligatoria, o cuando se usó la PDA, los ahorros pagaron el 100% de los costes. El coste de los lectores fue el coste adicional más importante (40−90%) en la implementación de la e-ID en ambos escenarios.

RESUMÉ

La législation européenne a ordonné l'utilisation de l'identification électronique (e-ID) pour les ovins et caprins, et son coût est un sujet de controverse dans la pratique. Le but de cette thèse est de quantifier les coûts et les éventuels bénéfices de l'utilisation de l'e-ID au niveau de la ferme. Pour cela, 4 expériences ont été réalisées pour évaluer les performances, les coûts-bénéfices d'implémenter un système manuel (M ; basé sur les étiquettes auriculaires visuelles et l'annotation sur papier) ou semi-automatisé (SA ; basé sur des bolus électroniques et collecte automatisée de données) pour l'enregistrement des performances.

Dans l'Exp.1, 24 chèvres laitières ont été utilisées pour comparer M et SA pour le contrôle laitier (CL) avec une traite quotidienne (×1). Pas de différence entre les temps de CL mais le transfert des données était 75% plus rapide en SA qu'en M. L'utilisation de SA a épargné 8 s/chèvre du temps total. Pas de différence dans les erreurs commises durant le CL entre M et SA (0.6%), mais environ 1.1% d'erreurs additionnelles se sont produites durant le transfert de données avec M. La réduction du coût de travail a varié en fonction de la taille du troupeau et était estimée à 40% des coûts d'application de l'e-ID. Les résultats mettent en valeur l'importance d'une préalable expérience de l'utilisation du système SA.

Dans l'Exp.2, 48 brebis laitières ont été utilisées pour comparer les CL M et SA (HHR, e-ID avec bolus ; PDA, agenda électronique et identification visuelle) avec ×1 ou 2 traites (×2) quotidiennes. Pas d'interaction significative entre jour de contrôle×système, ce qui démontre une expérience préalable de l'opérateur. Le transfert des données a été plus rapide en SA qu'en M. Par conséquent, le CL incluant le transfert des données a été plus rapide en SA qu'en M, épargnant 7 et 15 s/brebis pour ×1 et ×2, respectivement. Les erreurs ont été de 3.6% en M, tandis elles ont été nulles en SA. En conclusion, les systèmes HHR et PDA ont été efficients pour le CL des ovins.

Dans l'Exp.3, la collecte des données à l'agnelage (CDA) par M et SA a été comparée en utilisant 73 brebis laitières et 80 brebis à viande. Le temps de CDA a été plus élevé chez les brebis laitières que celles à viande dû à la faible expérience de l'opérateur et aux étiquettes auriculaires nécessitant nettoyage. Le temps total de CDA a été élevé en M que SA pour les brebis laitières et à viande, épargnant 36 et 48 s/brebis, respectivement. Lors du transfert des données, 4.9% d'erreurs se sont produites seulement en M.

Finalement, dans l'Exp.4, l'enregistrement du poids vif (EPV) de 120 brebis laitières et 120 brebis à viande en utilisant une balance électronique était accompli par systèmes M et AU (automatique en utilisant un lecteur fixe). Les temps d'EPV, du transfert des données et le temps total étaient plus élevés en M qu'en AU, épargnant en moyenne 22 s/brebis. Les erreurs de transfert des données ont été enregistrées sauf en M (8.8%). En conclusion, l'e-ID utilisée pour le contrôle des performances par SA et AU a épargné du temps et a augmenté la fiabilité des données collectées.

Les résultats des Exp.2, 3 et 4 ont été intégrés dans une analyse de coûts-bénéfices pour fermes d'ovins de type viande (700 brebis ; systèmes intensif ou extensif) et lait (400 brebis ; ×1 ou ×2). Les bénéfices obtenus de l'utilisation de l'e-ID dépendaient de l'aptitude productive, du nombre de contrôles/an, du coût des lecteurs et de la taille du troupeau.

En conclusion, l'utilisation de l'e-ID dans le scénario optionnel augmente les coûts d'enregistrement des performances et le coût initial d'investissement était partiellement (15 à 70%) payé. Dans le scénario où l'e-ID est obligatoire ou quand PDA est utilisée, l'épargne paie la totalité des coûts dans tous les types de fermes, indiquant l'efficacité de ces systèmes dans l'enregistrement des performances de production des ovins. Dans les 2 scénarios, le coût des lecteurs était le plus important (40 à 90%) pour l'implémentation de l'e-ID.

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INTRODUCTION

1.1 Identification of Sheep and Goats

1.1.1 General Aspects

Performance recording of sheep and goats provides useful data for stakeholders and allows them taking decisions for management (i.e., grouping, reproduction, replacement or culling, genetic evaluation) and use of farm resources (i.e., feeding strategies, sheltering). Collected data include individual animal ID and the recorded performances (i.e., body condition score, milk yield, data recording at lambing, body weight). In all cases, animal ID is a key and should be unique and permanent for an adequate performance recording.

Traditional methods of animal ID (i.e., branding and ear notching), which were used in the past to indicate property ownership or most rarely for performance recording (Landais, 2001; Blancou, 2001; Caja et al., 2004), are currently considered inefficient as a result of their poor performances and deplorable consequences in animal welfare. Thus, alternative visual ID devices (i.e., ear tags, leg tags, collars and tattoos) became the usual methods for the ID of sheep and goats in practice. However, these methods are not exempt of fraud and labor, as well as, they have not complete reliability due to the errors generated by misreading and mistranscription of code numbers by operators.

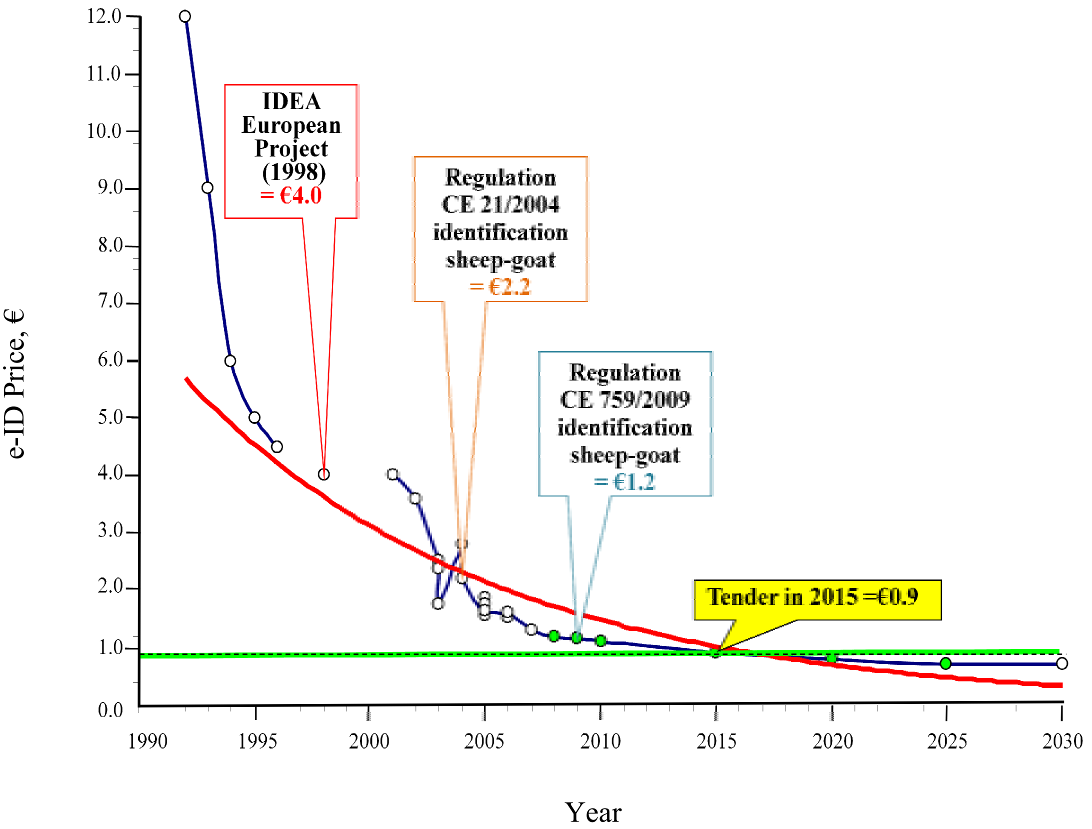
In the 90's, administration and consumers had special awareness toward safety of food products and public health, as a consequence of the food alarms by toxic episodes (e.g., dioxins, contaminated oils) and disease outbreaks (e.g., encephalopaties, hoof-and-mouth disease). At the same time, the technology hugely evolved which allowed its implementation in tagging for good logistics (food traceability) and intensive production systems (livestock precision).

For these reasons, improvement of animal ID using modern technologies became a pertinent priority for the deployment of modern animal recording systems (Barcos, 2001; Caja et al., 2004; Bass et al., 2008).

The first attempt for automating animal ID was based on the use of barcodes printed on plastic ear-tags and carcasses' surfaces (Wismans, 1999; AECOC, 2002). However, readability problems under on-farm (need of restraining, dirtiness) and slaughterhouse conditions, misadvised on its general use. The most significant technological step on livestock

ID was done on the 90's with the implementation of advanced radio frequency (**RF**) using low frequency passive transponders at a farm level (Lambooij, 1991; Caja et al., 2003). The use of RF technology offered effective contact-less reading and reliable data acquisition systems for automatic ID and performance recording (i.e., data recording and processing) of livestock. Moreover, it was considered as an innovative technique for improving the performance of visual ID methods, although the circumstantial high price was the main limitation for expanding its use at a farm level (Disney et al., 2001). This situation has changed at nowadays (Figure 1.1).

Figure 1.1. Evolution of electronic identification devices prices in the European Union market (Caja, 2013)



Use of electronic ID (**e-ID**), based on RF devices, has been adopted as mandatory ID system in many countries (Table 1.1) in which specific regulations have been published for official identification and registration (**ID&R**).

Table 1.1. Comparison of traceability systems in major sheep producing countries (updated from Bass et al., 2008)

Country	Sheep (1,000 head)[1]	Premises ID	Individual ID	Group or lot ID	Electronic ID	Movement recording	Retire number
China	173,899.2	V[2]	V	V	V	V	V
EU-27	109,942.4	M[2]	M	M	M[3]	M	M
Australia	100,100.0	M	V	M	V	M	M
New Zealand	40,106.8	V	V	V	V	V	V
USA	6,230.0	V	V	V	V	V	V
Namibia	2,660.2	M	M	V	V	M	M
World	1,101,639.1	-	-	-	-	-	-

[1]Sheep population in 2006 as reported by FAO; [2]M = Mandatory, V = Voluntary; [3]Mandatory in EU countries with a sheep and goat population greater than 600,000 head and for fattening lambs >1 yr.

1.1.1 Legislation Frame and ISO and ICAR Dispositions

In 1998, the European Commission launched a large-scale project on the electronic identification of animals (Ribó et al., 2001) known as IDEA project (Identification Electronique des Animaux). This project demonstrated that a considerable improvement in sheep and goat ID systems could be achieved by using e-ID for small ruminants (San Miguel et al., 2004; Ntafis et al., 2008). As IDEA project results, electronic ear tag (**e-ET**) and bolus (**e-RB**) had the lowest percentages of losses and breakages (<5%) and the highest retention rates (>99.5%), on average, than those of visual ear-tags (**v-ET**). Hence, results of IDEA project were considered a platform built to setup EU legislation (CE 21/2004) for sheep and goats.

Legislation Frame. In the European countries, the adopted ID&R system for sheep and goats was mandated initially by CE 21/2004 regulation, later updated by CE 933/2008 and CE 759/2009 (Table 1.2 and Table 1.3). These regulations established several requirements, among them:

- A double individual ID system. The first ID device should be a v-ET and the second shall be approved by the competent authority of the country. It may consist of tattoo, v-ET or e-ET, e-RB, visual or electronic leg-tag (**v-LT** or **e-LT**) or an injectable transponder (**e-IT**). Tattoos and leg-tags are not authorized in the case of animals involved in intra-community trade.

Table 1.2. Summary of EU legislation and the most important updates for sheep and goats identification and registration.

Item	Initial	Amendment (M2)	Amendment (M3)	Amendment (M4)
Regulation	CE 21/2004	CE 1560/2007	CE 933/2008	CE 759/2009
Date of publication	17/12/2003	17/12/2007	23/9/2008	19/8/2009
ID of animals born after	9/7/2005	9/7/2005	31/12/2009	31/12/2009
Countries > 600,000 head	e-ID from 1/1/2008	e-ID from 31/12/2009	e-ID from 31/12/2009	e-ID from 31/12/2009
Age at ID, mo[1]	6	6	6	6
Identification devices, no	2	2	2	2
First ID	v-ET[2]	v-ET[2]	v-ET[2] or e-RB[3] or e-ET[2]	v-ET[2] or e-RB[3] or e-ET[2]
Second ID	e-RB[3] or e-ET[2] or (v-ET[2] or v-LT[5,6])[7] or Tattoo[10]	e-RB[3] or e-ET[2] or (v-ET[2] or v-LT[5,6])[8] or Tattoo[10]	(e-RB[3] or e-ET[2])[4] or (e-LT[5] or e-IT[9])[4,10] or [(v-ET[2] or v-LT[5]) or Tattoo[10]][4,11] or [(v-ET[2] or v-LT[5]) or Tattoo[10]][12]	(e-RB[3] or e-ET[2])[4] (e-LT[5] or e-IT[9])[4,10] [(v-ET[2] or v-LT[5]) or Tattoo[10]][4,11] or [(v-ET[2] or v-LT[5]) or Tattoo[10]][12]
Countries[11] in which animals[10]	e-ID optional	e-ID optional	e-ID optional	e-ID optional
For slaughter <12 mo of age[13]	v-ET[2,14]	v-ET[2,14]	v-ET[2,14]	v-ET[2,14]
Holding register[15]	9/7/2005	9/7/2005	9/7/2005	9/7/2005
Include individual ID, dates of ID, birth & death of animals from	1/1/2008	1/1/2008	31/12/2009	31/12/2009
Movement document	9/7/2005	9/7/2005	9/7/2005	9/7/2005
Include individual animal ID from	1/1/ 2008	1/1/ 2008	1/1/2011	1/1/2011
Optional for animals[16] born until	−	−	31/12/2009	31/12/2009
Central register	Computer database	Computer database	Computer database	Computer database
Include Data of each holding from	9/7/2005	9/7/2005	9/7/2005	9/7/2005
With movement document after	1/1/2008	1/1/2008	1/1/2008	1/1/2008

[1]Before 6 mo or before leaving premise of origin; [2]Visual ear-tag; [3]Electronic ruminal bolus; [4]When the first ID is a visual ear-tag; [5]visual (v-) or electronic (e-) Leg-tag (LT); [6]Only for goats; [7]Until 1/1/2008; [8]Until 31/12/2009; [9]Electronic injectable transponder; [10]Not involved in intra-Community trade; [11]With a total number of sheep and goats equal to 600,000 or less (also if the total number of goats is 160,000 or less); [12]When the first ID is an electronic ruminal bolus or an electronic ear-tag;[13]Neither for intra-Community trade nor for export to third countries; [14]Includes country code (2 letters) and ID code of holding of birth; [15]Includes ID and data of the holding, the keeper and the transporter (if there is movement of animals); [16]When directly moved to a slaughterhouse. For other types of movement, CE 45/2012 (M6) made optional to include individual ID in the movement document for animals born until 31/12/2014.

Table 1.3. Mandatory (M) and voluntary (V) information as stated by the European regulation for sheep and goats (EC 21/2004 amended by EC 933/2008 and EC 759/2009) and effective implementation dates.

	Holding register		Movement document		Central register	
Regulation	EC 21/2004	EC 933/2008	EC 21/2004	EC 759/2009	EC 21/2004	EC 933/2008
Effective date	9/7/2005	31/12/2009	9/7/2005	1/1/2011	9/7/2005	1/1/2008
The holding						
ID code of the holding	M	M	M	M	M	M
Address & geographical coordinates	M	M	–	–	M	M
Type of production	M	M	–	–	M	M
Result & date of the last inventory	M	M	–	–	M	M[3]
The keeper						
Name & address	M	M	M	M	M	M
Signature	–	–	M	M	–	–
Animal data						
ID code	V	M	V	M	V	M
Dates of birth (yr) & ID	V	M	–	–	–	–
Month & year of death	V	M	–	–	–	–
Breed & genotype (if known)	V	M	–	–	–	–
Species	–	–	–	–	M	M
Animal movements						
Total number of animals	–	M[2]	M	M	M	M
Leaving the holding of origin						
Date of departure	–	–	M	M	M	M
Transporter name (Permit number)	M	M	M	M	–	–
Registration code of the mean of transport	M	M	–	–	–	–
ID code or name & address of destination[1]	M	M	M	M	M	M
Arriving to the holding of destination						
ID code of the holding of origin & arrival date	M	M	–	–	M	M
Date of arrival	–	–	–	–	M	M
Signature and date of checking	M	M	–	–	–	–
Data field reserved for the competent authority	–	–	–	–	M	M

[1]To another holding or slaughterhouse; [2]Includes group ID number of animals intended for slaughter <12 mo of age which identified with v-ET (Include country code (2 letters) and ID code of holding of birth); [3]Mandated by EC 759/2009.

- In all EU countries in which the total sheep and goat population exceed 600,000 head, the second device shall be e-ID (i.e., e-ET, e-RB, e-IT or e-LT).
- Updated register kept on each holding which should contain the individual ID codes, birth and ID dates, as well as the animal death date.
- Movement documents for any animal moved between 2 separate holdings, even if occurred within the national territory.
- A central register or computerized database providing information for each separate movement of animals.

In Spain, considering the great size of the national sheep and goats flock (>19 millions; MAGRAMA, 2014), the Spanish legislation (Real Decreto 947/2005, updated by RD 1486/2009) made mandatory the use of e-ID by means of e-RB after July 9, 2005 in all sheep and goats intended for replacement (age >6 mo). However, the e-RB may be replaced in sheep by an e-ET, if previously approved by the competent authority. Additionally, in the case of goats, the second ID device could be one of the following alternatives:

- An e-LT in the shank of the right hind leg.
- An e-IT on the right metatarsal.

In these special cases when the ID device is not an e-RB, the type of substitute device should be included in the movement document, indicating for injectables the exact location on the animal.

ISO Standards. There are different RFID technologies available for its use in livestock industry (Garín et al, 2003; Caja et al., 2004). The main differences among them refer to the method of information interchange or communication duplicity. Communication between the reader (transceiver) and the identifier (transponder) can be made by using simultaneous (full-duplex, FDX) or alternate (half-duplex, HDX) air interface. A priori, both systems should to be equivalent, because although FDX is faster, it is more vulnerable to interferences when compared to HDX. Moreover, HDX only uses phase modulation in the information transmission and carries this out in a narrow range of frequencies.

In 1996, the International Organization for Standardization (**ISO**) developed standards for the use of RFID in animals but, the conformance tests of the ID devices and corresponding readers with regard to these standards were not determined. The technical concepts, together with the terminology used in animal e-ID by RFID, were defined in the ISO 11785 approved in October 1996. The 11785 standard also defined the characteristics that the transceivers must fulfill to be considered ISO complying and that basically are: being able to work in an activation frequency of 134.2 kHz and to be able to read indifferently transponders of both accepted duplicity methods (FDX-B and HDX).

In addition, transponders are usually recorded with an information telegram consisting of a digital string in which the bits are partitioned in functional segments corresponding to: header, ID code, cyclic redundancy check, error detector, and trailer (Artmann, 1999; Hogewerf, 2013).

Identification code of transponders intended for animal ID, was approved by the ISO standard (ISO 11784) in 1996 and later reviewed in 2004 and 2010 (amendment I and II, respectively). As shown in Table 1.4, the standardized ID code is a unique 64 bit combination, structured in blocs of various sizes: 10 bits correspond to the country code (translatable to a 4 digit number according to ISO 3166 standard), 38 bits to the animal ID code (translatable to a 12 digit number) and the rest (16 bits) to different indications including retagging, animal species.

Table 1.4. Structure of the code for electronic animal identification (ISO 11784 AMD1:2004).

Bit (s) no.	Bits	Digits	No. combinations	Description
1	1	1	2	It indicates whether the transponder is used for animal ID or not. In all animal applications this bit shall be 1
2-4	3	1	8	Retagging counter (0 to 7)
5-9	5	2	32	User Information field (animal species code)
10-15	6	2	64	Empty - All zeros (reserved zone for future applications)
16	1	1	2	Bit indicating the presence or not of a data block (for the use in animals this bit shall be 0 = no data block)
17-26	10	4	1,024	Mandatory ISO 3166 numeric 3-digit country code preceded of 0
27-64	38	12	274,877,906,944	National Identification Code (unique number in each country from 000,000,000,000 to 274,877,906,943)

In 2011, ISO 24631-6 standardized the displaying forms of ID code transponder on the reader screen and the modes of its communication over a data connection. It was amended by ISO 24631-6 to display the country and e-ID codes, but not the retagging counter value, user information (EU, species code) and the additional information fields. However, the format used for the optional fields remains mandatory.

ICAR Guidelines. ISO agreed the International Committee for Animal Recording (ICAR) to be the registration authority to develop compliance procedures of RFID devices according to ISO standards. ICAR is a worldwide organization based in Rome, created in 1951 and focusing on standardization of procedures and methods for animal recording and testing of the recording equipment. ICAR has 4 sub-committees which offer permanent services to the members and 12 working groups which develop guidelines and standard methods of performance recording according to the technical development in the field conditions. There are 2 sub-committees of ICAR with activity directly relevant for farmers, as described by Rosati (2013):

- Animal ID sub-committee, which ensures the testing and the approval of visual and electronic ID devices. The exclusive code number assigned by ICAR to manufacturers guarantees that their ID devices fulfill both ISO standards 11784/85.
- Recording Devices sub-committee, which is related to testing and approving the recording devices according to their performances.

Within the agreement updated by ISO in 2006, ICAR tested hundreds of ID devices and approved most of them, offering certification of their quality to the worldwide animal industry. The list of approved ID devices and other relevant ICAR activities are available on the website (http://www.icar.org/pages/ICAR_approvals/ICAR_Approvals.htm).

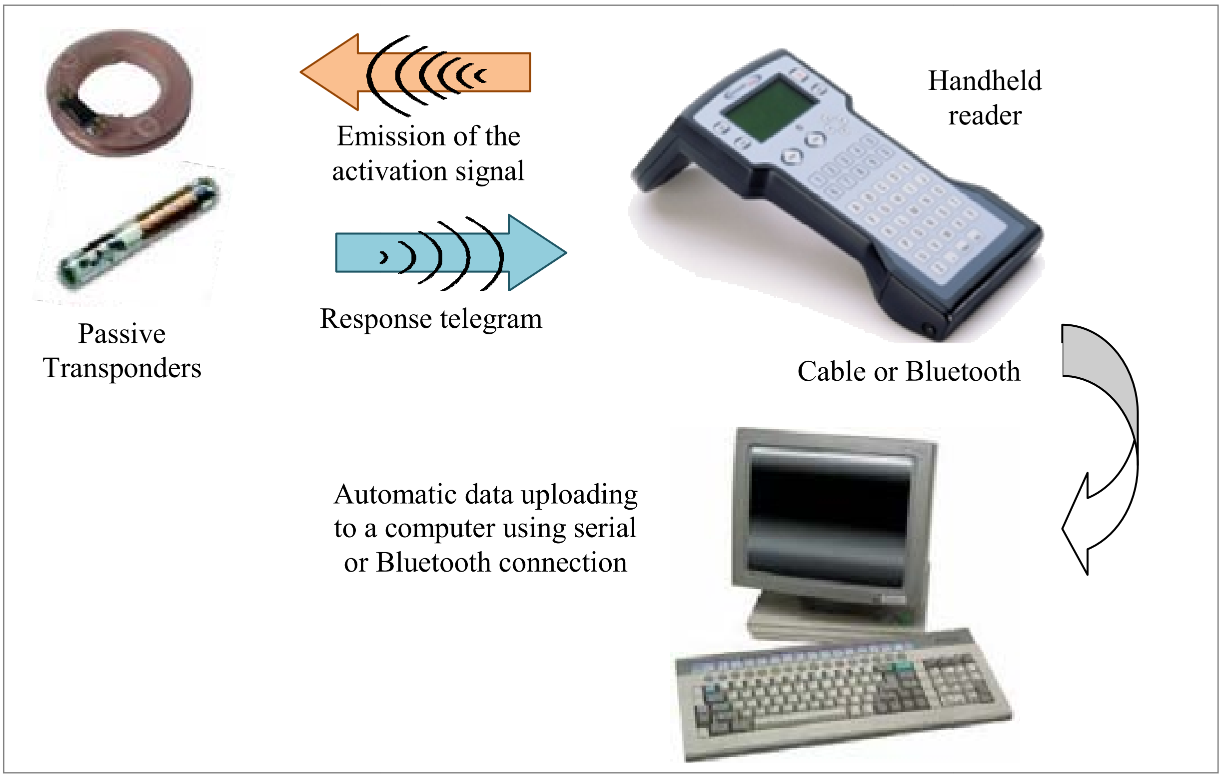
1.1.2 Use of Electronic Identification

It's obvious that acquisition and use of visual ID devices (e.g., v-ET, v-LT) and manual recording tools (e.g., forms, notebooks and pencils) are less expensive and its use did not require advanced expertise, compared to e-ID. However, the need of more detailed information and the increase in flock size, made v-ID and manual recording systems laborious and less practical.

Livestock e-ID had its origin towards the end of the 60's (Hanks, 1969) and it is based on the use of RFID waves in the low frequency band (100 – 150 kHz). The e-ID device is called 'transponder' (transmitter and responder) and it uses passive technology (without batteries). It consists of 2 main parts: 1) an integrated circuit (containing a unique code, memory for storing and processing of data, modulating and demodulating radio signals), and 2) an antenna for receiving and transmitting signals.

As shown in Figure 1.2, the reader generates an electromagnetic field which activates the passive transponder and receives a RF wave which contains an encoded telegram. The transponder code is translated and displayed on the reader screen and can be sent to a computer once a serial or Bluetooth connection is established.

Figure 1.2. An Operational e-ID system with interchange of radio signal and e-ID code between transceiver and transponder, and automatic data uploading to a computer.



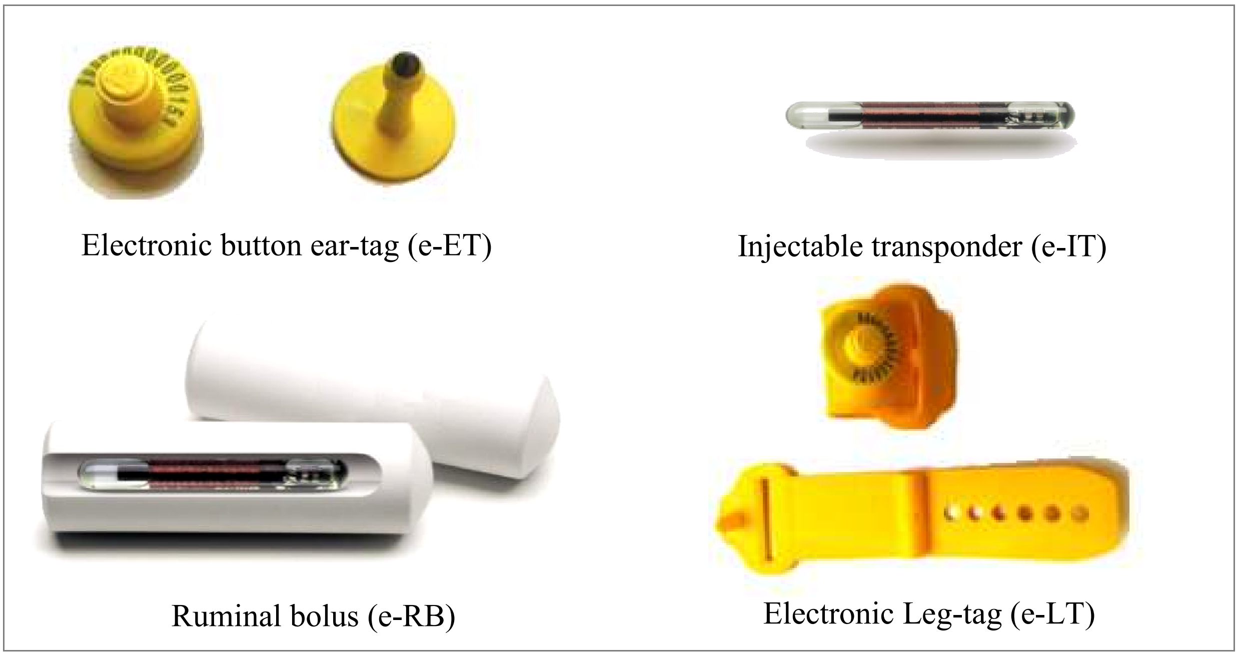
In the current sheep and goat industry, there are 4 main types of RFID devices used for e-ID according to their position on the animal's body (Figure 1.3):

- e-ET: Designed to be attached to the animals' ear and used in all livestock species. Their main advantage is to be visible, but its main drawback is not to be fully tamperproof.
- e-RB: Designed to be used exclusively in ruminants and consisting of capsules containing transponders. The capsules are specially made of resistant and dense materials, transparent to the RF waves, being orally dosed and mainly retained in the reticulo-rumen of ruminants (Caja et al., 1999a; Fallon, 2001; Ghirardi et al., 2006a,b; Carné et al., 2011). The major advantage of e-RB, compared to other e-ID devices, is that they are highly retained and tamperproof.
- e-IT: Designed to be injected under the skin of animals (e.g., subcutaneously, intramuscular or intraperitonealy) and usable in all livestock species. However, losses, migration to other parts of the body, bio-incompatibility to the glass or plastic capsules

or to the added antimigration substances (i.e., parylene), and its occasional breakage and retrieval difficulties in the slaughterhouse are the main drawbacks in practice.

- e-LT: Attached to the shank of the hind leg of different animal species and mostly used for sheep, goats and birds.

Figure 1.3. Electronic identification devices authorized by EU legislation for sheep and goats



With respect to the readers (transceivers), they can be of different types depending on if they just read the e-ID codes or they associated it to other data (i.e., performances). According to Artmann (1987), Diependaele (1995) and Caja et al. (1998b), the smart transceivers can markedly improve efficiency of livestock management. As shown in Table 1.5 and considering the mode of reading (for restrained or animals in movement), transceivers are classified in 2 groups:

1. **Hand-held readers (HHR)**: To be used in restrained animals, they work as small portable computers with capacity to store and immediately process the collected data. Moreover, they are provided of memory and able to be used for performance recording. The main advantage of this kind of readers is the possibility of uploading into their memory personalized software adapted to needs of the user. Data uploaded are associated with the e-ID code that is shown at the time at which the transponder is read. Moreover, the data can be directly printed or downloaded into/or uploaded to a computer. These main configurations of HHR are possible:

Table 1.5. Summary of characteristics of different transceiver types and purchase cost

Item	Handheld readers for restrained animals			Stationary reader unit for animals in movement
	Stick and mobile printer	Simple or multifunction	Including operating system	
Figures				
Characteristics	Robust & protected Reduced screen to show a simple list of e-ID Mobile printer optional Facilitate animal e-ID & avoid bending to read	Robust & protected Input individual animal data, maintain flock records, Adapted functions No data processing but automatically uploaded	Robust & protected with advanced keyboard & screen Integrated or associated stick antenna Include OS, software for data processing, GPS optional	Composed by a box (reader) and an associated panel antenna Panel antenna fixed laterally on the walls of race ways Continuous e-ID capture & produce a list of sheep numbers
Connection	Bluetooth or serial	Bluetooth or serial	Bluetooth	Bluetooth or serial
Minimum reading distance, cm	25	25	25	50
Supply & memory	Internal battery Internal memory	Internal rechargeable battery Internal memory available	Internal rechargeable battery Internal memory available	Battery or AC supply No memory, automatic e-ID reading & data transfer to pc
Purchase cost, €	300 to 800	400 to 800	1,000 to 1,400	1,200 to 2,000

- Stick readers: Designed for simple and easy reading. They display the code numbers and create simple animal sub-groups with time and date of reading. They can be optionally provided with a mobile printer. Current prices: €300 to 800.
- Handheld readers: Allow the automatic reading through an integrated antenna. They can be simple or in the form of a box with multi-functions and a digital keypad. The last allow adding easily basic management information. Prices for simple and advanced models ranged from €200 to 400 and €500 to 800, respectively.
- Handheld readers with operating system: They are like mini computers for operating under on-field conditions, and they allow individual animal data storage in combination with performance recording. They can be integrated with more advanced electronic devices, such as weighing scales. Current prices: €1,000 to 1,400.

2. **Stationary reading unit** (**SRU**): Designed to be used for dynamic reading of animals in motion. There is a simple type, which captures only animal e-ID, and advanced type which linked the e-ID with other collected data. Electromagnetic interferences can drastically reduce the reader's performance. Choice of the stationary reader, sitting and installation and nature of the power supply, are key features for SRU (Marguin et al., 2011; DEFRA, 2014). Current prices: €600 to 2,000.

Furthermore, reading distances vary dramatically according to transceiver type. For this reason, the CE 933/2008 regulation recommended minimum values that should be taken into count while reading e-ID devices as following:

- 12 cm for an e-ET and e-LT when read with a HHR,
- 20 cm for a e-RB and e-IT when read with a HHR,
- 50 cm for all types of e-ID devices when read with a SRU.

1.2 Performance Recording of Sheep and Goats: State of the Art

Sheep and goat farms produce mainly meat, fleece and milk. According to the breed, they offer unique or mixed performances for recording. Usually, performances of sheep and goats are recorded at 2 main levels:

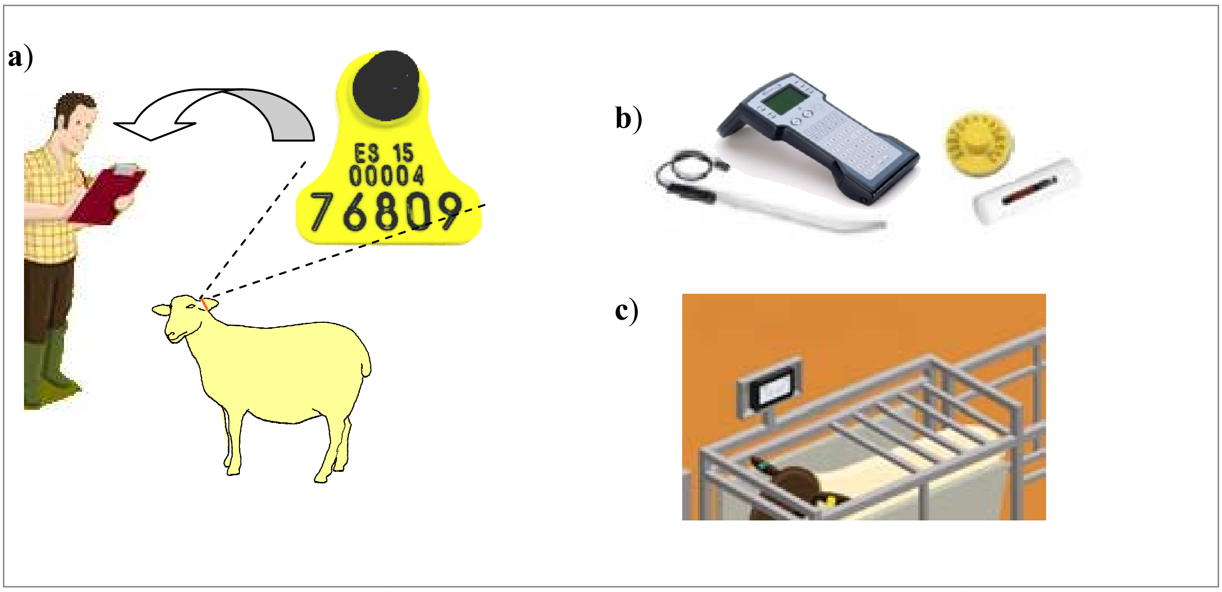
- At a national level for public health, genetic improvement and traceability purposes, where the registration is carried out by officers according to a government or industry authorities' procedures.

- At a farm level, performed directly by the stakeholders or farm services, for their economy, management or to be included in databases for genetic improvements.

Methodology of performance recording varies depending on the productive purposes and the animal performances. According to ID devices, the technology used and animal management, 3 main methods of performance recording at the farm level are used (Figure 1.4):

a) Conventional method, based on v-ID by reading an ID code printed in the ear-tag surface, and manual recording of sheep performances on paper forms.
b) For restrained animals, they use HHR provided or no of stick antennas and keyboard. They are used for automatic reading of e-ID.
c) For animals in motion by using SRU for the automatic reading of e-ID and the recording of the performances (e.g., body weight by electronic scale).

Figure 1.4. Visual (a) and electronic techniques (b, restrained animals; c, animals in motion) of e-ID reading and performance recording



Data of performance recording contain mainly: 1) the individual ID code, and 2) the related animal performances. With regard to techniques used for performance recording of livestock, they should be simple, reliable, and inexpensive. It can be performed objectively, using conventional or electronic tools (e.g., measurement of body live weight with an electronic scale), or subjectively assessed by trained operators using an established scale (e.g., body condition score by manual palpation, udder typology).

Aided by the study of Holst (1999), we summarized in Table 1.6 the most common performance recording types practiced in sheep and applicable for small ruminants.

Table 1.6. Productive traits and performance recording techniques in sheep (modified from Holst, 1999)

Sheep	Productive aim	Recorded trait	Assess/Measure
Ewe	Milk	Quantity	Milk meter (L or kg)
		Quality	Laboratory analyses
	Lambing	Lambs per litter	Visual assessment
		Weight	Weighing scale
		Body condition score	Palpation
	Fleece	Color	Visual assessment
		Diameter	Laboratory analyses
		Weight	Weighing scale
	Reproduction	Fertility	Lambed ewes, ultrasonography
		Lamb survival	Lambs sold/ewes pregnant
	Culling	Weight	Weighing scale
		Health conditions	Veterinary assessment
Lamb	Body weight	Birth weight	Scale
		Growth rate	Periodical weighing
	Meat quality	Tissue fat depth	Palpation or ultrasound pre- or post-slaughter
		Muscle dimension	Real time scanning pre-slaughter
	Feed conversion	Intake and weight	By pen

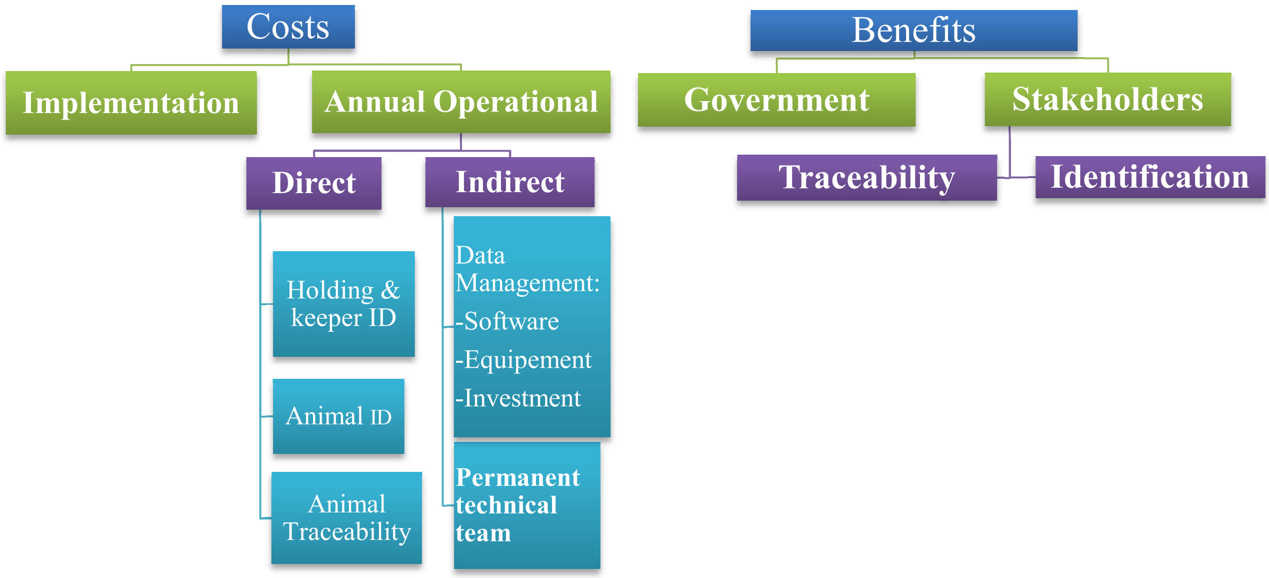
1.3 Cost-Benefit of Identification and Registration

Despite the mandatory character of e-ID in EU countries, there is no doubt about the technical superiority of ID&R electronic systems compared to conventional ones. Furthermore, administration and farmers are concerned for the cost associated of such systems. At nowadays, the RFID technology has hugely developed and is being applied in the most productive and service companies. Moreover, the expansion of RFID techniques for livestock ID was boosted by the decreasing prices and availability of a large variety of user-friendly RF readers. Conventional ID and performance recording systems will not be compliant with the great demand of information and processing expected in a next future. Moreover, e-ID is a must for the livestock precision systems (LPS).

As shown in Figure 1.5, an animal ID and traceability (**AIT**) system concerns government and stakeholders and, according to Rehben (2013), it can be performed in 4 steps:

1) Description of the AIT system and the agrifood sector
2) Inventory and categorization of stakeholders
3) Cost evaluation for each sector
4) Cost benefit evaluation for each stakeholder

Figure 1.5. Cost-benefit diagram of identification and traceability system (Rehben, 2013)



1.3.1 National Level (Primary Benefits)

At outbreaks of contagious diseases like BSE (mad cow), FMD (Foot-and-Mouth Disease), swine flu and bird flu, countries over the world needed to implement policies and procedures for livestock ID in order to:

1) Protect public and animal health,
2) Ensure whole traceability of individual animals,
3) Provide safe livestock products to the market.

In the same context, The European Union, the US, Canada, Uruguay, China, Australia and New Zealand have either performed or are in the process to require legislation for livestock e-ID. Australia and the EU were the pioneer in implementing animal ID&R systems at national level. Australian NLIS (National Livestock Identification Scheme) is the largest implemented system of animal tracking in the world. In contrast, the National Animal Identification System (NAIS) of the USA has a voluntary implementation character comparing to EU. In other world parts, there is a concern to build specific ID&R systems adapted to conditions and necessity of each country.

Additionally, a complete ID&R implementation system for sheep and goats at national level is achieved when the following objectives are well fulfilled:

1) Permanent ID of individual animals at early ages or before leaving the premise of birth.
2) Indication of the holding where animals are kept.
3) Official sheep and goat movement recording, as stated in EU regulation.
4) Computerized networked databases properly updated and easily consulted.

In relation to the implementation of sheep and goats ID&R systems, and taking into account the above indicated points, the most important costs should be considered firstly at the moment of implementation and secondly at annual activities (i.e., inventory, re-identification, inspections).

With regard to the primary benefits from an animal ID&R system, they concern to the improvement of government abilities to quickly and successfully contain a food safety incidence or a disease outbreak. On our knowledge, scarce information is available on the evaluation of these benefits. Main difficulties encountered to assess these benefits are mainly related to the unpredictable character of the diseases and the percentage of animals recorded in the system. However, Ruhil et al. (2013) mentioned in their study various primary benefits of implementing a national ID system:

- Improvement of milk yield through selective breeding
- Animal disease control and eradication
- Flock improvement programs
- Tracking animals through trading
- Monitoring a movement of animals
- Vaccination and health programs
- Implementation of governmental or industry policies
- Confidence of the consumer in traceability of livestock products
- Control of animal diseases outbreak
- Better access to international market for meat and dairy exporters.

1.3.2 Farm Level (Secondary Benefits)

In order to demonstrate the advantages of implementing an e-ID system for performances recording in sheep farms, our study included a cost-benefit study. Commonly, such analyze are used by governments and other organizations (i.e., private sector business) to assess the interest of a given project or policy. According to Encyclopædia Britannica (2013), cost-benefit analysis (**CBA**) attempts to measure the social benefits of a proposed project in monetary terms and compare them with its costs. The procedure was first proposed in 1844 by the French engineer J. Dupuit. It was not seriously applied until the 1936 U.S. Flood Control Act, which required that the benefits of flood-control projects exceed their costs.

Recently, Boardman (2006) suggested nine steps that should be taken in consideration to perform a CBA:

1) Specify alternative projects or programs.
2) Decide whose benefits and costs count (stakeholders).
3) Select measurement indicators and measure all cost/benefit elements.
4) Predict outcome of cost and benefits over relevant time period.
5) Convert all costs and benefits into a common currency.
6) Discount benefits and costs (discount rate) to obtain present values.
7) Calculate the net present value of project options.
8) Perform sensitivity analysis.
9) Adopt recommended choice.

Few data are available demonstrating objectively the advantages of using e-ID at a farm level, but there are studies which demonstrating the benefits and advantages of implementing e-ID systems for cattle and pigs (Disney et al., 2001) and for sheep and goats (San Miguel et al., 2004; Saa et al., 2005).

As aforementioned, there are many expected benefits when implementing an individual animal ID system at the farm level. In their study, Ruhil et al. (2013) mentioned some considerations in order to assess the benefits from such systems. They are:

- Type of farm and conditions of productions.
- Quantity of automatic devices present in the farm.
- Number and types of performances recording annually done.

CHAPTER 2

Objectives

CHAPTER 2.

OBJECTIVES

The core goal of the thesis was to evaluate the secondary benefits offered by the use of electronic identification (e-ID) in sheep and goat farms. In order to shed light the goal of our study, comparison of visual ID (based on the use of management or official plastic ear tags) and e-ID (based on the use of electronic standard- or mini-boluses) was made by measuring the labor time saved and the committed errors during performance recording in dairy sheep and goats.

The study made specific comparisons between the manual system (M), based on visual ID and manual data management using paper forms, and a system using e-ID based on electronic ruminal bolus for ID and handheld or stationary readers for automatic data management, in sheep and goat farms according to the requirements of the European regulation 21/2004 (modified by CE 933/2008 and CE 759/2009) and the Spanish Real Decreto 947/2005 (updated by RD 1486/2009), for the most common performance recording tasks done at farm level:

1. Milk recording of dairy goats milked once-daily in a conventional side by side milking parlor (Casse system) comparing:
   - Manual milk recording and,
   - Semi automatic milk recording
2. Evaluation of using e-ID for performance recording in dairy and meat flocks:
   - Milk recording of dairy ewes milked once- or twice- daily in a casse milking parlor (equivalent to the AT4 and A4 milk recording systems standardized by ICAR (2012):
     - Milk yield performances
     - Milk recording and data transfer times
     - Milk recording errors
   - Lambing data recording in dairy and meat ewes for flock-book registration.
   - Body weight recording in dairy and meat ewes by using an electronic scale.
3. Results of the experiments were integrated into a cost-benefit calculation considering 4 case-studies of dairy (once or twice milk recording) and meat (extensive or intensive systems) sheep farms under Spanish exploitation conditions.

4. Finally, the results obtained are discussed with regard to existing bibliography, as well as, giving advantages for farmers of applying e-ID systems for performance recording in sheep and goat farms.

This thesis was partially developed at 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

Comparison of manual versus semiautomatic milk recording systems in dairy goats

CHAPTER 3.

Comparison of Manual versus Semiautomatic Milk Recording Systems in Dairy Goats

3.1 ABSTRACT

A total of 24 Murciano-Granadina dairy goats in early-mid lactation were used to compare the labor time and data collection efficiency of using manual (M) vs. semi-automated (SA) systems for milk recording. Goats were milked once daily in a 2 × 12 parallel platform, with 6 milking units on each side (3 units/operator) and automatic head lockers, and concentrate was distributed manually. The M system used visual identification by large plastic ear tags (48 × 38 mm, recorded with 3 digits of 27 × 10 mm each), on-paper data recording (ear tag number, milk yield and observations), and data were manually uploaded to a computer. The SA system used electronic identification (21 × 68 mm and 75 g ceramic boluses, containing 32 × 3.8 mm HDX transponders), automatic identification (hand-held reader with a stick antenna), manual data recording on reader keyboard (milk yield and observations) and automatic data uploading to computer by bluetooth connection. Data were collected for groups of 2 × 12 goats for 15 test days of each system during a period of 70 d. Time data was converted to a decimal scale. No difference in milk recording time between M and SA (1.32 ± 0.03 and 1.34 ± 0.03 min/goat, respectively) was observed in the milking parlor. As expected, time needed for transferring data to the computer was greater for M when compared to SA (0.20 ± 0.01 and 0.05 ± 0.01 min/goat; $P < 0.001$). Total milk recording time, corrected by milk yield, was greater in M than in SA (1.52 ± 0.04 vs. 1.39 ± 0.04 min/goat; $P < 0.001$), the latter significantly decreasing by operator training throughout test days ($P < 0.01$). Time for transferring milk recording data to the computer was 4.81 ± 0.34 and 1.09 ± 0.10 min for M and SA groups of 24 goats, respectively, but only increased by 0.19 min in SA for the next additional 24 goats. No difference in errors at data acquisition was detected between systems during milk recording (0.6%), but an additional 1% error was found in the M system during data uploading. Predicted differences between M and SA increased with the number of goats processed on the test-day, ranging from 3.0 to 77.3 min for 24 to 480 goats, respectively. Reduction in labor time cost ranged from €0.5 to 12.9 per milk recording, according to number of goats, and accounted for 40% of the electronic identification costs. In conclusion, electronic identification proved more efficient for labor costs and resulted in fewer data errors, the benefit being greater with trained operators and larger goat herds.

3.2 INTRODUCTION

Automation of milk recording in dairy small ruminants may be a way of reducing costs and human errors (Astruc et al., 1992; Ricard et al., 1994; Ilahi et al., 1999) due to the large number of animals processed on the test-days. Although automatic equipment is available on the market (Afimilk, 2014; DeLaval, 2014), in practice few commercial goat farms have implemented automated milk recording systems. The main drawback for farmers is the high acquisition cost of the equipment required for automatic goat identification (ID) and for the recording of milk volume or milk flow.

Electronic identification (e-ID) of goats, using glass encapsulated transponders s.c. injected in the armpit, jointly with manual milk recording, were implemented in 1995 for the official milk recording of the ARCC (Catalonian Dairy Goat Association, Barcelona, Spain) (Caja et al., 1999b). As reported, total milk recording time and data processing errors were significantly lower when compared to visual ID and manual milk recording (Caja et al., 1999b). More recently, injectable transponders have been substituted by electronic boluses, according to European Union (EU) Regulation 21/2004 and Spanish legislation (Real Decreto 947/2005), which proposes the mandatory use of e-ID after 2008 in all EU states with a total sheep and goat population over 600,000.

An electronic bolus is a high density capsule containing a passive transponder which is orally administered and retained in the reticulo-rumen during the animal lifespan (Caja et al., 1999a; Fallon, 2001; Ghirardi et al., 2006a,b). Bolus retention rate in goats may vary according to bolus design (Ghirardi et al., 2006a,b; Carné et al., 2011) but goat ID by optimized electronic boluses using ISO (International Organization for Standardization) transponders (ISO, 1996a) has been proved efficient under practical farming conditions (Caja et al., 1999a; JRC, 2002; Pinna et al., 2006).

The objective of this study was to evaluate the impact of using e-ID in a semi-automated system for milk recording of dairy goats on labor time and data collection efficiency when compared to the conventional system based on visual ID and manual data collection.

3.3 MATERIAL AND METHODS

3.3.1 Animals and Management Conditions

Animal care conditions and management practices agreed with the procedures stated by the Ethical Committee of Animal and Human Experimentation of the Universitat Autonoma de

Barcelona (UAB) and the codes of recommendations for the welfare of livestock of the Ministry of Agriculture, Fisheries and Food of Spain (MAPA, 2007).

A total of 24 multiparous Murciano-Granadina dairy goats, located on the experimental farm of the S1GCE (Servei de Granges i Camps Experimentals) of the UAB in Bellaterra (Barcelona, Spain), were used. Goats gave birth during autumn (September to October) and were milked once daily throughout lactation according to Salama et al. (2003). Milking was done at 0900 h in a double-12 stall Case system parallel milking parlor (Westfalia-Surge Ibérica, Granollers, Spain) equipped with a low milk pipeline, 6 milking units on each side, recording jars, and automatic head lockers. Typical milking settings for the breed were used (vacuum, 42 kPa; pulsation rate, 90 pulses/min; and pulsation ratio, 66%). Milking routine, to which the goats were adapted in previous lactations, included machine milking (cluster attachment without udder preparation), machine stripping, cluster removal and teat disinfection by dipping (P3-cide plus, Henkel Hygiene, Barcelona, Spain). Goats grazed Italian rye-grass for 6 h/d and were supplemented with 0.5 kg/d of alfalfa pellets in the shelter, and with 0.5 to 1.0 kg/d of a commercial concentrate (1.53 Mcal NEL/kg; 16% CP, as fed) according to lactation stage, in the milking parlor.

Experimental period was initiated when the goats were in early-middle lactation (60 to 120 DIM) and consisted of 15 milk recording test days in 24 goats for each treatment during 70 d (720 milk recording data). Milk recording data were collected by parlor side in random groups of 12 goats.

3.3.2 Manual Milk Recording

Additionally to the plastic round button ear tags (Azasa-Allflex, Madrid, Spain) used for mandatory health programs in Catalonia, goats were identified in the left ear with a second plastic ear tag of flag type and large size (48 x 38 mm, yellow color; Azasa-Allflex). These ear tags were manually marked with 3 digits of 27 × 10 mm each (black plastic ink, Allflex Tag Pen, Dallas, TX) for easy reading in the manual (M) identification system experimental treatment.

At the M milk recording, groups of 12 goats were individually identified by sequential visual reading of the large ear tags (from the front side of the milking parlor platform with the help of the milker) and their numbers recorded in sequential order on paper forms. Time necessary for ID of the 12 goats was recorded by using an electronic chronometer (Geonaute Trt'L 100, Decathlon, Alcobendas, Spain). Milking time, including individual recording of milk yield (but not milk sampling) and observations (i.e. suspected mastitis, cluster fall down, etc.), were separately recorded for each 12-goat group using the same chronometer and paper form.

Finally, milk recording data were manually uploaded to a computer spreadsheet data base.

3.3.3 Semi-Automatic Milk Recording

All goats were also electronically identified with an electronic bolus (75 g; 21 × 68 mm, Rumitag, Barcelona, Spain) which consisted of a high density ceramic capsule containing an ISO radiofrequency transponder (ISO, 1996a) and were used for the semi-automatic (SA) milk recording treatment. Transponders were of half-duplex technology, glass encapsulated (32 × 3.8 mm) and marked with a serial code which included the manufacturer code (code 964, Rumitag, n = 18; code 983, Tiris, Almelo, The Netherlands, n = 6) according to the International Committee for Animal Recording (ICAR, 2012).

Reading of electronic boluses was done by using a hand-held intelligent transceiver with internal memory and keyboard (Smart Reader, Rumitag), which could be connected to a 70 cm long stick antenna (SAS-ISO, Rumitag). A list of equivalences (correspondence between transponder identification code and visual ear tag number) was previously uploaded from a computer to the transceiver memory by means of a Bluetooth connection using the software provided by the manufacturer (Smart software v.3.3.2, Rumitag).

Groups of 12 goats were individually identified by reading their boluses at the time of milk recording by the same operator doing the milk recording. Boluses were read from the goat's rear side (milking parlor pit) by approaching the stick antenna of the hand-held transceiver to the reticulum (cranial left side) or to the barrel (ventral rumen sac) of the goat in order to read the transponder contained inside the bolus. Milk yield and observation data were typed by the operator on the transceiver keyboard. Data were stored in the memory of the transceiver and automatically uploaded to the computer by using the Bluetooth connection and the same software as above. Milk recording time for the group of 12 goats, including time for identification and recording of milk yield and observations, was recorded by using the chronometer.

3.3.4 Statistical Analyses

Data were analyzed by ANOVA using the PROC GLM (version 9.1; SAS Inst. Inc., Cary, NC). Time measurements were converted to a decimal scale (1 min = 100 units) for calculations. The statistical model for milk recording time contained the effects of the milk recording system or treatment (M, SA), the milking recording groups (1 or 2), the test-day (d 1 to 15), the first order interactions, and the residual error. Milk yield of each goat group at the test day was used as covariate. When the probability of the factor or the interaction term was non significant (*P* > 0.20), it was deleted from the model. Comparison of times for M or SA systems data upload was analyzed for groups of 24 goats performed on the same test day.

Differences between least square means (LSM) were separated using the PDIFF test in SAS and declared significant at *P* < 0.05. Pearson's correlation coefficients were also calculated.

3.4 RESULTS AND DISCUSSION

Goat individual milk yield during the experiment ranged between 0.33 and 4.10 L/d, averaging 1.93 ± 0.04 L/d (Table 3.1). No differences (*P* > 0.05) in milk yield according to milk recording system and goat group were detected but, as a result of stage of lactation, milk yield decreased (*P* < 0.001) throughout the experiment. Monthly coefficient of persistency for milk yield was 91.4%, showing the typical flat lactation curve of Murciano-Granadina dairy goats milked once daily (Salama et al., 2003). Measurement of milk rate at recording did not differ between M and SA systems, averaging 1.46 ± 0.04 L/min (Table 3.1). Consequently, milk yield or milk flow rates were similar between treatments during the experiment.

Table 3.1. Comparison of manual and semi-automated milk recording systems in dairy goats (Values are Least Square Means ± SE)

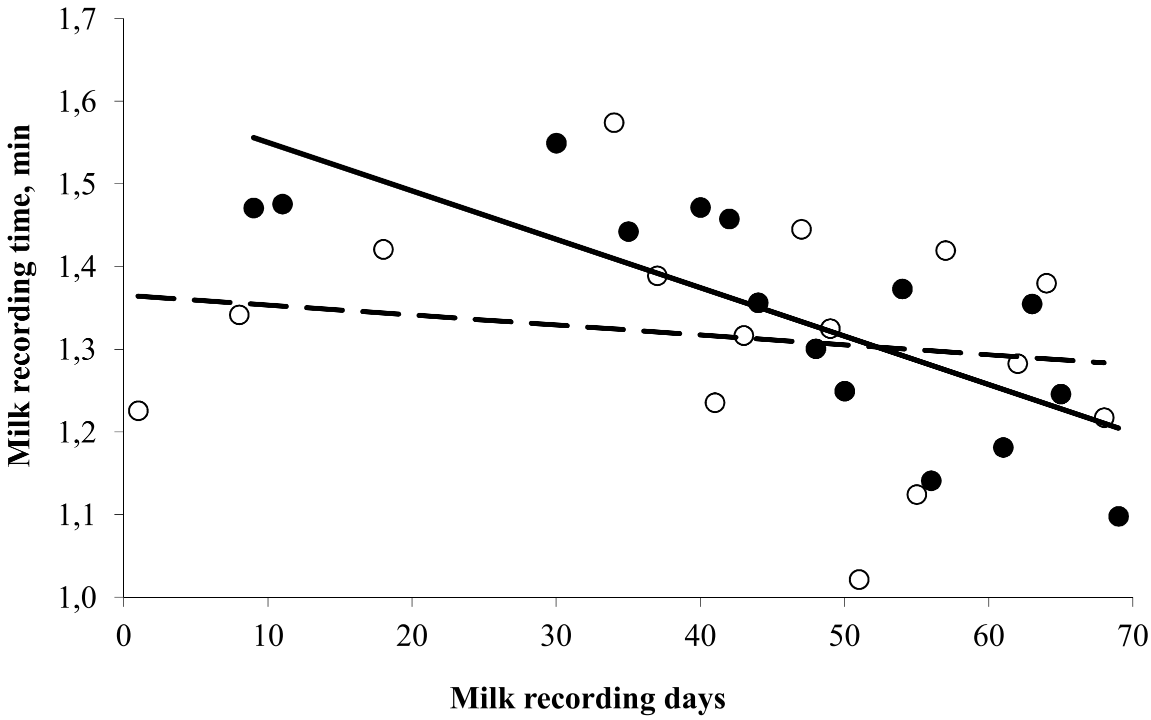
Item	System		Effect
	Manual	Semi-automatic	(*P* =)
Records, n	360	360	-
Milk yield per goat, L/d	1.91 ± 0.04	1.94 ± 0.04	0.156
Milk rate at recording, L/min	1.45 ± 0.03	1.46 ± 0.04	0.539
Group recording time, min/24 goat[1]			
Milk recording[2]	31.45 ± 0.60	32.16 ± 0.69	0.505
Data transfer[3]	4.81 ± 0.34	1.09 ± 0.10	0.001
Overall	36.26 ± 0.91	33.25 ± 0.91	0.011
Unitary recording time, min/goat[1]			
Milk recording[2]	1.32 ± 0.03	1.34 ± 0.03	0.511
Data transfer[3]	0.20 ± 0.01	0.05 ± 0.01	0.001
Overall	1.52 ± 0.04	1.39 ± 0.04	0.002
Errors, n			
Milk recording	2 (0.6%)	2 (0.6%)	-
Data transfer	4 (1.1%)	0	-

[1]Group of 24 goats in a double-12 stall parallel (side by side) milking parlor; time expressed in a decimal scale (1 min = 100 s). [2]Includes goat identification, machine milking, machine stripping and collecting milk recording data. [3]From paper forms or intelligent transceiver to computer data base.

Time required for milk recording of each group of 12 goats (including goat ID, machine milking and machine stripping, but excluding goat entrance and exit in the milking parlor and teat disinfection after milking) was 15.90 ± 0.32 min on average during the experiment. There was no difference ($P > 0.05$) in milk recording time between M and SA treatments, either when expressed per batch of 24 goats (2 milking platforms) or as unitary time per goat, as shown in Table 3.1. Although first order interactions were in general non-significant and were deleted from the model, a significant interaction between milk recording system and milk recording test day ($P = 0.029$) was detected for time required for milk recording.

As shown in Figure 3.1, milk recording time for group of 12 goats in SA milk recording decreased linearly at a rate of 0.006 min/d ($r^2 = 0.40$, $P < 0.001$) when test days progressed during the experiment (15 milk recording events in 70 d), indicating that operator skill for using the SA system increased and resulted in saving time for milk recording. This effect was

Figure 3.1. Effect of operator experience for milk recording time when using the manual (M, ○) or semi-automatic (SA, ●) milk recording systems in dairy goats. The regression for the SA system (—) was significant ($y = 1.61 - 0.006\ x$; $r^2 = 0.40$, $P < 0.001$), but was non-significant for the M system (–––).



not observed in the M system, for which the regression between milk recording time and milk recording day was non significant ($r^2 = 0.03$, $P > 0.05$) proving that no extra training was necessary. At the end of the experimental period (d 70), the estimated times for SA and M were 1.19 and 1.28 min/goat, respectively, the difference being 0.09 min/goat (6 s/goat) or 2.16 min/24 goats.

With regard to data transfer, a significant ($P < 0.001$) reduction in time needed for transferring milk recording data to the computer spreadsheet was observed in favor of SA system (Table 3.1); the reduction of using electronic transfer was 3.72 min/24 goats or 0.15 min/goat (9 s/goat) compared to the paper based M system.

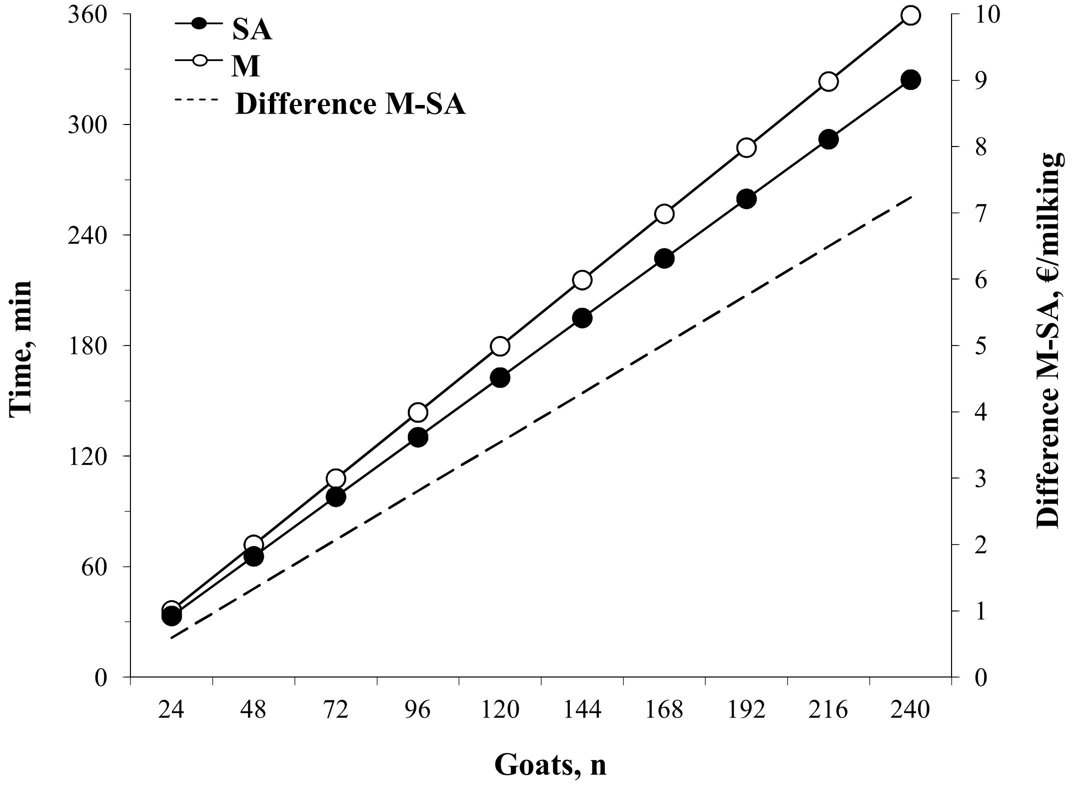
Total transfer time in the M system linearly increased with number of goats processed at a constant rate of 4.81 min/24 goats (i.e. 48 goats, 9.62 min; 72 goats, 14.43 min). The increase was only 0.19 ± 0.01 min/24 goats for the SA system, obtained by measuring the transfer time in 10 simulations of 48 goats from previously collected data.

Registered errors during milk recording were approximately 0.6% for both milk recording systems, and corresponded to 1 reading and 1 typing error in M, and 2 incorrect automatic readings of goats in SA. Moreover, 1.1% typing errors were also produced in the M system during data transfer (Table 3.1).

Finally, overall time needed for milk recording and data transfer jointly was greater ($P <$ 0.05) for M compared to SA system (Table 3.1), the difference being 3.01 min/24 goat or 0.13 min/goat (8 s/goat). This difference increased according to number of goats processed on the same test day as shown in Figure 3.2 for herd sizes of multiples of 24 (2 milking platforms of 12 goats) and between 24 and 480 goats. Billon and Baritaux (1999), and Peris et al. (1999) indicated that a range of 40 to 200 goats/h can be milked in a 2 × 12 side by side milking parlor (Casse system), depending on milking routine and milking frequency (once or twice daily), which is adequate for medium size goat herds lower than 500 goats.

As a result, for a work wage of €10.0/h or €0.167/min, the use of the SA system would produce a saving in labor cost ranging from €0.5 to 12.9 per milk recording, for goat herds from 24 to 480 goats, respectively (Figure 3.2). On the other hand, the SA system saving can only be obtained if all the goats are previously e-ID with a bolus and read (on average 6 test days per lactation) with a transceiver. According to the unitary prices on small scale in the EU during 2007 (bolus, €1.4; hand-held transceiver, €400), for an amortization period of 5 yr and a minimum of 20,000 readings/yr (200 d × 100 goats/d) the extra cost estimated for each milk recording in the e-ID goats was €0.051/goat. This cost value for an e-ID reading is in the range of the values previously reported by Saa et al. (2005) for sheep and goat in Spain.

Figure 3.2. Estimation of the overall time for milk recording of manual (M) vs. semi-automatic (SA) systems and value of labor time difference between both systems.



The estimated e-ID extra cost ranged between €1.22 and 24.48 for goat herds ranging 24 to 480 goats. The estimated saving of using the SA system (€0.50 to 12.9 for 24 to 480 goats) did not compensate the extra cost of using e-ID, but represented a contribution to the cost of implementing the e-ID of approximately 40%. The other 60% should be due to other uses of the e-ID in the farm (i.e. automatic registration, kidding recording, health programs, traceability, automatic weighing, etc.). In this regard, the Spanish Ministry of Agriculture is currently subsidizing the cost of the mandatory double system of sheep and goat identification used in Spain (1 plastic ear tag and 1 electronic bolus) to farmers implementing the European Regulation 21/2005 of sheep and goat identification and registration.

Although the main advantage of using the SA instead of the M system was the reduction in data transfer time, Caja et al. (1996) reported advantages in feasibility and reduction in number of operators needed for milk recording in dairy sheep, when e-ID boluses were read from the parlor pit (rear reading) vs. electronic ear tags read from the head lockers (front reading).

3.5 CONCLUSIONS

Obtained results in this experiment showed that the use of a semi-automatic milk recording system, based on the use of electronic boluses, has advantages in reading and transferring milking data in dairy goats. The semi-automatic system allowed the reduction of labor costs for milk recording and increased the truthfully of milk records, avoiding confusion and errors during data transfer. Advantages of the semi-automatic milk recording system would be greater for previously trained operators and for large goat herds.

Ongoing innovations of automatic milk data collection (i.e., milk volume, milk flow rate) and software for dairy herd management may also make more profitable the use of electronic identification in dairy goats in the future.

CHAPTER 4

Implementing electronic identification for performance recording of sheep:

1. Manual vs. semi-automatic milk recording in dairy farms

CHAPTER 4.

Implementing Electronic Identification for Performance Recording in Sheep: I. Manual vs. Semiautomatic Milk Recording in Dairy Farms

4.1 ABSTRACT

With the aim of assessing the secondary benefits of implementing the use of electronic identification (e-ID) in the sheep industry, radiofrequency boluses or visual ear tags were evaluated for milk recording. Manual (M) and semi-automatic (SA) milk recording systems were compared on 10 test-days during 70 d in a flock of 48 dairy ewes yielding 0.2 to 3.5 L/d. Ewes were machine milked once- (×1, n = 24) or twice- (×2, n = 24) daily in a 2 × 12 milking parlor. The M system consisted of visual identification (v-ID) by plastic ear tags, on-paper data recording and manual data transfer. The SA systems used: 1) v-ID complemented with a personal digital assistant (PDA) for data recording; or 2) e-ID with ceramic small-boluses (20 g; containing 32 × 3.8 mm half-duplex transponders) and a handheld reader (HHR) for sheep e-ID and milk data recording. Both PDA and HHR used Bluetooth connection for transferring data to a computer. Data were collected in groups of 24 ewes and time was converted to a decimal scale. Milk yield was 1.21 ± 0.04 L/d, on average, the ×1 being 30% lower than ×2 ewes. Milk recording time correlated positively with milk yield (r^2 = 0.71) and decreased as lactation advanced for all systems. Data transfer was markedly faster for both SA systems (P < 0.001) and slower in M (P < 0.001). As a result, overall milk recording time (including data transfer) was faster for both milking frequencies in SA systems (×1, 12.1 ± 0.6 min; ×2, 22.1 ± 0.9 min; P < 0.001) than for M (×1, 14.9 ± 0.6 min; ×2, 27.9 ± 1.0 min; P < 0.001) per group of 24 ewes. No differences between PDA and HHR were found. Time savings for both milking frequencies and with regard to M, were similar for PDA (×1, 2.8 ± 0.1 min; ×2, 6.0 ± 0.2 min; P < 0.001) and HHR (×1, 2.8 ± 0.4 min; ×2, 5.6 ± 0.6 min) per 24 ewes. Data transfer errors averaged 3.6% in M, whereas no errors were found in either SA system. In conclusion, HHR and PDA systems were time-effective for milk recording in dairy ewes, saving time and improving data accuracy. Working load and time for ewe identification were faster in HHR but it did not affect the milk recording time which depended on milk yield and individual milking time. The PDA was the fastest device for data download. Further research will evaluate the costs of implementing e-ID for other uses in sheep farms.

4.2 INTRODUCTION

Animal identification systems have evolved with technology, and nowadays different systems for the livestock industry are available and economically affordable (Caja et al., 2004; Bass et al., 2008). Among them, visual (v-ID; e.g., plastic ear tags) and electronic (e-ID; e.g., injectable, ear tag and bolus transponders) identification systems are frequently used in practice.

Despite being mandatory in some countries for sheep and goat, the primary objectives of adopting a national animal identification system (i.e., food safety, animal-borne outbreaks, animal health surveillance, disease eradication, animal product traceability) are not well understood by the stakeholders, because implementing an identification system increases their production costs. Cost of e-ID is related to the device performances and size of operations, being key the acquisition values of the tagging and reading devices (Saa et al., 2005; Butler et al., 2009).

Sheep farm efficiency is improved when adequate information is available for making decisions, which requires frequent data recording (e.g., flock inventory, performance recording). Permanent identification is a key for individual performance recording during the animal productive life. Although acquisition of v-ID devices is always less expensive than e-ID, its use is burdened by labor and costs associated with reading, data recording and data management, which are key steps in performance recording.

European Regulation CE 21/2004 (modified by CE 933/2008 and CE 759/2009) made e-ID mandatory in European Union member states with sheep and goat populations greater than 600,000 head. Nevertheless, there is a reaction against the obligatory character of this regulation based on the apparent lack of direct advantages for the stakeholders, which are currently supporting the cost of acquiring the e-ID devices.

On-farm performance recording practices, such as milk recording, require considerable time and labor from the farmers and are scarcely widespread in the world dairy sheep industry (ICAR, 2014; <20%). Combining e-ID with automatic milk meters offered the possibility of reducing the associated cost of automatic milk recording systems in dairy cows (Ordolff, 2001). Automatic milk meters for dairy small ruminants are also available (Ricard et al., 1994; ICAR, 2012) and are commercially offered in dairy sheep and goat milking parlors (Afimilk, 2014; DeLaval, 2014). Nevertheless, the use of e-ID and visual recording jars is a time and cost-effective alternative to automatic milk recording systems in dairy goat farms (Caja et al., 1999b; Ait-Saidi et al., 2008).

Sheep e-ID based on transponders included in ear tags (Caja et al., 1996; ADAS, 2006), injects (Caja et al., 1996, 1998b; Marie et al., 1994; Conill et al., 2002) and rumen boluses (Caja et al., 1999a; Garín et al., 2003; Ghirardi et al., 2006b), proved to be effective under on-field conditions. The choice of devices may depend on readability performances, species and breed, exploitation conditions and additional on-farm uses, as is the case of performance recording. Current interest in livestock precision techniques evidenced the need of developing new tools to record welfare indicators and performances (Morris et al., 2012; Cappai et al., 2014). Innovative and robust handheld readers, with user-friendly program interfaces (San Miguel et al., 2004; Abas et al., 2007) and affordable purchasing costs, are also needed (Samad et al., 2010).

There is no available information on the secondary benefits of using e-ID for dairy sheep farm management practices, including the monthly periodical milk recording test, which is a long time-consuming and costly duty (Milán et al., 2013). The objective of this study was to evaluate labor time and data errors of milk recording in dairy ewes when a manual system (M), based on ear tags and manual data collection, or semi-automatic (SA) systems based on: 1) v-ID and a personal digital assistant (PDA) for data recording; or 2) e-ID and a handheld reader (HHR) for data capturing and recording, were used.

4.3 MATERIAL AND METHODS

4.3.1 Animals and Management Conditions

Animal care conditions and management practices agreed with the procedures stated by the Ethical Committee of Animal and Human Experimentation (CEEAH) of the Universitat Autònoma de Barcelona (UAB) and the codes of recommendations for the welfare of livestock of the Ministry of Agriculture, Alimentation and Environment of Spain (MAPA, 2007).

A total of 48 dairy ewes (Manchega, n = 26; Lacaune, n = 22) located at the experimental farm of the SGCE (Servei de Granges i Camps Experimentals) of the UAB in Bellaterra (Barcelona, Spain), were used. Ewes were divided into 2 balanced groups according to milking frequency: once daily (×1; n = 24) and twice daily (×2; n = 24). Ewes were milked (×1, 0830 h; ×2, 0800 and 1730 h) in a double-12 stall Casse system (2 × 12) parallel milking parlor (Westfalia-Surge Ibérica, Granollers, Barcelona, Spain) equipped with a low milk pipeline, 6 milking units on each side, recording jars, and head lockers. Usual machine milking settings for the breeds were used (vacuum, 42 kPa; pulsation rate, 120 pulses/min;

and pulsation ratio, 50%). Milking routine included machine milking (after cluster attachment without udder preparation), machine stripping, cluster removal, and disinfection by teat dipping (P3-ioshield, Ecolab Hispano-Portuguesa, Barcelona, Spain).

Ewes grazed on an Italian rye-grass pasture for 6 h/d, and were supplemented with 0.5 kg of dehydrated tall fescue hay and 0.5 kg/d of alfalfa pellets in the shelter, and with 0.5 to 1.0 kg/d of a commercial concentrate (1.89 Mcal NEL/kg; 18.8% CP, as fed) in the milking parlor, according to milk yield.

4.3.2 Milk Recording Systems Comparison

The experiment was carried out when the ewes were in mid lactation (70 to 140 DIM) and consisted of 10 milk recording test-days at weekly intervals by treatment. Experimental design was a factorial with 2 fixed daily milking frequencies (×1 and ×2) and 3 milk recording systems applied at random (M, PDA and HHR). Milk recording data (n = 1,440) were collected in random groups of 12 ewes by milking frequency.

4.3.2.1 Manual Milk Recording (M)

Ewes were identified on the right ear with an official plastic ear tag (polyurethane, 2 yellow flags; male flag, 40 × 38 mm; female flag, 42 × 38 mm; total weight, 5.2 g; Azasa-Allflex, Madrid, Spain) which were laser recorded with 14 alphanumeric characters (country code, ES; 12 serial digits, the last 5 printed with a height of 8 mm) according to the Spanish legislation (Real Decreto 947/2005 updated by RD 1486/2009).

For M milk recording system, groups of 12 ewes were identified individually by reading visually the last 5 digits of the official ear tag, after being head-locked in the milking platform, and data were recorded on paper forms. Ear tags were cleaned at the start of the experiment and read by the milk recording operator from in front of the animal. Time necessary for v-ID of each 12 ewes was recorded by using an electronic chronometer (Geonaute Trt'L 100, Decathlon, Alcobendas, Spain). Milking time, including individual recording of milk yield without milk sampling, and observations (e.g., mastitis, cluster fall down) were recorded for each ewe group using the same chronometer and paper forms. Finally, milk recording data were manually transferred to an Excel (Microsoft Office 2003, Microsoft Corporation, Redmond, WA) spreadsheet on a desktop computer. Transfer time was recorded per group of 24 ewes.

4.3.2.2 Personal Digital Assistant (PDA).

Manual milk recording system was transformed in a SA system by typing the v-ID codes and the milk volume data into a PDA (Pocket PC iPAQ h2200, Hewlett-Packard, Palo Alto, CA) provided with an adapted Excel spreadsheet version. The same time as for the M system was considered for v-ID and milk recording by group of 24-ewes in this case. Transfer of the PDA recorded data to a computer was done using the appropriate software (Microsoft ActiveSynch 3.7, Microsoft Corporation) and the spreadsheet files were automatically uploaded and stored in a previously assigned folder. Transfer time was also recorded for groups of 24 ewes.

4.3.2.3 Hand Held Reader (HHR).

This SA system was based on using e-ID by high density ceramic small-boluses (20 g; 11 × 56 mm, Rumitag, Esplugues de Llobregat, Barcelona, Spain), according to the Spanish legislation (RD 947/2005 updated with RD 1486/2009). Each bolus contained a half-duplex glass encapsulated radio frequency transponder (32 × 3.8 mm) recorded with a serial number of 22 digits (animal bit, 1 translated as A; retagging counter, 0; user information-specie, 04; additional information, 000; country code, 724; national identification code, 12 serial digits) in agreement with the International Organization for Standardization (ISO) 11784 and 11785 standards (ISO, 1996a,b).

Electronic boluses were read using a HHR transceiver with internal memory and keyboard (Smart Reader, Rumitag) connected to a 70-cm-long stick antenna (Sas-ISO, Rumitag). Bolus e-ID was automatically captured placing the stick antenna in the left flank from the rear of the ewe, being the operator in the milking parlor pit, at the end of milking of each animal and according to the procedure previously described in goats by Ait-Saidi et al. (2008). Milk yield data and observations of each animal were typed by the operator on the transceiver keyboard. Milk recording time for groups of 12 ewes, including times needed for identification and milk volume and observations recording, was also measured by using the above indicated chronometer. Data were stored in the memory of the HHR and automatically transferred to a desktop computer in the form of text file data by using the Bluetooth connection and the appropriate software provided by the manufacturer (Smart software v.3.3.2, Rumitag). Data text files were uploaded into spreadsheet files. Transfer time was also recorded for groups of 24 ewes.

4.3.3 Dynamic Reading of Dairy Ewes

Time of entrance into the milking parlor was measured for a total of 500 passages of dairy ewes, in groups of 12 and on different test-days. Entrance time was the time elapsed from passing in front of a frame antenna (94 × 52 cm), placed on the left side of a race-way (width: 0.5 m) and at 10 m from the milking parlor entrance, and restraining all ewes in the head lockers of the milking stalls. Dynamic reading of the e-ID boluses was performed using an F-110 stationary transceiver (Rumitag) connected to the frame antenna and interfaced with a desk computer via RS232 connection. The F-110 unit automatically and simultaneously collected the e-ID number and time at which each ewe passed in front of the antenna by using commercial software (Gesmanga v2.6.2, Rumitag). Dynamic reading efficiency (DRE) was calculated according to Caja et al. (1999a) and Conill et al. (2000), using the following expression:

DRE (%) = [(no. read transponders) / (no. readable transponders)] × 100

Total time and number of ewes were also used to calculate the speed of passage through the race-way.

4.3.4 Statistical Analyses

Data were analyzed by ANOVA using the PROC GLM (version 9.2; SAS Inst. Inc., Cary, NC). The statistical model for milk recording time contained the effects of the milking frequency (×1 or ×2), the recording system (M, PDA or HHR), the test-day order (d 1 to 10), the first order interactions, and the residual error. Milk yield of each ewe at the test-day was used as covariate. Time measurements were converted to a decimal scale (60 s = 100 units) for calculations. Comparison of times for milk recording data transfer was analyzed for groups of 24 ewes performed on the same test day. Differences between least squares means (LSM) were separated using the PDIFF test in SAS and declared significant at $P < 0.05$, unless otherwise indicated. Pearson's correlation coefficients were also calculated.

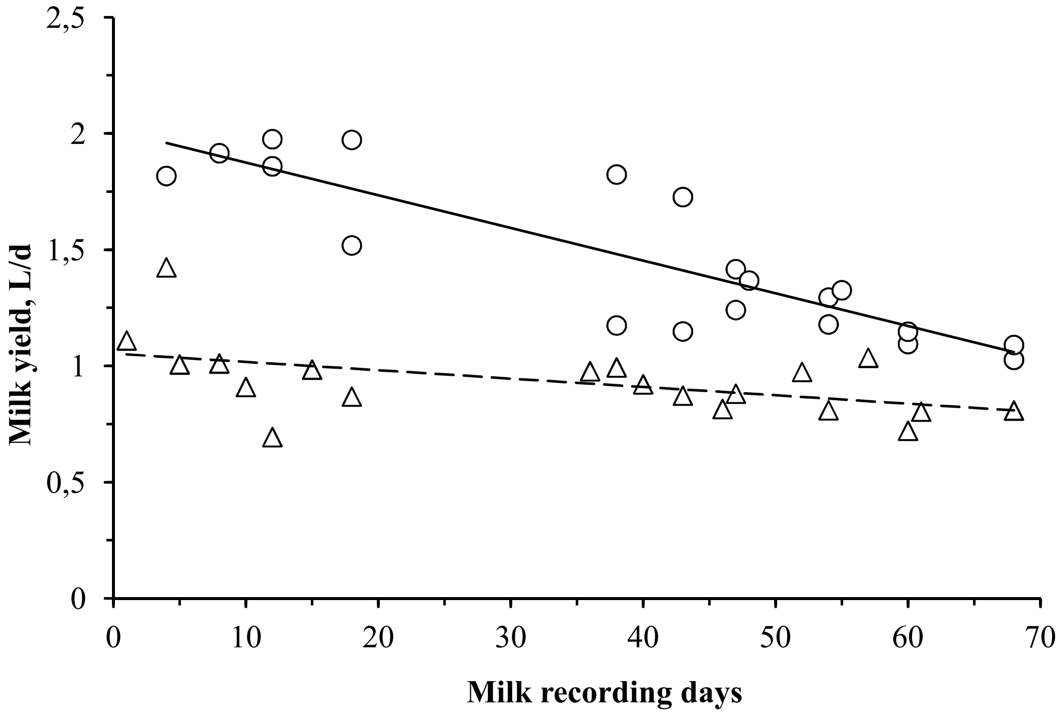
4.4 RESULTS AND DISCUSSION

4.4.1 Milk Yield Performances

Daily milk yield per ewe depended on milking frequency, ranging between 0.25 and 3.50 L/d for ×2 (1.40 ± 0.08 L/d, on average), and between 0.20 and 3.00 L/d for ×1 (0.98 ± 0.05 L/d, on average). The ×1 ewes yielded –36% less milk daily than ×2 ewes ($P < 0.001$) but the difference declined as lactation advanced (Figure 4.1). Milk loss produced as a consequence of ×1 was in the range of values reported by Castillo et al. (2005) in Manchega (–37%) and Lacaune (–13%) dairy ewes at early lactation. Moreover, agreeing with the milking interval applied (16-8 h) and previous studies in the same dairy ewes and conditions (Castillo et al., 2008), morning to evening milk yield ratio was 60:40, on average.

As shown in Figure 4.1, milking frequency affected the rate of decrease of daily milk yield during the experimental period (×2, 14 ± 1 mL/d; ×1, 6 ± 2 mL/d; $P < 0.001$) being their persistency coefficients for the whole period 77.6 and 84.5%, respectively.

Figure 4.1. Change in daily milk yield according to elapsed time and milking frequency (×1, --Δ--; ×2, –○–) in dairy sheep. Regressions were: ×1, y = 1.20 – 0.006 x ($r^2 = 0.45$; $P < 0.01$); ×2, y = 1.95 – 0.014 x ($r^2 = 0.92$; $P < 0.001$).



4.4.2 Milk Recording Time

Milk recording time by 24-ewes (including ewe ID, machine milking and stripping) by milk recording system is shown in Table 4.1. According to the experimental procedure, the same values were considered for the M and PDA systems. Throughout the experimental period, milk recording time decreased with stage of lactation by 0.002 min/d ($r^2 = 0.40$; $P <$

Table 4.1. Comparison of manual and semi-automatic milk recording systems in dairy ewes according to daily milking frequency (values are least squares means).

	Manual				Personal digital assistant				Handheld reader				
	Once	Twice daily			Once	Twice daily			Once	Twice daily			
Item	daily	a.m.	p.m.	Total[1]	daily	a.m.	p.m.	Total[1]	daily	a.m.	p.m.	Total[1]	SEM
Recordings, n	240	240	240	480	240	240	240	480	240	240	240	480	-
Milk yield, L/ewe	0.96^{c}	0.92^{c}	0.60^{e}	1.52^{a}	–	–	–	–	0.91^{c}	0.83^{d}	0.57^{e}	1.40^{b}	0.02
Group recording time, min/24 ewes[2]													
Milk recording[3]	11.8^{b}	11.4^{bc}	9.8^{d}	21.2^{a}	11.8^{b}	11.4^{bc}	9.8^{d}	21.2^{a}	11.3^{bc}	11.1^{c}	9.6^{d}	20.7^{a}	0.22
Data transfer[4]	3.1^{c}	3.5^{b}	3.2^{c}	6.7^{a}	0.3^{g}	0.3^{g}	0.3^{g}	0.7^{f}	0.8^{e}	0.8^{e}	0.8^{e}	1.6^{d}	0.04
Overall	14.9^{c}	14.9^{c}	13.0^{d}	27.9^{a}	12.1^{e}	11.7^{e}	10.1^{f}	21.9^{b}	12.1^{e}	11.9^{e}	10.4^{f}	22.3^{b}	0.22
Unitary recording time, min/ewe													
Milk recording	0.49^{b}	0.47^{bc}	0.41^{d}	0.88^{a}	0.49^{b}	0.47^{bc}	0.41^{d}	0.88^{a}	0.47^{bc}	0.46^{c}	0.40^{d}	0.86^{a}	0.01
Data transfer	0.13^{c}	0.15^{b}	0.13^{c}	0.28^{a}	0.01^{f}	0.01^{f}	0.01^{f}	0.03^{e}	0.03^{e}	0.03^{e}	0.03^{e}	0.06^{d}	0.01
Overall	0.62^{c}	0.62^{c}	0.54^{d}	1.16^{a}	0.50^{de}	0.48^{e}	0.42^{f}	0.91^{b}	0.50^{de}	0.49^{e}	0.43^{f}	0.92^{b}	0.01

$^{a\text{-}f}$Means with different superscript within the same row differ ($P < 0.05$); [1]Total daily values; [2]Group of 24 ewes in a double-12 stall parallel milking parlor; time expressed in a decimal scale (1 min = 100 units); [3]Includes ewe identification, machine milking, machine stripping and collecting milk recording data; [4]From paper forms or intelligent transceiver to computer data base.

0.001) for M and PDA, and by 0.003 min/d ($r^2 = 0.45$; $P < 0.001$) for HHR system (Figure 4.2). Reduction in milk recording time in M and both SA systems throughout the experiment may be explained by the decreasing milk yield as lactation advanced. Significant correlation ($r^2 = 0.71$; $P < 0.01$) was found between milk recording time and milk yield in M and HHR systems.

Although there are scarce data on milk recording in small ruminants, the milk recording time values obtained in our results for M and HHR in the ×1 ewes were lower than those previously reported by Ait-Saidi et al. (2008) in dairy goats milked ×1. This was a consequence of the lower milk yield (0.98 ± 0.05 L/d) and the greater milk flow rate (1.83 ± 0.07 L/min) of our dairy ewes compared to the Ait-Saidi et al. (2008; 1.93 L/d and 1.46 L/min) dairy goats. Moreover, no differences ($P = 0.198$) between milk recording time for M, PDA and HHR systems were observed throughout the experiment which evolved similarly (Figure 4.2), indicating that the operator had enough expertise in SA milk recording at the start of the experiment.

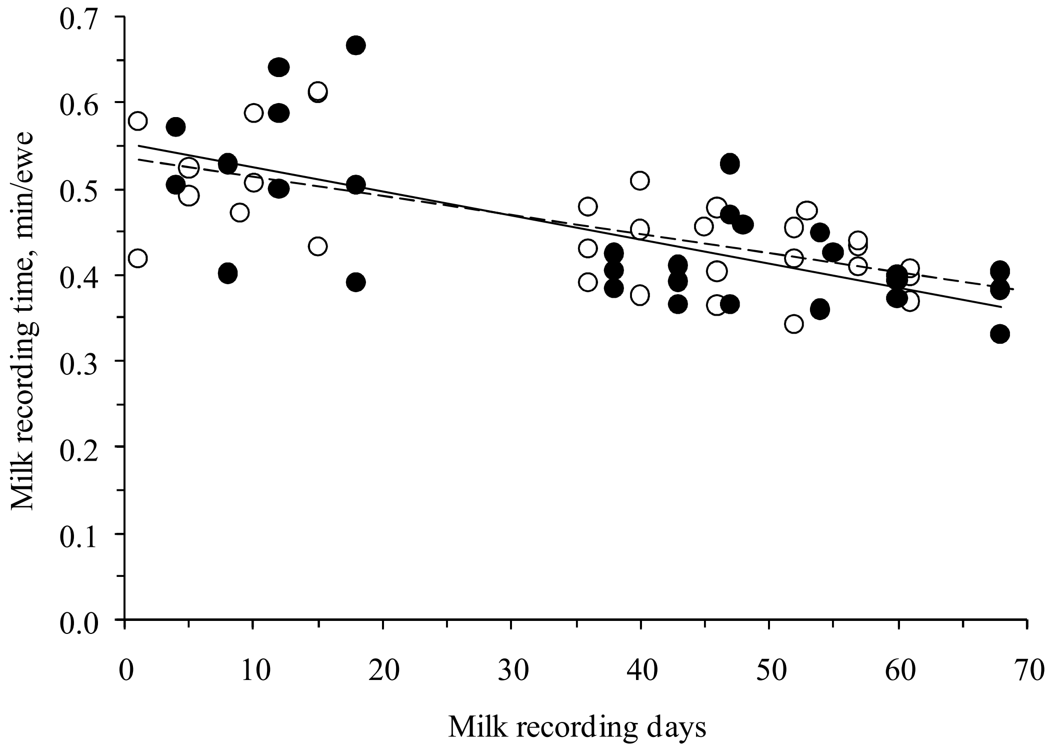
For all recording systems (Table 4.1), milk recording time for ×2 a.m. and ×1 tended to differ ($P = 0.051$), and ×2 p.m. was greater than a.m. ($P < 0.001$). According to milk yield and milk recording time, ×1 represented approximately half the time consumed daily in ×2. Milking throughput ranged approximately between 122 to 150 ewes/h (9.6 to 11.8 min/group 24-ewes), which agreed with the expected milking throughput for a double parallel (type Casse 2 × 12) milking platform in dairy sheep (Berger et al., 2004).

4.4.3 Milk Recording Data Transfer

On average, time for data transfer in the M system (3.3 ± 0.1 min/24-ewes), from paper forms to the computer's data base, was longer than for the SA systems (Table 4.1; $P < 0.05$), regardless of the milking frequency used, agreeing with Ait-Saidi et al. (2008). Moreover, time for data transfer using the PDA system was faster than with HHR (0.3 ± 0.1 vs. 0.8 ± 0.1 min/24-ewes; $P < 0.001$); this was a result of the automated and user friendly procedure implemented for data transfer in the PDA used.

The average time reduction of using HHR instead of M was 2.5 min/24 ewes (76.1%), which was lower than the previously estimated reduction values in goats under commercial farm (Caja et al., 1999b; 7.3 min/24 goats) and experimental farm conditions (Ait-Saidi et al., 2008; 3.7 min/24 goats). Moreover, the automatic data transfer avoided the possible mistakes of data typing and, in the case of both SA systems, time of data transfer was the fastest and not proportional to the amount of data.

Figure 4.2. Change in milk recording time for manual (M and PDA, ○) or semiautomatic (HHR, ●) milk recording systems in dairy ewes during the experiment. The regression for the M and PDA system (–––) was: $y = 0.54 - 0.002\ x$ ($r^2 = 0.40$, $P < 0.001$); and for the HHR system (—) was: $y = 0.55 - 0.003\ x$ ($r^2 = 0.45$, $P < 0.001$)



Overall milk recording time was greater ($P < 0.001$) in M than in PDA, but no differences were detected between PDA and HHR systems ($P = 0.123$) for both milking frequencies (Table 4.1). Total time saving between M and HHR treatments was on average 4.2 ± 0.4 min/24 ewes (0.18 min/ewe), and varied according to milking frequency (×1, 2.8 ± 0.4 min/24 ewes; 2×, 5.6 ± 0.6 min/24 ewes; $P < 0.001$). Likewise, overall time difference between M and PDA systems was 4.4 ± 0.4 min/24 ewes (0.18 min/ewe) on average, and also varied according to milking frequency (×1, 2.8 ± 0.1 min/24 ewes; ×2, 6.0 ± 0.2 min/24 ewes; $P < 0.001$). Differences between systems would increase with flock size for multiple groups of 24 ewes according to the milking parlor design used (2 milking platforms of 12 ewes) up to an approximate functional size of 400 ewes (72 min, on average, equivalent to 1 h and 12 min). Moreover, the ×1 and ×2 values may be related with the standard milk recording methods recommended by ICAR (2012) in dairy sheep (A4, official a.m. and p.m. recording method done monthly; AT, alternate method done at a.m. or p.m. milkings alternatively each month).

Errors reported during M milk recording were 1.2 and 0.8% for ×1 and ×2, respectively. Additionally 1.7% more errors were found during data transfer, being 2.9 and 2.5% in total respectively. No errors were detected for milk recording and data transfer with HHR and PDA systems during the experiment. Error values in our data were greater than those reported by Ait-Saidi et al. (2008) when using M in dairy goats (0.6%), which may be a consequence of the larger v-ID codes printed in the ear tags and of the smaller number of animals than in our study in sheep.

4.4.4 Dynamic Reading of Dairy Ewes

Time of entrance into the milking parlor per group averaged 0.5 ± 0.03 min/12 ewes. Dynamic reading efficiency of all dairy ewes at the entrance to the milking parlor was 100%. This value was similar to those reported earlier for dynamic reading of 32 mm half-duplex transponders either in injectable transponders or standard electronic boluses in calves, sheep and goats (Caja et al., 1999a; Conill et al. 2000; Ghirardi et al., 2006b), and allow the utilization of small-boluses for dynamic recording practices. Estimated passage speed of the ewes in our study was 1 ewe/s on average, which agreed with Ghirardi et al. (2006b).

4.5 CONCLUSIONS

In conclusion, whatever milk recording system used (manual or semi-automatic) there was no difference in time devoted exclusively to milk recording under our milking parlor and flock size conditions. Nevertheless, when data transfer was included, total milk recording time was markedly longer in the manual system. On the contrary, when semi-automatic systems were used total milk recording time was faster than manual and no errors were detected. We stressed the need for automated and user friendly procedures (e.g., plug and play) for instantaneous milk recording data transfer in the dairy sheep industry. Despite the similar throughput of the personal digital assistant and the handheld reader systems, the latter was preferred due to the lower risk of mistakes in ewe identification. Semi-automatic systems implemented in our study were time-effective for milk recording in dairy ewes, saving more than 1 h of labor time for a flock size of 400 ewes milked in a parallel 2 × 12 stalls milking parlor. Further research will evaluate the costs of implementing manual and semi-automatic systems for milk recording and other performances recording in sheep farms.

CHAPTER 5

Implementing electronic identification for performance recording of sheep: II. Lambing and body weight recording and cost-benefit analysis in dairy and meat farms

CHAPTER 5.

Implementing Electronic Identification for Performance Recording of Sheep: II. Lambing and Body Weight Recording and Cost-Benefit Analysis in Dairy and Meat Farms

5.1 ABSTRACT

Secondary benefits of using electronic identification (e-ID) for lambing data and BW recording were studied by comparing the use of manual (M), semi-automatic (SA) and automatic (AU) data collection systems in 2 flocks of dairy and meat ewes. Ewes were identified with official plastic ear tags and rumen boluses (small-boluses, 20 g). The M used visual identification (v-ID), on-paper data recording and manual data typing on a computer. The SA used for automatic e-ID, manual data typing into the reader and automatic data uploading to a computer. The AU was only used for BW recording and consisted of e-ID, automatic data recording in the scale and automatic data uploading to a computer. In Exp. 1, 73 dairy and 80 meat ewes were recorded at lambing using M and SA systems. Ewes were processed in groups of 10 in 2 lambing seasons (winter, dairy ewes; autumn, meat ewes). Despite their similar prolificacy, time for lambing recording was greater in dairy than in meat ewes, due to the operator inexperience and ear tag dirtiness. Overall time for lambing recording was greater in M than SA in dairy (1.67 ± 0.06 vs. 0.87 ± 0.04 min/ewe) and meat (1.30 ± 0.03 vs. 0.73 ± 0.03 min/ewe) ewes. Recording errors were greater in dairy (9.6%) than in meat (1.9 %) ewes. Data uploading errors only occurred in M (4.9%). In Exp. 2, 120 dairy and 120 meat ewes were weighed in groups of 20 using M and AU. In both flocks, mean BW recording and data uploading times, as well as overall BW recording time (0.63 ± 0.02 and 0.25 ± 0.01 min/ewe, respectively) were greater in M than in AU. Uploading errors only occurred in M (8.8%). Results of Exp. 1 and 2 were integrated with previous milk recording data into a whole cost-benefit study for typical meat (700 ewes; extensive or intensive) and dairy (400 ewes; ×1 or ×2 milk recording daily) farms. Benefits of using SA or AU mainly depended on sheep breed, test days per yr, reader prices (handheld reader and personal digital assistant) and flock size. In conclusion, e-ID for SA and AU performance recording saved approximately 50% of the time required by M, and increased the reliability of the collected data. Use of e-ID increased the cost of performance recording in the optional scenario, partially paying the investment made (15 to 70%). For mandatory e-ID, savings paid 100% of

the extra-costs in all farm types and conditions. In both scenarios, reader price was the most important extra-cost (40 to 90%) of e-ID implementation. Calculated extra-costs of using the personal digital assistant covered more than 100% of the implementation costs in all type of farms, indicating that this device was cost-effective for sheep performance recording.

5.2 INTRODUCTION

Electronic identification (e-ID) by using passive radio frequency transponders is currently mandatory for small ruminants in the European Union (Regulation CE 21/2004, amended by CE 933/2008 and CE 759/2009), jointly with visual identification (v-ID) by official ear tags, and its cost has been calculated for the identification and registration of sheep and goats at national level in Spain (Saa et al., 2005), the United Kingdom (ADAS, 2006), the U.S. (APHIS, 2009) and the Netherlands (Velthuis et al., 2009). Despite producing primary benefits at national and international level (i.e., food safety, public health), there is a concern about the secondary benefits of e-ID at the farm level where the main costs are currently supported.

The e-ID devices can be a key tool for the management and data collection of farm animals at individual level (i.e., precision livestock). The current technological advances and the decreasing prices of electronic devices have increased the probability that computerized performance data acquisition will become cost-effective and be adopted by farmers. In this sense, the use of e-ID combined with monitoring platforms (Trevarthen and Michael, 2007) or of shared databases (Voulodimos et al., 2010), have been proposed as complete systems of farm management.

Previous research proved that e-ID reduced the working time and implementation costs of milk recording in dairy goats (Caja et al., 1999a; Ait-Saidi et al., 2008), but there is no information on the evaluation of implementation benefits in sheep farms.

As a follow up to previous research (Ait-Saidi et al., 2014a) on the implementation of e-ID for milk performance recording in dairy sheep farms, the current study aimed to evaluate the labor time and data collection efficiency of v-ID and e-ID for lambing and weight performance recording in dairy and meat sheep farms using manual or automated systems (semiautomatic and automatic). As a final aim, a cost-benefit analysis comparing typical dairy and meat sheep farms, under extensive or intensive production systems, was made.

5.3 MATERIAL AND METHODS

5.3.1 Animal and Management Conditions

Two consecutive experiments were carried out on sheep performance recording in the experimental farm of the SGCE (Servei de Granges i Camps Experimentals) of the Universitat Autònoma de Barcelona (UAB, Barcelona, Spain) during winter and autumn lambing seasons. Sheep care conditions and management practices agreed with the procedures stated by the Ethical Committee of Animal and Human Experimentation of the UAB and the codes of recommendations for the welfare of livestock of the Ministry of Agriculture, Fisheries and Food of Spain (MAPA, 2007).

5.3.2 Data Recording at Lambing

In order to complete the flock-book of the farm, a total of 73 dairy (Manchega, Spanish dairy breed, n = 31; Lacaune, French dairy breed; n = 42) and 80 meat (Ripollesa, Catalonian local breed, meat sheep, semi-fine wool) ewes were used to register data at lambing. Data recording was done in groups of 7 to 10 ewes lambing as close as possible. Lambing occurred in different seasons: winter for dairy ewes and autumn of the next year for meat ewes, according to their respective reproduction schedule.

Before data recording at lambing, newborn lambs were weighed, their umbilical cord was cut and disinfected (2% iodine solution in ethanol 96%), and they were tagged on the left ear with a small plastic ear tag (two-piece rigid plastic rectangular flaps; 1.5 g; and, 1.0 × 3.5 cm; Tip-Tag, Azasa-Allflex, Madrid, Spain) recorded with a correlative 3-digit number and considered as temporary ID until slaughtering or permanent ID for ewes intended for breeding.

Data recording at lambing was sequentially done by ewe group using manual (M) and semi-automatic (SA) recording systems, respectively. Ewes wore official ear tags (2 piece flexible plastic tamper-resistant flaps; male flag, 40 × 38 mm; female flag, 42 × 38 mm; total weight, 5.2 g; Azasa-Allflex) recorded by the manufacturer. Official ear tag numbers and letters were recorded in 3 lines and the third line contained 5 digits of a larger size (8-mm height) which were used for management purposes. Ear tags unreadable by dirtiness were cleaned with warm water during data recording. Additionally, all ewes carried an e-ID small-bolus (11 × 56 mm and 20 g; Rumitag, currently Datamars, Bedano, Switzerland), containing 32-mm half-duplex radio frequency transponder fulfilling ISO standards (ISO, 1996a,b) recorded with the same code as the ear-tags. Ewes were restrained in head-lockers for lambing data recording and lamb data was provided by 1 assistant.

In the M system, lambing data was recorded on a paper form, and consisted of: visual ID (5 digits of the last line of the official ear tag) of the ewe, date and type of lambing (single, twin or multiple lambs), lamb ear tag numbers and individual data (sex, birth weight and observations). Data from paper forms were manually uploaded to a database by typing on a computer keyboard. Recording and data uploading time were measured using an electronic chronometer (Geonaute Trt'L 100, Decathlon, Alcobendas, Spain).

Lambing data recording by the SA system was done after the M recording procedure. In the SA system, ewe's electronic ID was read by a handheld (HHR) intelligent transceiver (Smart reader, Rumitag) provided with a stick antenna (SAS-ISO, Rumitag) and previously uploaded with the visual ear tag numbers of the ewes via Bluetooth connection and manufacturer software (Smart software v.3.3.2, Rumitag). Ewes were recorded in the same order as in the M system and lambing data typed on the keyboard of the HHR reader. Lambing data saved in the memory of the HHR reader were automatically transferred to a computer via Bluetooth connection using the same software as previously indicated.

Use of a personal digital assistant (PDA) with v-ID, similar to that described in Ait-Saidi et al. (2014a) for data recording and downloading to a computer, was also considered. Table 5.1 summarizes the use of different devices for each type of performance recording system.

Table 5.1. Uses of devices according to the type of performance recording conducted in sheep farms

	Performance recording			
Device	Lambing	Body weight	Inventory	Milk
Handheld reader[1]	Yes	–	–	Yes
Personal digital assistant	Yes	Yes	Yes	Yes
Stationary reader[1]	–	Yes	Yes	–

[1]Radio frequency devices.

5.3.3 Body Weight Recording of Adult Ewes

A total of 114 dairy (Manchega, n = 56; Lacaune, n = 58) and 102 Ripollesa meat ewes were used to compare M and automatic (AU) weighing systems with regard to labor time and data transfer efficiency. In order to obtain objective comparisons by sheep type, ewes were divided into groups of 20 according to breed and recorded on 12 test-days to obtain 480 body weight data. In both systems, weighing was performed by 1 operator and 1 assistant previously trained and using the same electronic scale (Tru-Test SR2000, Pakuranga, Auckland, New Zealand) interfaced to an F-210 stationary reading unit (Rumitag) and to a desk computer via RS232 interface.

For the M weighing system, ewe group used the same raceway and scale, but it was necessary to restrain their head for reading the 5 digits of the official ear tag. A paper form previously prepared was used to record the BW displayed for each ewe on the scale screen. Finally, BW data were manually uploaded to a database using the computer keyboard.

In the case of AU weighing recording, ewe's e-ID was automatically read by the F-210 unit and saved jointly with the BW in the memory of the scale. Both e-ID and BW were thereafter sent to the computer database by using specific software (PesoyTir version 1.0, Gesimpex Com., Barcelona, Spain). The same chronometer was used to measure times of ewe identification, BW recording and to upload data onto a computer in M and AU systems.

Use of a PDA, as previously indicated for lambing recording, was also considered.

5.3.4 Cost-Benefit Study

Costs and savings of implementing e-ID for performance recording using SA and AU systems, were calculated, in relation to the M costs, for the lambing data and BW recording of dairy and meat sheep. Moreover, cost and savings were calculated for milk recording of dairy ewes as previously reported (Ait-Saidi et al., 2014a). Overall data were combined to perform a cost-benefit study under different scenarios: 1) dairy sheep farms performing once- (×1) or twice-daily (×2) milk recordings; and 2) meat sheep farms under extensive or intensive production systems. Additionally, according to European legislation (CE 21/2004 updated by CE 933/2008 and CE 759/2009), an annual inventory of adult sheep, which is compulsory since 2011, was also included.

These scenarios covered most typical dairy and meat sheep farms and the parameters used for the cost-benefit study of implementing the e-ID for performance recording are summarized in Table 5.1 and 5.2. Rate of return (ROR), calculated as the difference between saving and costs with regard to costs, and the break-even point (BEP) were also calculated for comparing the different options.

Unitary costs of readers used for the different performance recording done (i.e., lambing weighing, milk recording) were calculated taking into account the depreciation period, flock size, lambings per yr and test-days per lambing (Table 5.2). We considered the possibilities

Table 5.2. Parameters used for the cost-benefit study of implementing electronic identification for performance recording in dairy and meat sheep farms.

	Dairy		Meat	
Item	×1 (or AT4)[1]	×2 (or A4)[2]	Intensive	Extensive
Ewes/farm	400	400	700	700
Lambings/yr	1	1	1.5	1
Lifespan, yr	5	5	6	7
Test-days/lambing				
Milk recording	4	8	–	–
Lambing data	1	1	1	1
Body weight	3	3	2	2
Farms per test-day	2	1	1	1
Inventories, n/yr	1			
Wage price, €/h	10.0			
Price of e-ID devices, €				
Electronic bolus	1.4			
Handheld reader[3]	600			
Personal Digital Assistant (PDA)[3]	300			
Stationary reader[4]	1,300			
Depreciation period, yr	5.0			

[1]Alternate milk recording system done once-daily (a.m. or p.m.) every 4 wk according to ICAR (2012); [2]Official milk recording system done twice-daily (a.m. and p.m.) every 4 wk according to ICAR (2012); [3]One per farm and another per technician doing the milk recording in a group of farms; [4]Shared by 30 farms for body weight recording and inventories.

that the HHR readers (for milk and lambing recording) and the PDA (for milk, lambing, body weight and inventory recording) were owned by the farmers or by the milk recording technicians, in the case of dairy farms (working time, 200 d/yr). Moreover, electronic scales and stationary reading units (for body weight and inventory recording) were considered as shared by groups of 30 farms.

5.3.5 Statistical Analysis

Data were analyzed by ANOVA using the PROC GLM of SAS (version 9.1; SAS Inst. Inc., Cary, NC). Time measurements were converted to a decimal scale (60 s = 100 units) for calculations. The model used for lambing data recording time contained the effects of the system (M or SA), group of ewes (1 to 8), lambing season (winter or autumn), first order interactions, and the residual error. For body weight recording time, the model contained the effects of the weight recording system (M or AU), the test-day (d 1 to 6), ewe type (dairy or meat), first order interactions, and the residual error. When the probability of one factor or the interaction term was not significant ($P > 0.20$), it was deleted from the model. Differences between least squares means (LSM) were separated using the PDIFF test in SAS and declared significant at $P < 0.05$, unless otherwise indicated. Pearson's correlation coefficients were also calculated.

The cost-benefit study consisted of a Microsoft Excel 2007 spreadsheet (Microsoft Corp., Redmond, WA), which calculated the total annual costs and savings of using e-ID bolus and readers (HHR and PDA) under 2 e-ID scenarios (optional and mandatory) for dairy (×1 and ×2) and meat (extensive and intensive) sheep farms. Likewise, the same spreadsheet was used to calculate the ROR and BEP values in all cases considered.

5.4 RESULTS AND DISCUSSION

5.4.1 Data Recording at Lambing

On average, time of data recording at lambing was 24% greater ($P < 0.05$) in the dairy ewes lambing in winter than the meat ewes lambing in autumn, but the difference was more marked for M (30%) than for SA (15%) system, as shown in Table 5.3. An interaction ($P < 0.01$) between data recording system and season was found which was a consequence of the operator skill improvement throughout the experiment and of ear tag cleaning at the start of readings. Approximately, 5 of 10 ear tags in dairy ewes needed to be cleaned for the first visual reading. Time for cleaning was 0.2 ± 0.01 min/ear tag, which accounted for 33% of the difference in total recording time between M and SA. On the contrary, in the meat ewes the operator had greater expertise in the procedures and the ear tags had been already cleaned before starting the experiment. Despite the lambing period and ear tag cleaning, time employed for data recording at lambing was 10% greater in M than SA system ($P < 0.001$).

With regard to lambing data transfer to a computer, values for M system in the dairy ewes were 7% greater than in the meat ewes ($P < 0.05$) as a consequence of the operator expertise, but no difference between seasons was detected with the SA system ($P > 0.05$). In both periods, transfer time was faster for SA than for M ($P < 0.001$), being 0.06 ± 0.01 min/ewe, on average. Transfer time for M was related to the number of ewes, but this was not the case for SA. Time reduction by using SA, when compared to M, was 4.87 ± 0.17 and 4.70 ± 0.11 min/10 ewes (0.49 ± 0.02 and 0.47 ± 0.01 min/ewe) in dairy and meat ewes, respectively.

Table 5.3. Comparison of manual and semi-automatic systems for data recording at lambing according to ewe type (values are least squares means).

	Dairy[1]		Meat[2]		
Item	Manual	Semiautomatic	Manual	Semiautomatic	SEM
Ewes, n	73		80		–
Lambs, n	110		130		–
Time, min/10 ewes					
Recording	11.10[a]	8.01[b]	7.77[b]	6.80[c]	0.25
Data transfer	5.57[a]	0.70[c]	5.21[b]	0.51[c]	0.09
Overall	16.67[a]	8.71[c]	12.98[b]	7.31[d]	0.21
Unitary time, min/ewe					
Recording	1.11[a]	0.80[b]	0.78[b]	0.68[c]	0.03
Data transfer[3]	0.56[a]	0.07[c]	0.52[b]	0.05[c]	0.01
Overall	1.67[a]	0.87[c]	1.30[b]	0.73[d]	0.02
Errors, n[4]					
Recording	10 (9.1%)	11 (10%)	2 (1.5%)	3 (2.3%)	–
Data transfer	9 (8.2%)	0	2 (1.5%)	0	–

[a-d]Means with different superscript within the same row differ ($P < 0.05$); [1]Lambing recording of dairy ewes during winter with a few experienced operator and dirty ear tags; [2]Lambing recording of meat ewes with experienced operator and cleaned ear tags; [3]From paper forms or intelligent transceiver to computer data base; [4]Errors were calculated according to the number of lambs.

Overall time for data recording at lambing was also greater in M than in SA, the difference being greater in dairy than meat (7.96 ± 0.23 vs. 5.67 ± 0.39 min/10 ewes, respectively; $P < 0.001$). These differences are expected to increase as flock size increases.

Errors registered for each recording system (M or SA) are shown in Table 5.3. As expected, number of errors in meat was lower than in dairy ewes due to the operator's greater expertise. No errors were detected for the data transfer by the SA system in either period. Advantages of using the SA system include feasibility, labor time saving, and accurate data transferred automatically and independently of the flock size.

5.4.2 Body Weight Recording of Adult Ewes

Values of recorded BW ranged from 57.6 to 98.2 kg in dairy ewes and from 39.7 to 71.4 kg in meat ewes. Data of M and AU weight recording on the same test day correlated positively ($r^2 = 0.97$, $P < 0.001$).

Weighing the meat ewes needed 11% more time ($P < 0.01$) than the dairy ewes, regardless of the system used (Table 5.4). This difference was due to the tough behavior of the meat ewes which had less direct contact with the farmer and varied by test-day ($P < 0.05$). No interactions were found. On average, BW recording time was 48% faster using AU than M ($P < 0.001$) for both sheep breeds (Table 5.4), agreeing with the results of Hua et al. (2012) when automatic weighing system was implemented. Estimated weighing throughput by AU and M systems, were 262 and 136 ewes/h, respectively, which are in the ranges of previously reported data in other species by Turner and Smith (1975; 200 pigs/h), Filby et al. (1979; 80 calves/h) and Frappat (1996; 125 heifers/h).

Table 5.4. Comparison of manual and automatic weighing systems in dairy and meat sheep (values are least square means).

	Dairy		Meat		
Item	Manual	Automatic	Manual	Automatic	SEM
Records, n	120	120	120	120	–
Mean body weight, kg	76.32^a	75.86^a	50.82^b	50.96^b	0.70
Time, min/20 ewes					
Recording	8.52^b	4.17^d	9.15^a	5.09^c	0.18
Data transfer[1]	3.58^a	0.35^b	3.64^a	0.33^b	0.07
Overall	12.10^b	4.52^d	12.79^a	5.42^c	0.21
Unitary time, min/ewe					
Recording	0.43^b	0.21^d	0.46^a	0.25^c	0.01
Data transfer	0.18^a	0.02^b	0.18^a	0.02^b	0.01
Overall	0.61^b	0.23^d	0.64^a	0.27^c	0.01
Errors, n					
Identification	3 (2.5%)	0	3 (2.5%)	0	–
Weights	10 (8.3%)	0	5 (4.2%)	0	–

$^{a\text{-}d}$Means with different superscript within the same row differ ($P < 0.05$); [1]From paper forms or stationary reader connected to automatic scale to computer data base.

Time required for transferring the weighing data to a computer was 91% lower in AU than M (P < 0.001), with no differences between sheep breed. Data transfer time in M system depended on the number of ewes processed, but this was not the case for AU. A reduction of 3.27 ± 0.08 min/20 ewes (P < 0.001) in the time needed for uploading BW records to the computer was observed in favor of AU (Table 5.4). Transfer time of AU BW recording data (0.34 ± 0.03 min/20 ewes) represented only 43 and 67% of the time necessary for data transfer using the SA system in milk recording of dairy ewes, as reported in the previous study (Ait-Saidi et al., 2014a), and in the case of lambing data, respectively. Overall time of BW recording was 60% greater in M than AU (P < 0.001) for both ewe breeds.

With regard to the errors occurred during BW recording, they were only detected for the M system (Table 5.4) and included errors due to miscopied v-ID (2.5%, on average) and BW data (6.3%). No errors were detected during data transfer. Moreover, overall errors were numerically lower in meat ewes than in dairy ewes, although the difference was not significant (P = 0.18).

5.4.3 Cost-Benefit Study by Type of Performance Recording

5.4.3.1 Data Recording at Lambing

5.4.3.1.1 Handheld Reader

Calculation of extra-costs resulting from the implementation of e-ID for lambing recording was based on using 1 HHR reader/farm (owned by the farmer) for ewe e-ID according to the key parameters described in Table 5.1 and 5.2. As a result, calculated unitary extra-cost (i.e., e-ID bolus and HHR), with regard to M, for a meat flock of 700 ewes and 1 lambing/yr was €0.371/ewe and yr (Table 5.5). For a more intensive meat production system, with 1.5 lambings/yr, the unitary extra-cost was €0.270/ewe per lambing, equivalent to €0.404/ewe and yr (Table 5.5). Farm size dramatically altered these unitary extra-costs. For extensive meat sheep farms, sized 10 to 700 ewes, e-ID extra costs ranged from €3.7 to 259.7/yr (Table 5.5); values for intensive meat sheep farms ranging from €4.0 to 282.8/yr, respectively.

Regarding dairy sheep farms, extra-cots for a typical 400 ewes of dairy flock lambing once-a-year depended on milking frequency (×1, €0.340; ×2, €0.313/ewe per lambing and yr; Table 5.6). Estimated e-ID extra-costs for lambing recording in dairy sheep farms sized 10 to 400 ewes, according to milking frequency, ranged from €3.4 to 136.0/yr and €3.1 to 125.2/yr for ×1 and ×2, respectively.

Table 5.5. Costs and benefits of implementing automated systems for performance recording in meat sheep farms according to the device used

	Meat			
	Extensive		Intensive	
Item	HHR[1]	PDA[2]	HHR[1]	PDA[2]
Electronic ID costs, €/ewe and yr				
Bolus	0.200	–	0.233	–
Readers				
Milk recording	–	–	–	–
Lambing	0.171	0.021	0.171	0.023
Body weight	0.012	0.043	0.012	0.047
Inventory	0.006	0.021	0.004	0.016
Total costs	0.390	0.085	0.421	0.086
Saving, €/ewe and yr				
Milk recording	–	–	–	–
Lambing	0.095	0.085	0.142	0.128
Body weight	0.125	0.057	0.187	0.085
Inventory	0.055	0.028	0.055	0.028
Total saving	0.274	0.170	0.384	0.241
Benefits e-ID optional				
€/ewe and yr	−0.116	0.084	−0.037	0.155
€/flock and yr	−80.9	59.0	−26.1	108.6
Rate of return, %[3]	−29.6	98.3	−8.9	181.0
Break-even point, n[4]	1,785	352	874	249
Benefits e-ID mandatory[5]				
€/ewe and yr	0.084	0.084	0.196	0.155
€/flock and yr	59.0	59.0	137.2	108.6
Rate of return, %[3]	44.4	98.3	104.3	181.0
Break-even point, n[4]	485	352	343	249

[1]Hand-held reader: Semi-automated system based on electronic identification (e-ID) with radio frequency using bolus and hand-held reader for milk and lambing recordings, or stationary reader device for BW recording; [2]Personal Digital Assistant: semi-automated system based on visual identification and pocket PC device for performance recordings in dairy and meat farms; [3]Calculated as a percentage of the difference between total savings and costs divided into total costs; [4]Number of ewes for which savings covered all costs of e-ID implementation; [5]Excluding the e-ID cost of bolus.

With regard to savings, we took into account the above calculated time differences of using SA for lambing (dairy and meat sheep, 7.96 and 5.67 min/10 ewes, respectively), as previously indicated. In the worst case (meat sheep), the calculated labor cost savings of using SA for lambing recording in meat sheep farms (sized 10 to 700 ewes; wage price, Table 5.2) under extensive conditions (1 lambing/yr) were €0.95 to 66.3/yr, respectively. Under intensive conditions, values were €1.42 to 99.4/yr, respectively. On average, savings represented 25.6 and 35.1% of e-ID implementation costs for extensive and intensive conditions, respectively.

Table 5.6. Costs and benefits of implementing automated systems for performance recording in dairy sheep farms according to the device used

	Dairy			
	×1 or AT[1]		×2 or A4[2]	
Item	HHR[3]	PDA[4]	HHR	PDA
Electronic ID costs, €/ewe and yr				
Bolus	0.280	–	0.280	–
Readers				
Milk recording	0.240	0.067	0.267	0.092
Lambing	0.060	0.017	0.033	0.012
Body weight	0.016	0.050	0.016	0.034
Inventory	0.005	0.016	0.005	0.012
Total costs	0.601	0.150	0.601	0.150
Saving, €/ewe and yr				
Milk recording	0.078	0.078	0.155	0.167
Lambing	0.095	0.085	0.095	0.085
Body weight	0.187	0.085	0.187	0.085
Inventory	0.055	0.028	0.055	0.028
Total saving	0.415	0.276	0.492	0.365
Benefits e-ID optional				
€/ewe and yr	−0.187	0.126	−0.109	0.215
€/flock and yr	−74.9	50.4	−43.8	86.0
Rate of return, %	−31.1	84.1	−18.2	143.3
Break-even point, n	957	217	608	165
Benefits e-ID mandatory				
€/ewe and yr	0.093	0.126	0.171	0.215
€/flock and yr	37.1	50.4	68.2	86.0
Rate of return, %	28.9	84.1	53.0	143.3
Break-even point, n	310	217	262	165

[1]Once –daily milking or alternate milk recording system done once-daily (a.m. or p.m.) every 4 wk according to ICAR (2012); [2]Twice –daily milking or official milk recording system done twice-daily (a.m. and p.m.) every 4 wk according to ICAR (2012); [3]Hand-held reader: Semi-automated system based on electronic identification (e-ID) with radio frequency using bolus and hand-held reader for milk and lambing recordings, or stationary reader device for BW recording; [4]Personal Digital Assistant: semi-automated system based on visual identification and pocket PC device for performance recordings in dairy and meat farms.

Regarding dairy sheep farm size, savings ranged from €0.95 to 37.9/yr (10 to 400 ewes, respectively), without effect of milking frequency on absolute values (Table 5.6), but varying in relation to the e-ID implementation costs (×1, 27.9%; ×2, 30.4%). Consequently, increasing flock size and lambing frequency per year would increase the savings of using e-ID for lambing recording and the returns of e-ID implementation.

5.4.3.1.2 Personal Digital Assistant

Although we did not test experimentally the use of a PDA for data management (data recording and uploading to a computer) when v-ID was used for lambing recording, we estimated its expected costs and savings from parameters reported in Table 5.2 and from results of the previous experiment done in dairy sheep (Ait-Saidi et al., 2014a), respectively. On average, expected unitary extra-costs of using PDA for lambing recording in meat sheep farms were €0.021 and €0.023/ewe and yr (extensive, 1 lambing/yr; and intensive, 1.5 lambing/yr, respectively; Table 5.5). For dairy sheep farms and by milking frequency, values were €0.017 and €0.012/ewe and yr, for ×1 and ×2, respectively (Table 5.6).

Values of extra-costs varied according to flock size, being €0.2 to 14.7/yr and €0.2 to 16.1/yr, in the case of extensive and intensive sheep meat farms (10 to 700 ewes), and €0.17 to 6.8/yr and €0.12 to 4.8/yr for ×1 and ×2 dairy sheep farms (10 to 400 ewes), respectively.

To estimate the PDA cost savings, we considered that M and PDA systems only differed in time for data uploading to the computer (no time difference for lambing recording). So, we compared data uploading time of M (0.52 min/ewe; Table 5.3) and data from the previous experiment done in dairy sheep (0.01 min/ewe; Ait-Saidi et al., 2014a), the saving being €0.085/ewe per lambing recording. Values per year were similar for extensive meat and dairy farms, having the same lambing frequency (€0.085/ewe and yr), and increased to €0.128/ewe for intensive meat sheep farms (Table 5.5). For all farm types, savings by using a PDA for lambing recording fully paid (100%) the unitary implementation costs of PDA, when considering all uses reported in Table 5.1. Saving values changed by flock size, being €0.9 to 59.5/yr and €1.3 to 89.6/yr, in the case of extensive and intensive sheep meat farms (10 to 700 ewes), and €0.9 to 34.0/yr in dairy sheep farms (10 to 400 ewes), respectively, which represented more than 100% PDA unitary implementation costs in all cases.

5.4.3.2 Body Weight Recording

5.4.3.2.1 Handheld Reader

The same key values as above were considered to estimate the extra-costs of using AU and PDA systems in different farms types. As electronic scale was supposed to be the same in M, AU and PDA weighing systems, its acquisition price was not included in the extra-cost calculation. For the AU system, the estimated e-ID extra-costs (i.e., e-ID bolus and stationary reader) were €0.212 and €0.245/ewe and yr, for extensive and intensive meat sheep farms, respectively (Table 5.5), and €0.296/ewe and yr, for dairy sheep farms (Table 5.6). Values also varied according to flock size, ranging from €4.2 to 148.4 and €4.9 to 171.5/ewe and yr in extensive and intensive meat sheep farms (20 to 700 ewes), and from €5.9 to 118.4/ewe and yr in dairy sheep farms (20 to 400 ewes), respectively. As we did not detect differences in time savings for BW recording when comparing M and AU in dairy and meat farms (Table 5.4), values were pooled and their average (0.375 min/ewe) was used for all farms types.

The AU savings calculated with the wage price reported in Table 5.2 was, as a consequence, €0.063/ewe and BW recording, resulting in €0.125 and €0.187 ewe/yr in extensive and intensive meat farms (Table 5.5) and €0.187 ewe/yr in dairy sheep farms (Table 5.6), respectively. According to flock size, the saving values were €2.5 to 87.5 and €3.7 to 130.9/ewe and yr for extensive and intensive meat sheep farms (20 to 700 ewes), and €3.7 to 74.8/ewe and yr for dairy sheep farms (20 to 400 ewes), respectively. Calculated savings represented a contribution of 59.0, 76.3 and 63.2% implementation costs of e-ID in extensive and intensive meat and dairy flocks, respectively.

5.4.3.2.2 Personal Digital Assistant

With regard to the use of PDA for weight recording, as above discussed, estimated unitary extra-costs were €0.043 and €0.047/ewe and yr, for extensive and intensive meat sheep farms, and €0.050 and €0.035/ewe and yr for ×1 and ×2 dairy sheep farms, respectively.

As previously done, estimated savings by using PDA for BW recording calculated as the difference between M data uploading time (0.18 min/ewe; Table 5.4) and PDA (0.01 min/ewe, on average; Ait-Saidi et al., 2014a) systems, for extensive meat sheep farms, resulted €0.057/ewe and yr (Table 5.5) or €0.028/ewe and BW recording. In the case of intensive meat sheep farms (Table 5.5) and dairy farms (Table 5.6), calculated unitary savings were similar, being €0.085/ewe and yr. Values changed by flock size, being €1.1 to 39.9/yr and €1.7 to 59.5/yr in the case of extensive and intensive sheep meat farms (20 to 700 ewes) and €1.7 to 34.0/yr in dairy sheep farms (20 to 400 ewes), respectively, which surpassed 1.3 to 2.5 times the PDA implementation costs for all types of farms studied (Table 5.5 and 5.6).

5.4.3.3 Once Daily Milk Recording

5.4.3.3.1 Handheld Reader

Results obtained from the previous study of e-ID implementation for milk recording of dairy ewes (Ait-Saidi et al., 2014a) and parameters reported in Table 5.2 were used to calculate the extra-costs in this case study. Calculation of extra-costs for the implementation of e-ID for ×1 milk recording, equivalent to the official alternate AT4 milk recording system in dairy sheep (ICAR, 2012), considered that the HHR was owned by the farmer for ewe identification at milk recording and parameters described in Table 5.1 and 5.2. As a result, calculated unitary extra-cost (i.e., e-ID bolus and HHR) with regard to M, for a 400-ewe dairy flock, was €0.130/ewe per ×1 milk recording. For 4 test-days/ewe and yr the calculated extra-cost was €0.520/ewe and yr (Table 5.6). Variation according to flock size (milk recorded ewes, 24 to 400 ewes) resulted in e-ID extra-costs ranging from €12.5 to 208.0/yr, respectively. With regard to savings, use of e-ID with a HHR for ×1 saved 2.8 min/24 ewes (0.12 min/ewe; Ait-Saidi et al., 2014a) in labor time at each milk recording which, for a work wage of €10.0/h per operator (Table 5.2), produced a saving of €0.468/24 ewes or €0.078/ewe and yr (Table 5.6). The calculated savings increased according to flock size ranging from €1.9 to 32.1/yr (time savings, 11.2 to 192.0 min) for flock sizes from 24 to 400 ewes, respectively. On average, these savings only covered 15.0% of the overall e-ID implementation costs for the ×1 milk recording. Additional uses are needed in this case to justify the implementation of e-ID in dairy flocks.

In the case of the HHR owned by the technician doing the milk recording (or milk recording service company), the calculated unitary extra-cost dairy flock, was €0.072/ewe per ×1 milk recording (400 ewes) or €0.286/ewe and yr for 4 test-days/ewe. Flock size variation (24 to 400 ewes) resulted in e-ID extra-costs ranging from €6.9 to 115.2/yr, respectively. Values of savings did not vary by HHR ownership and, on average, the HHR owned by the milk recording technician slightly increased the percentage of implementation costs covered by the savings (27.3%) in the case of ×1.

5.4.3.3.2 Personal Digital Assistant

Estimated extra-cost of using the PDA for ×1 milk recording in dairy sheep farms, taking into account the same considerations as above (e.g., 4 test-days, 400 dairy ewes) and the parameters of Table 2, was €0.067/ewe and yr (Table 5.6), varying from €1.6 to 26.8/yr according to flock size (24 to 400 ewes). The low extra-costs estimated in this case were a consequence of the lower PDA reader price and because the bolus cost was not included (i.e., the PDA used the v-ID). Labor time was assumed to be the same as assumed for e-ID using HHR (Ait-Saidi et al., 2014a), being the saving €0.078/ewe and yr (Table 5.6) and ranging according to flock size between €1.9 to 32.1/yr (24 to 40 ewes). As a result, the difference between savings and costs for the PDA system was €0.011/ewe and yr, which paid 1.2 times the PDA system implementation costs.

In the case of the PDA owned by the technician or a service company, the estimated extra-cost taking into account the same considerations as above, was €0.003/ewe and yr, varying from €0.1 to 1.2/yr by flock size (24 to 400 ewes). Similarly as above, PDA ownership did not change the savings obtained. As a result, the difference between savings and costs for the PDA system was €0.075/ewe and yr, which paid more than 25 times the PDA system implementation costs. Use of a shared PDA showed a high profitability in the implementation of dairy sheep milk recording in practice.

5.4.3.4 Twice Daily Milk Recording

5.4.3.4.1 Handheld Reader

Calculated extra-costs for ×2 milk recording, or official A4 milk recording (ICAR, 2012), using e-ID were €0.547/ewe and yr (Table 5.6), the value ranging between €13.1 and 218.8/yr according to flock size (24 to 400 dairy ewes, respectively). Using the Ait-Saidi et al. (2014a) data, the e-ID system for ×2 milk recording saved 5.6 min/24 ewes (0.23 min/ewe) in labor time per daily milk recording by using a HHR which, according to the wage price reported in Table 5.2, produced a saving of €0.039/ewe and milk recording day, equivalent to €0.155/ewe and yr (Table 5.6). Labor time savings varied according to flock size from 22.4 to 373.3 min (24 to 400 ewes, respectively) and, consequently, calculated savings ranged from €3.7 to 62.3/yr, respectively. In this case, savings covered 28.3% of the extra-costs associated with e-ID implementation, and were greater than values previously reported for ×1 milk recording.

In the case of the HHR owned by the technician and brought to the farm for milk recording, the extra-costs calculated for ×2 milk recording (or A4) using e-ID were €0.292/ewe and yr, ranging between €7.0 and 116.8/yr according to flock size (24 to 400 dairy ewes, respectively). Savings were similar to those obtained for ×1, being €0.155/ewe and yr. In this case, savings covered 53.1% of the extra-costs associated with e-ID implementation, which doubled the value previously reported for ×1 milk recording.

5.4.3.4.2 Personal Digital Assistant

With regard to the PDA system and considering the same parameters as previously used for ×2 milk recording (Table 5.2), the extra-costs obtained were €0.092/ewe and yr (Table 5.6), varying from €2.2 to 36.8/yr according to flock size (24 to 400 dairy ewes). Similarly, the savings estimated when PDA system was used for ×2 milk recording were €1.0/24 ewes or €0.042/ewe and milk recording day (€0.167/ewe and yr; Table 5.6). According to flock size (24 to 400 dairy ewes), savings of PDA ranged from €4.0 to 66.8/yr, respectively, which exceed 1.8 times the PDA system implementation costs and proved to be profitable for ×2 milk recording.

With regard to the PDA system owned by the technician, and considering the same parameters as for ×2 milk recording (Table 5.2), the extra-costs obtained were €0.006/ewe and yr, varying from €0.1 to 2.4/yr according to flock size (24 to 400 dairy ewes). Similarly, savings ranged from €4.0 to 66.8/yr according to flock size (24 to 400 dairy ewes), respectively, which dramatically increased (2,783%) its contribution to PDA system implementation costs and showed that the use of shared PDA was highly profitable for ×2 milk recording in practice.

5.4.3.5 Annual Inventory

Cost of all the equipment necessary for doing the annual inventory was already considered in the case of BW recording, being its unitary cost similar. Estimated mean time for doing the M inventory, according to the measurements done, was 0.37 ± 0.01 min/ewe (~1.6 ewe/min). This value included manual restraining, visual reading, manual recording and data transfer of ewe's v-ID. On the other hand, mean time for the AU inventory was considered similar to a dynamic reading (e.g., at the entrance of the milking parlor as done by Ait-Saidi et al., 2014a; 0.04 ± 0.01 min/ewe). As a consequence, the difference between M and AU resulted in a saving of 0.33 min/ewe or €0.055/ewe and yr for the wage price reported in Table 5.2.

Likewise, for an inventory done by using the PDA system, in which the only difference with regard to M (0.18 min/ewe; Table 5.4) was the PDA data transfer (0.01 min/ewe; Ait-Saidi et al., 2014a), the calculated mean saving time was 0.17 ± 0.01 min/ewe or €0.028/ewe and yr for the wage price reported in Table 5.2.

5.4.4 Cost-Benefit Study by Type of Sheep Farm and Scenario

5.4.4.1 Meat Farms under extensive

Benefits for typical meat sheep farms (700 ewes) using the considered performance recordings (i.e., lambing, weighing and inventory) were calculated using the parameters summarized in Table 5.2. The calculated ROR for meat sheep farms under extensive were −29.6 and 98.3% for HHR and PDA systems, respectively (Table 5.5), the PDA showing a return of approximately 2 times the investment made to implement the system. In the case of compulsory e-ID for extensive meat sheep farms, ROR was positive and its value increased to 44.4% in the HHR system (Table 5.5), closer to the PDA value, which demonstrates the benefits of implementing the e-ID system under these conditions.

With regard to BEP, number of ewes for zero benefit was markedly lower for PDA when compared to HHR (352 vs. 1,785 meat ewes; Table 5.5). Nevertheless, when e-ID was considered compulsory, the BEP value of HHR system decreased to 485 meat ewes (−72.8%, Table 5.5).

5.4.4.2 Meat Farms under Intensive

Similarly, benefits for a typical meat sheep farm (700 ewes) under intensive conditions were −8.9 and 181.0% for HHR and PDA systems (Table 5.5), respectively, which was the maximum difference observed between the PDA and HHR recording systems. The PDA showed in this case a return of approximately 2.8 times the investment made to implement the system, whereas the HHR was negative but close to the full return. For compulsory e-ID, value of ROR in the HHR system become more positive than under extensive conditions (Table 5.5), being the return approximately 2 times the investment.

Calculated BEP in number of ewes was also lower for PDA when compared to HHR under intensive meat sheep farms (874 vs. 249 meat ewes; Table 5.5). Furthermore, in the compulsory e-ID scenario, BEP value of the HHR system decreased to 343 meat ewes (−60.7%, Table 5.5), which was under the average flock size of Spanish meat sheep farms

(MAGRAMA, 2014) and similar to the value above reported for the PDA system under extensive conditions.

5.4.4.3 Dairy Farms Using ×1 Milking

As previously done for typical meat sheep farms, the estimated benefits of using the SA (HHR or PDA) and AU (stationary reader) performance recording systems, for typical ×1 dairy sheep farm (400 ewes) using performance recording (i.e., milk recording, lambing, weighing and inventory), were calculated by using the data summarized in Table 5.2. The calculated ROR for ×1 milk dairy farms were −31.1 and 84.1% for HHR and PDA systems, respectively (Table 5.6), the PDA being able to return 1.8 times the investment made for implementation. For conditions where the use of e-ID is compulsory, as currently adopted in many EU countries, the cost of e-ID bolus was removed from calculations. As a consequence, the ROR value for the HHR system changed to positive and increased to 28.9% (Table 5.6), making the implementation of this system profitable for the farmer. Changes did not apply for the PDA system but, the use of PDA instead of HHR system for ×1 milk recording, resulted in additional benefits of 115.2 and 55.2% for the optional e-ID and the compulsory scenarios of e-ID use, respectively.

Calculated BEP, expressed as number of ewes for zero benefit, was lower for PDA vs. HHR (217 vs. 957 dairy ewes, respectively; Table 5.6). Moreover, when considering e-ID as compulsory, BEP of HHR system decreased 67.6% (310 dairy ewes), lower than the average flock size in the current Spanish dairy farms (MAGRAMA, 2014; Milán et al., 2013) and than the flock size chosen for the typical dairy farm in this study.

When the milk recording technician owned the reader, the calculated ROR for ×1 milk dairy farms were −31.8 and 80.5% for HHR and PDA systems, respectively, the PDA returning 1.8 times the investment made for implementation. For conditions where the use of e-ID is compulsory, the ROR value for the HHR system changed to positive and increased to 26.5%, making the implementation of this system profitable for the farmer. Changes did not apply for the PDA system but, the use of PDA instead of HHR system for ×1 milk recording, resulted in additional benefits (112.3 or 54.0% when the e-ID was considered optional or compulsory, respectively) which were similar to the case of PDA owned by the farmer.

Calculated BEP, expressed as number of ewes, was very low for PDA when compared to HHR (10 vs. 973 dairy ewes). Moreover, when considering e-ID as compulsory, BEP of HHR system decreased 67.5% (316 dairy ewes), lower than the average flock size in Spanish dairy farms (MAGRAMA, 2014; Milán et al., 2013) and the flock size chosen for the typical dairy farm of this study.

5.4.4.4 Dairy Farms Using ×2 Milking

The same method and considerations as above indicated were used for the cost-benefit study in a typical dairy sheep farm (400 ewes) using ×2 milk recording. The calculated ROR for ×2 milk dairy farms were −18.2 and 143.0%, for HHR and PDA systems, respectively (Table 5.6), the PDA returning 2.4 times the investment made for the implementation of the system. For compulsory e-ID, value of ROR in the HHR system became more positive than ×1 (Table 5.6) and covered the full return of the investment. Consequently, the difference of ROR values between 1× and 2× milk recordings were 12.9 or 24.1 points of percentage for HHR system under optional or mandatory e-ID scenarios and 58.9 points for the PDA system.

Calculated BEP in number of ewes was also lower for PDA when compared to HHR in ×2 dairy sheep farms (608 vs.165 ewes; Table 5.6). Furthermore, in the compulsory e-ID scenario, BEP value of the HHR system decreased to 262 dairy ewes (−56.9%, Table 5.6), which was again under the average flock size of Spanish dairy sheep farms using ×2 milk recording (MAGRAMA, 2014; Milán et al., 2013) and made evident the cost-effectiveness of implementing e-ID in dairy sheep farms.

The same method and considerations as above indicated were used for the cost-benefit study in a typical dairy sheep farm (400 ewes) using ×2 milk recording when the technician owned the reader. The calculated ROR for ×2 milk dairy farms were −19.8 and 134.0% for HHR and PDA systems, respectively, the PDA returning 2.3 times the investment. For compulsory e-ID, value of ROR in the HHR system become more positive than ×1, indicating the full return of the investment. Consequently, differences between ROR values of 1× and × 2 milk recording systems were 12.0 or 21.0 percentage points for HHR system under optional or mandatory e-ID scenarios, respectively, and 53.5 points for the PDA system.

Calculated BEP in number of ewes was also lower for PDA when compared to HHR in ×2 dairy sheep farms (629 vs.171 dairy ewes). Furthermore, in the compulsory e-ID scenario, BEP value of the HHR system decreased to 271 dairy ewes (−56.9%), which was again under the average flock size of Spanish dairy sheep farms using ×2 milk recording (MAGRAMA, 2014; Milán et al., 2013), making evident the cost-effectiveness of implementing e-ID in dairy sheep farms.

5.4.4.5 Impact of Reading Device Price

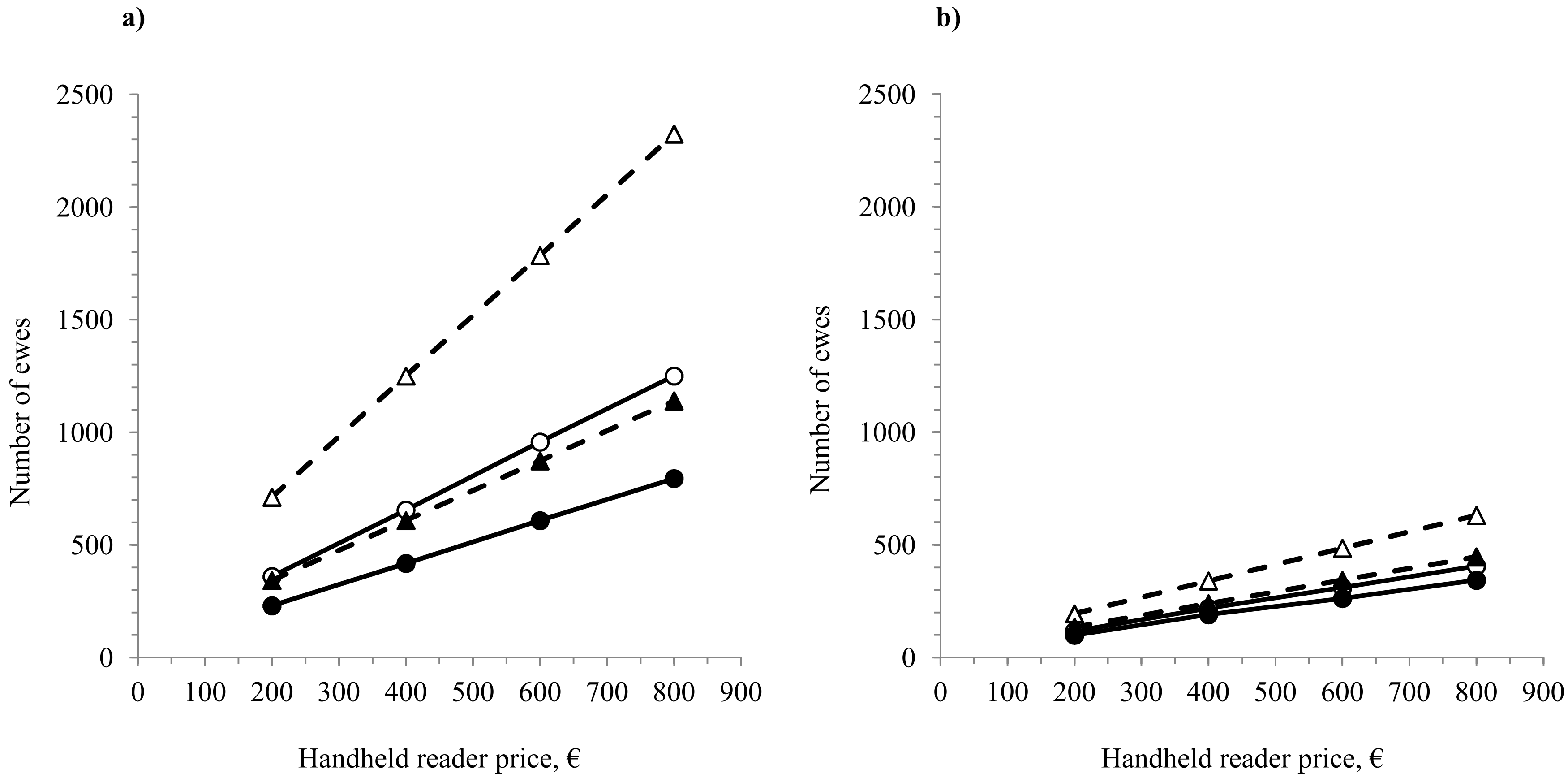
According to data shown in Table 5.5 and 5.6, readers were, on average, one of the most expensive components of the extra-costs which necessarily are to be paid for the implementation of the HHR performance recording systems in meat (46.7%) and dairy (53.4%) sheep farms for the optional e-ID scenario. Moreover, when the e-ID bolus cost was removed from the calculation, due to the e-ID compulsory scenario, the HHR was also responsible of the greatest extra-costs in both meat (91.0%) and dairy (93.5%) sheep farms. Consequently, we evaluated the effect of the HHR price (in the range of €200 to 800, as currently found in the market) in the cost-benefit study.

The price of the reading devices used conditioned the break-even point, expressed as the minimum flock size (number of sheep), of the typical farms considered in the study. Break-even point also varied according to the scenario considered.

For an optional e-ID scenario, HHR price dramatically affected the BEP of meat and dairy sheep farms (Figure 5.1a), the effect being more marked in the case of extensive meat sheep farms (1 lambing/yr) and lower for the ×2 milk recording dairy sheep farms. Differences were slight between intensive meat sheep (1 lambing/yr) and ×1 milk recording dairy sheep farms. As a consequence, taking into account the flock size considered for the typical meat sheep farm in the study (700 ewes), the desirable HHR price should be lower than €235 and 481, for extensive and intensive conditions, respectively. In the case of the typical dairy sheep farm of the study (400 ewes), the desirable HHR price should be lower than €251 and 395, for ×1 and ×2 milk recording, respectively. All values were lower than the prices observed currently in the market and than the standard price used in our study (€600), indicating a real need for offering cheaper HHR to sheep farms (i.e., optimizing their design and recording performances, increasing the amount of devices sold) for a cost-effective implementation of the e-ID technology in the sheep industry.

For mandatory e-ID scenarios (Figure 5.1b), the BEP differences between sheep farms types were smaller than in the optional e-ID scenario (Figure 5.1a), being its value slightly greater in the case of the extensive meet sheep farms (Figure 5.1b). All BEP values were under the average flock size of the Spanish meat and dairy sheep farms (MAGRAMA, 2014) for the HHR price considered in the study (€600). Moreover, taking into account the typical flock size of the meat sheep farms in the study (700 ewes), the critical HHR price can reach €866 and 1,224, for extensive and intensive conditions, respectively. In the case of typical

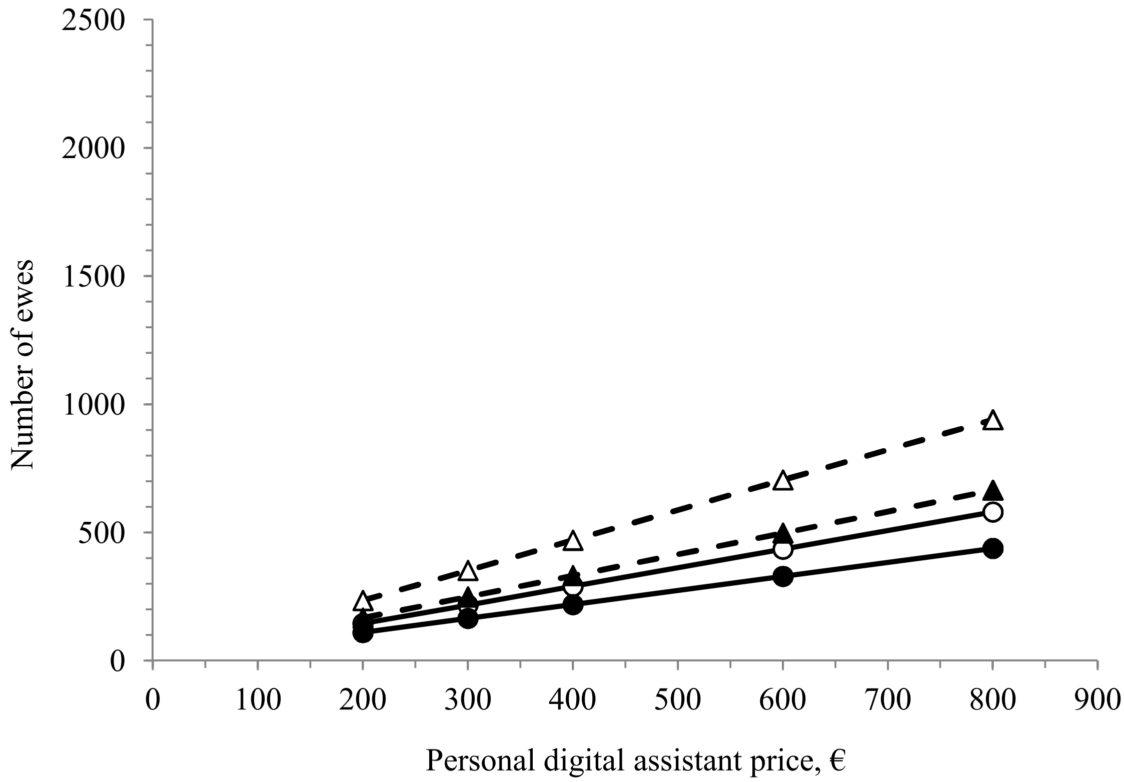
Figure 5.1. Effect of handheld reader price used for performance recording on flock size break-even point (number of ewes) in meat sheep farms under extensive (--Δ--) or intensive (--▲--) conditions and in dairy sheep farms using ×1 (-○-) or ×2 (-●-) milk recordings daily in an optional (a) and mandatory (b) electronic identification scenario.



dairy (400 ewes) sheep farms, the critical HHR prices were €774 and 916, for ×1 and ×2 milk recording, respectively.

The calculated BEP values for using the PDA were independent of the e-ID scenario (Figure 5.2). Critical PDA prices for the typical meat (€596 and 843, extensive and intensive conditions, respectively) and dairy (€553 and 727, ×1 and ×2 milk recording, respectively) sheep farms were greater than the PDA standard price considered in our study (€300). Consequently, the use of PDA was cost-effective for all types of farm considered.

Figure 5.2. Effect of personal digital assistant price used for performance recording on flock size break-even point (number of ewes) in meat sheep farms under extensive (--Δ--) or intensive (--▲--) conditions and in dairy sheep farms using ×1 (-○-) or ×2 (-●-) milk recordings daily.



Comparing PDA and HHR, BEP values dramatically varied according to the e-ID scenario considered, the HHR only being close to PDA in the case of mandatory e-ID, as currently done in the EU. The difference of flock size for zero benefit were 133 and 94 ewes, for extensive and intensive meat sheep farms, and were 93 and 97 ewes for ×1 and ×2 milk recording dairy sheep farms, respectively. The difference in the estimated BEP values (<100 ewes) for intensive meat and dairy sheep farms may be compensated by other uses and possible advantages offered by the e-ID and not included in this study (i.e., sorting gates, veterinary treatments, genetic improvement, etc.).

5.5 CONCLUSIONS

Use of e-ID for semi-automatic (lambing data recording) and automatic (body weight recording) performance recording in meat and dairy sheep farms saved approximately 50% of the time required and increased the reliability of the collected data (lower misrecorded data and no transmission errors). Nevertheless, additional equipment was required (i.e., e-ID devices and readers) increasing the cost of performance recording. Calculated extra-costs depended mainly on farm type (i.e., meat or dairy), conditions (i.e., extensive or intensive), scenario (i.e., optional or mandatory e-ID), flock size (number of sheep), test-days per day (×1 and ×2 milk recordings) and per year, as well as on reader price.

When extra-costs were considered, the use of e-ID produced savings which only paid partially (15 to 70%) the investment made for e-ID system in the optional scenario. In the case of mandatory e-ID, as currently used in the EU and in which the bolus costs were excluded, the savings paid 100% of the extra-costs in all farm types and conditions. In both scenarios, HHR price was the most important extra-cost (40 to 90%) of e-ID implementation.

As a possible alternative to reduce the cost of implementing semi-automatic performance recording systems, the use of PDA was considered. Calculated extra-costs of using the PDA covered more than 100% of the implementation costs in all type of farms, indicating that this device was cost-effective for sheep performance recording.

In conclusion, the use of e-ID proved to be cost-effective under the e-ID mandatory scenario currently adopted in European Union, but not when e-ID was considered optional. Other uses (i.e., management, selection, veterinary treatments) or the reduction in the price of the readers should be necessary for fully paying the e-ID extra-costs. Finally, the use of PDA devices for data management should be a recommendable option for semi-automatic performance recording in many productive scenarios of the current sheep industry.

CHAPTER 6

Current advances of using electronic identification systems in performance recording of sheep and goat farms

CHAPTER 6.

Current Advances of Using Electronic Identification Systems in Performance Recording of Sheep and Goat Farms

6.1 Abstract

Since the disease outbreaks of the last 2 decades, efficient systems for individual sheep and goat identification (ID) were developed worldwide to outface the public health concerns, to improve genetic and traceability purposes as well as to make accurate performance recording. In the European Union, standardized electronic ID (e-ID) devices based on radio-frequency technology are compulsory in member states with sheep and goats population greater than 600,000 head. Main limitation to wide-spread e-ID implementation at farm level was the higher cost acquisition which is currently in continuous decreasing. Cost and primary benefits of ID and registration systems at national level were analyzed in some countries; which took into account costs of ID devices, their loss rate; as well as costs of equipments and software, database creation and management, and animal movement recording.

This paper reviews researches carried out on implementing e-ID systems at farm level (secondary benefits). When a system based on electronic bolus and readers was implemented for automatic e-ID and performance recording (milk recording, lambing and body weight recording) and compared to visual ID and manual paper recording, saved on average more than 19, 44 and 60% of time respectively, which could pay on average 31, 30 and 65% of e-ID implementation costs, respectively. Moreover, use of e-ID for performance recording decreased errors; even eliminate them while uploading data. However, previous operator's expertise in e-ID use is needed.

With regards to calculation of e-ID implementation costs according to farm types, prices of e-ID devices and reading equipment were considered. The total costs varied according to flock size, sheep lifespan and test-days per yr. As a result, costs were distributed mainly for e-ID devices (50%) and handheld reader (50%).

Benefits of e-ID implementation at farm level are mainly the considerable reduction in labor, automatic reading, time saving and reliability of collected data. In conclusion, cost-benefit analysis determined the cost effective strategy to choose according to the farm type and performance recording. Furthermore, it is expected that implementation of e-ID systems at farm level will provide several possibilities to automate performance recording and to

improve flock management by availability of updated animal data (i.e., performances, health and movement). Finally, the most important needs to wide-spread e-ID implementation in sheep industry are the improvement of readability of e-ID devices in all conditions and the development of efficient low-cost e-ID devices and readers.

6.2 Introduction

Farmers are involved to manage their herds or to improve animal traits of interest; mainly by practicing performance recording. As known, on-farm performance data recording allows following the animals in their different productive and health status. The key of any recording is to dispose of a suitable individual identification (**ID**) which provides data precision of animal performances. As well as, tamperproof new ID techniques for livestock and their products would be very helpful to prevent theft and fraud in commerce (Ruhil et al., 2013), and also for tracing animals and their products to origin (McKean, 2001; Caja et al., 2003).

As summarized by Ruhil et al. (2013), an individual animal ID system is implemented at farm level for the following main reasons:

- To mark ownership, distinct from other farms and to protect against theft
- Segregating animals into different groups (young, dry, milking, pregnant, etc.)
- Nutritional and health care of individual animals
- Behavior monitoring and early disease diagnostic of individual animals
- Automatic on-farm performance recording (milk recording, weighing, feeding etc.)

Most electronic identification (**e-ID**) devices currently in use (ruminal bolus, e-RB; electronic ear-tags, e-ET; electronic leg-tags, e-LT or injectable transponders, e-IT) are considered efficient means for linking animal ID to their information and performances data (Trevarthen and Michael, 2007; Samad et al., 2010; Voulodimos et al., 2010). Additionally, errors of ID, data recording and uploading decreased to 0.1% or less by using electronic systems (Austin, 1995); in contrast, with visual methods, false attribution of ID and transmission mistakes are usually close to 6% (ADAS, 2006). According to studies summarized in Table 6.1, automated systems of livestock through RFID technology can facilitate management of farms, reduce recording errors and decrease manual labor time, and provide benefits to the farmer.

At this point, a discussion on the use of visual and e-ID devices for performance recording of sheep and goats is required. Since 2 decades, various studies reviewed implementation of livestock ID systems for performance recording and data management at farm level especially for cattle and porcine species (Lambooij, 1991; Artmann, 1999; Eradus and Janssen, 1999; Klindtworth et al., 1999; Ntafis et al., 2008; O'Connor, 2009) but those evaluating the secondary benefits in sheep and goat farms are very limited (Table 6.1). Thus, and taking into account results of previous experiments, this chapter aimed to discuss current advances and secondary benefits of using e-ID systems for performance recording of sheep and goats at farm level.

6.3 Secondary Benefits

Implementation of accurate ID systems provides primary benefits (at national level) by increasing the control of movements and reducing the risks of disease outbreak and warranting traceability. In addition, the ID system can be used in livestock management programs as vaccinations, health monitoring and genetic schemes. In the EU countries, identification and registration (**ID&R**) systems are currently implemented at national level and mainly took into account a suitable ID technique (for animals intended to slaughter or replacement), a premise's register and movement recordings. Moreover, availability of detailed animal data and their performances in local and national databases allows managing them efficiently in the premises and to follow their movement between premises, and throughout their lifecycle.

Apart these primary benefits allowed by the implementation of e-ID systems, farmers are interested to take more profits from the RFID technology. Low cost and easiness of using e-ID systems for different livestock industries (i.e., slaughterhouse, market sale) promoted the wide-spreading of e-ID for farm management. Use of e-ID devices, reading equipment (i.e., automatic scales and automatic milking systems) and related software allow farmers to link the e-ID number with the relevant information and performances of animals. Then, when performance recording data are uploaded to a computer, they become available in databases for their future use. According to management objectives, additional information can be included to the recorded data such as, genetics or pedigree, breeding and health data, growth rate, relevant periods of pharmaceutical treatments, data of artificial insemination and pregnancy scan, wool weight and milk measurements, etc. Usually, animal performances are collected by a farmer, a technician or a veterinary at farm level or recorded during and after animal movement between premises.

Table 6.1. Implementation of e-ID for on-farm performance recording

Performance recording	Specie	Identification device	Effects produced	References
Milk recording & data collection	Sheep	e-RB[1]	Facilities in data recording; efficient management system	Pinelli et al., 2002
	Sheep	Tattoo vs. e-RB[1]	Time saving of reading & recording (45%), improvement in accuracy & efficiency	Pinna et al., 2008
	Goats	v-ET[2] vs. e-RB[1]	Time saving (9%); data accuracy (100%)	Ait-Saidi et al., 2008
	Goats	v-ET[2] vs. e-IT[3]	Improvement in efficiency & accuracy	Caja et al., 1999b
Automatic Milking	Bovine	e-ET[4]	Improvement in accuracy; decrease of stress at milking; whole management facilities	Stankovski et al., 2012
Automatic milking, sorting and feeding	Bovine	Visual and e-ET[4]	Automated systems & labor saving; Return on investment & benefits	Trevarthen and Michael, 2007
Data recording and Processing	Sheep	Visual and e-ET[4]	e-ID implemented for lambing & BW recording, sorting & tracking; milk recording; feeding & at slaughtering	Weisbecker et al., 2006
Dynamic reading	Bovine & Pigs	e-ET[4]	Automatic data capture at slaughterhouse & upload in a national database	Barge et al., 2013
Body weight	Sheep & Goats	e-ET[4]	Static & dynamic reading; feeding system; inventory & movement recording; Automatic weighing; milk recording	Marguin et al., 2011
	Sheep	e-ET[4]	Individual data collection	Morris et al., 2012
	Bovine	e-ET[4]	Automatic weighing system (125 heifers/h)	Frappat, 1996
	Livestock	e-ET[4]	Saving in time (50%) & in labor (70%)	Hua et al., 2012
Automatic sorting	Sheep	e-RB[1]	Dynamic reading speed 2 ewes/s	Maton et al., 2006

Heat detection	Sheep	e-RB[1]	A male equipped with a reader detects females in estrus when read their e-ID, automatic e-ID & time recording, optimal timing for AI	Bocquier et al., 2006
	Bovine	Visual and e-ID[5]	Use of DEC system produced >87% of estrus detection accuracy	Saumande, 2002
Seasonality by using an estrus detector	Sheep	e-RB[1]	Characterization of sheep breeding seasonality in their environment	Maton et al., 2010
Movement recording between areas	Sheep	e-RB[1]	Monitoring times spent by sheep in determined area, 98% of sheep trained to use non-return gates & motivated by concentrate feed	Champion et al., 2005
Breeding, pregnancy test, calving, milk recording, drying off, body weight	Bovine	e-ET[4]	Accurate data of e-ID & recording system for small-holding, provide assurance & benefit to farmer, veterinary & administration; labor ID&R costs decreased by automation, profits generated by optimizing animal productivity	Samad et al., 2010
Productive, reproductive & movement recordings	Livestock	e-ID[5]	Accurate data recording & storing; effective platform database for livestock performance & movement recording	Voulodimos et al., 2010

[1]Ruminal bolus; [2]Visual ear-tags; [3]Injectable transponder; [4]Electroni ear-tag; [5]Electronic identification.

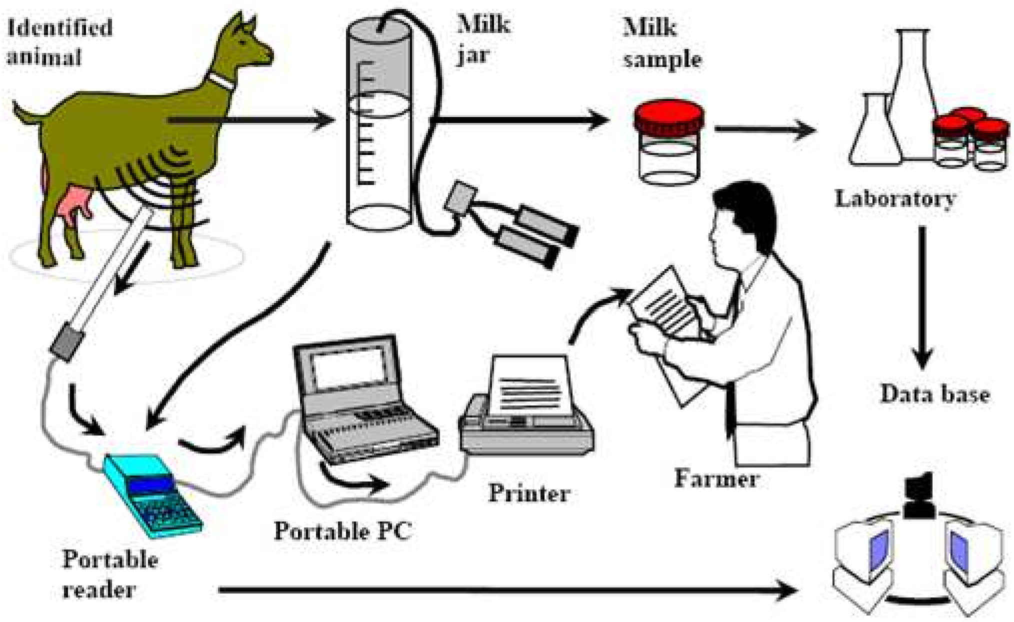
6.3.1 Automation of Milk Recording

Automatic systems are usually used in milking parlors for dairy animals. They obtain individual ID by means of RFID transponders and record milking data automatically. The signal from the transponder of each animal (included in e-RB, e-ET or e-LT) is automatically transmitted to the computer with the recorded milk yield and other relevant information at milking. Currently, new systems are developed including sensors to collect automatically the individual milk yield of each animal in the herd and to upload it by mean of a specific program installed in the computer. This type of software records the collected information into the animal's database, analyzes it and produces reports according to the requests of the farmer (Afimilk, 2014).

With regard to milking systems for dairy cows, Trevarthen and Michael (2007) and Samad et al. (2010) described different on-farm management systems which are using e-ID (Table 6.1). Stankovski et al. (2012) tested the use of a monitoring system based on RFID technology for 305 Holstein-Frisian dairy cows in the Republic of Serbia for e-ID and monitoring of the entire milking cycle. They observed an improvement in collected data accuracy, a decrease of cow stress at milking and a better management.

In dairy goats, Caja et al. (1999b) proposed a milk recording system based on e-ID by means of e-IT, a handheld reader and recording jars. As shown in Figure 6.1, a portable reader was used for semi-automatic goat e-ID and to upload the volume of milk read from the milk jar. Data collected in the reader was then transferred to a portable computer and thereafter to the centralized data base. Data uploaded into the computer can be printed for immediate release to the farmer. Milk recording may also be combined with milk sampling and milk analyses in laboratory, the results being also incorporated to the database for the entire lactation yield calculations. Similarly, Ait-Saidi et al. (2008) in dairy goats compared 2 systems (manual, M; semi-automatic, SA) of milk recording based respectively on: 1) visual ID by conventional ear tags, 2) e-ID by electronic bolus. Results did not shown difference in milk yield and recording time between M and SA. Decrease of SA recording time over the lactation period indicated an increase in operator expertise. Moreover, use of automatic data uploading to a computer by Bluetooth connection in the SA system saved 75% of labor time (−3.7 min/24 goats). Furthermore, errors occurred during milk recording with both systems averaged 0.6% and an additional 1.1% error was registered during M data uploading. Total milk recording time was 8.6% greater in M than in SA which resulted in time saving and permitted to pay 40% of e-ID implementation costs. As conclusion of the study, implementation of e-ID system for dairy goats was cost effective and resulted in fewer data errors. Benefits may extend with operator's skill and larger goat herds.

Figure 6.1. Automatic ID and procedures of milk recording in dairy goats (Caja et al., 1999b).



In dairy sheep, a first prototype of automatic milk recording system was used in France based on the use of electronic jars (Ricard et al., 1994). Other models were developed and approved by ICAR for high performance coupling e-ID and milk measurements (Lhomme and Lecomte, 2010; Afimilk, 2014; DeLaval, 2014). ICAR has the authority to approve milk recording devices according to ISO standards (Rosati, 2013). Transponders subcutaneously injected (Caja et al., 1998a), inserted into ceramic ruminal bolus (Caja et al., 1996) or in ear tag (Marguin et al., 2011) made an easy automatic reading in milking parlors from rear or front side.

Pinna et al. (2008) implemented M and SA systems for milk recording of dairy Sarda sheep (Table 6.1). In dairy Manchega and Lacaune sheep, additional considerations were taken into account by Ait-Saidi et al. (2014a), as well as milking frequency (once, ×1 or twice, ×2 daily milking) and a use of a personal digital assistant (**PDA**). There was no difference in ×1 milk recording time between systems; and milk recording time of dairy ewes was 30.3% lower when compared to dairy goats (Ait-Saidi et al., 2008), the difference was due mainly to the lower milk yield of dairy ewes. Moreover, operator expertise to use SA system for milk recording of dairy sheep was improved and accurate data were obtained (no errors). Implementing SA milk recording in dairy ewes for an average flock size up to 480 ewes (MAGRAMA, 2014) was cost-effective, saving time (19.5%, Ait-Saidi et al., 2014a; 45.0%, Pinna et al., 2008) and improved data accuracy. Additionally, use of a PDA for instantaneous data uploading resulted 2.7 and 11 times (Ait-Saidi et al., 2014a) faster compared to SA and M, respectively.

6.3.2 Data Recording at Lambing

Ait-Saidi et al. (2014a) implemented a SA system based on the use of e-RB for e-ID and a handheld reader for automatic reading and manual recording at lambing. Results showed an overall time saving (0.57 min/ewe; 43.8%) regarding the M system. Data were wholly accurate in SA; however 4.9% of uploading errors occurred in M. We did not meet other studies quantifying advantages of automated systems when were implemented to record data at lambing; although, recording of new born lambs and ewe at lambing is of major importance to the farmer and costs great labor.

6.3.3 Body Weight Recording

Body weight (BW) is an important indicator of the wellbeing and considered as a mean to evaluate nutritive status of an animal (i.e., growth rate, body condition). With the development of advanced weighing techniques, automatic systems has been designed and available for chicken (Turner et al., 1984), pigs (Turner et al., 1985), cows (Peiper et al., 1993) and sheep (Tru-Test, 2014; Gallagher, 2014). In the case of pigs, with the use of image analyzing system (Brandl and Jorgensen, 1996; Schofield et al., 1999), the knowledge of their growth rate allows valuable information on health and productivity. However, the great labor expended and the stress caused by the conventional weighing systems make it impractical in most farm conditions. With this regard, automatic weighing systems can allow frequent weighing without most of the drawbacks (Marguin et al., 2011; Ait-Saidi et al., 2014a).

A first automatic weighing machine was reported by Filby et al. (1979) and Laycock and Street (1984). It consisted of a load cell connected to a platform across which cows walked when leaving the milking parlor. Peiper et al. (1993) studied an electronic weighing system combined with automatic individual ID of dairy cows and the system resulted feasible and accurate. Moreover, Frost et al. (1997) indicated the need of individual e-ID for the automatic weighing which can easily used to monitor growth rates of animals specially intended for slaughter.

At nowadays, the Walk-Over-Weighing (WOW) system was developed to collect regular BW without the need of handling or bringing animals to the pen. When an animal is attracted by a presented feed or water to walk over a weight platform, its e-ID and the associated BW are recorded and showed into a scale display. Obtained BW over a determined period are used to calculate growth rates and to predict when the animal reach a target weight to be slaughtered or for market sale at a correct time. The system is also useful to examine animals' condition by monitoring small changes in BW well before conditions score are assessed. According to Richards et al. (2010), use of e-ID and automatic BW recording allows decreasing animal stress and unnecessary handling; as well as permits to save labor and time for the farmer.

Hua et al. (2012) implemented an automatic BW recording system by e-ID which saved 50% of recording time. Results of Ait-Saidi et al. (2014a) in sheep agreed with the last data, and no errors were registered during BW recording with the AU system.

6.4 Cost- Benefit Evaluation

6.4.1 At National Level

Cost-benefit studies which estimated ID&R systems at national level were summarized in Table 6.2.

In Spain, Saa et al. (2005) developed a model to evaluate the implementation costs of the EU regulation CE 21/2004 for sheep and goat ID&R, in which compared 3 main strategies including the use of e-ID devices (Table 6.2):

1) Conventional identification (CID) of all animals by using 2 plastic v-ET;
2) Electronic identification (EID) by using 1 e-RB and 1 plastic v-ET;
3) Mixed strategy (MID), using CID for all the animals intended for slaughtering, and EID for replacement animals.

The main variation factors that directly affected the total costs of the different strategies (range €2.48 – 4.64) were the e-ID devices' price and the v-ET losses. Simulated scenarios for market prices in 2004 (e-RB, €2.2; v-ET, €0.3 for ewes and €0.15 for lambs) showed that total annual cost of CID reached the EID cost when v-ET losses reached 18%. Moreover, cost of MID equaled CID when v-ET losses varied between 7.5 and 11.5% and e-RB price ranged between €1.8 and 3.3. According to the actual price of e-RB (<€1.5), the current cost of the EID strategy decreased and are close to that of the CID strategy. The MID strategy was the chosen as a practical option for sheep and goat ID&R in Spain.

Table 6.2. Studies carried out to evaluate national Identification and Registration systems in sheep

References (Country)	Scenario	Recording[1]	ID devices[2]	Recording System[3]	Uploading to a Database[4]	Holding register[5]	Movement document[6]
Saa et al., 2005 (Spain) [7]	Conventional	I	×2 v-ET	M	M	M	M
	Electronic	I	e-ID	AU	AU	e-ID	e-ID
	Mixed[8]	I	v-ET & e-RB	M & AU[9]	SA	M or e-ID	M or e-ID
APHIS, 2009 (USA)[10]	Premises Registration	G	Lot ID number	M	M[11]	M	M[11]
	Animal ID system	I	v-ET	M	M[11]	M	M[11]
Velthuis et al., 2009 (Netherlands)	FIR[12]	I	v-ET	M	M	M	M
	CIR[13]	I	e-ET	AU	AU	Central Database[14]	Voice or AU[15]
	CGR[16]	I	e-ET	AU	AU	e-ID	Central Database[14]
ADAS, 2006 (UK)	Option 1	G	×1 v-ET	M	M	M	M
	Option 2	I	×2 v-ET	M	M	M	M
	Option 3	I	v-ET & e-ID	M & AU[9]	SA	e-ID	e-ID
	Option 4	I	v-ET & e-ID	AU	AU	e-ID	e-ID

[1]Sheep identified by group (G) with the premise of origin code or individually (I); [2]Single (×1) or double (×2) identification (ID) by visual ear-tag (v-ET) and/or an electronic identification (e-ID) device by bolus (e-RB) or an electronic ear-tag (e-ET); [3]ID and Recording by manual (M) using a paper form, or automatically (AU) by using a handheld reader; [4]M by using a hard copy to a paper form; Semi-automatic (SA) by using a hard copy and M uploading to a computer; AU by using a Stick reader to a computer; [5]M by a hard paper to a holding register (paper form); or e-ID by stick or stationary readers to a holding register (computer software system); [6]M by a paper form, or e-ID by stick or stationary readers with a possibility to a central database connection; [7]According to EC 21/2004 legislation for individual animal ID, holding register and movement recording; [8]ID with 1 v-ET and 1 e-RB for sheep destined for breeding <12 mo of age; [9]M used for lambs intended to slaughter (<12 mo of age) and AU for replacement sheep; [10]Based on the National Animal Identification System applied in the USA: lambs intended for slaughter identified by group (premise of origin code) and sheep of replacement with v-ET (scrapie program); [11]Use of internet connection to send reports of sheep and premises recording as well as the movements to a central database; [12]Farm Individual Registration; [13]Central Individual Registration; [14]Use of a central database to receive animal data and movement recording; [15]By voice recording or by AU recording with a farm management system; [16]Central Group Registration.

In 2007, Animal and Plant Health Inspection Service (APHIS) of U.S. Department of Agriculture implemented a large scale project to study the cost-benefit of adopting the National Animal Identification System (NAIS). The project included the evaluation of premises registration, animal ID system and animal movement recording for cattle, sheep, goats and other farm species (Table 6.2). In the U.S. sheep industry, lambs were identified with a unique group ID number, but, individual ID was implemented for replacement sheep by using a v-ET (like those used for scrapie program). Cost-Benefits were calculated by size of operations which depends mainly on flock size (<100, 100-499, 500-4,999 and more than 5,000 head). Unitary cost of sheep v-ET was estimated on average to $0.27. Costs of RFID devices implementation were not considered for sheep specie because they used only visual ID. Extra cost per lamb sold was estimated to $1.39, including costs of ID device and tagging, costs of reading and premises registration. Moreover, it was reported that the total cost decreased as size of operations increased; these is due to the great number of identifiers used (decreasing costs) and the reduced labor costs with large flock size (APHIS, 2009).

With regard to the National Livestock Identification System (NLIS) for sheep and goats in Australia, until 2006 it used a handheld reader for ID and recording of v-ET (mandatory device for sheep ID) and a paper document for movement recording. In November 2008, it was introduced the handheld reader also for the movement recording which can be accessed quickly from a central database and also used to enhance traceability. NLIS considered voluntary the use of e-ET for sheep.

In the Netherlands, Velthuis et al. (2009) estimated the costs and reliability of 2 ID&R systems (CIR, Central Individual Registration; CGR, Central Group Registration) based on the use of e-ET for sheep and goats when compared to the FIR system (Farm Individual Registration) based on v-ET currently in use (Table 6.2). As a result, the total annual costs for ID&R systems varied according to sheep farm types and were greater in CIR (+78.0%) and CGR (+80.7%) compared to FIR system, due to the replacement with e-ID devices. In relation to the reliability of the ID&R systems, they concluded that CIR (3.4% errors/yr) was better than the CGR registration system (7.6% errors/yr).

In England, with the compulsory implementation of e-ID by EC 21/2004, DEFRA (Department for Environment, Food and Rural Affairs) commissioned ADAS (Agricultural Development Advisory Service) to conduct field trials on 11 commercial farms for comparing 3 ID&R systems for sheep with the reference system used in UK (ADAS, 2006; Table 6.2). Thus, in order to collect information supporting the production of a Regulatory Impact Assessment, specific data on times, labor inputs, physical performance and cost implication of e-ID implementation for sheep were evaluated. As a part of results, hand-held equipment used did not show difference in speed of data capture between manual and e-ID systems in small sheep flocks (<300 head). However, in large sheep flocks, the use of e-ID was needed to: 1) achieve a considered level of data accuracy by reducing errors; and 2) increase reading rate of individual animals and their movement recording in brief time.

6.4.2 At Farm Level

Identification devices and equipment for e-ID and recording of farm animals appear more expensive than traditional devices, but apart the primary benefits obtained at national level, it allows making many other applications at farm level (Ait-Saidi et al., 2014a). Costs and benefits of e-ID implementation at farm level were studied by Ait-Saidi et al. (2014b). In their analysis, 2 electronic recording devices were taken into account: 1) a handheld reader (HHR) and 2) a personal digital assistant (PDA); and the costs-benefits were estimated for 4 case studies of meat (under extensive and intensive) and dairy (×1 and ×2 daily milking) sheep farms. Additionally, they considered 2 scenarios where e-ID is optional (e-RB price included in calculation) or mandatory (excluding e-RB price). Rate of return (ROR) and the break-even point (BEP) were also calculated for comparing the different options.

Results of the cost-benefit study (Ait-Saidi et al., 2014b) by type of performance recording (Table 6.3) indicated that increase of flock size and performance recording (lambing and BW recording) frequency per yr increased the saving obtained by e-ID implementation. In these cases, calculated savings represented on average a contribution of 29.8 and 65.4% of e-ID implementation costs in lambing and BW recording, respectively. Likewise, use of PDA for lambing and BW recording is fully cost-effective. As shown in Table 6.3, savings obtained surpassed in all cases costs of PDA implementation.

When e-ID was implemented for milk recording by using an HHR owned by the farmer, calculated savings only covered 15.0% of the overall costs. In the case of an HHR owned by the milk recording technician, costs are more covered (27.3%) by savings (Table 6.3). Likewise for PDA implementation which resulted in costs fully paid by savings and return on investment was directly related to the reader owning (Table 6.3). Similarly in the case of ×2 milk recording, calculated savings covered approximately the double of the values reported previously for ×1.

In relation to results of cost-benefit study by type of sheep farm and scenario (Ait-Saidi et al., 2014b), ROR and BEP values were calculated for each case. When the use of e-ID was considered compulsory, costs of e-RB were removed from calculations. As a consequence, the ROR value for the HHR system increased between 60 and 113% according to the type of sheep farms, making the implementation of this system profitable for the farmer. However, no changes were observed in ROR values for the PDA system when considering compulsory or optional scenarios (PDA system doesn't use e-ID devices).

Table 6.3. Summary of cost-benefits according to performance recording types (lambing, body weight, milk and inventory recording) in meat (under extensive and intensive conditions) and dairy (×1, once; and ×2, twice daily milking) farms (Ait-Saidi et al., 2014b).

	Return on investment[1], %				
	Performance recording			Milk recording	
Item	Lambing	BW[2]	Inventory	Farmer[3]	Technician[4]
HHR[5]					
Extensive	25.6	59.0	26.9	-	-
Intensive	35.1	76.3	23.2	-	-
×1	27.9	63.2	19.3	15.0	27.3
×2	30.4	63.2	19.3	28.3	53.1
PDA[6]					
Extensive	405	133	133	-	-
Intensive	557	180	175	-	-
×1	500	170	175	120	2600
×2	709	243	233	182	2780

[1]Percentage of costs (ruminal bolus with unitary price of €1.4 and readers' price) paid by savings (difference between total times of semi-automated and manual systems, Ait-Saidi et al., 2014a multiplied by a wage price of €10/h); [2]Body weight; [3]The farmer owned the reader (HHR or PDA); [4]A technician working 200 d/yr owned the reader (HHR or PDA); [5]Use of a Handheld reader (price, €600); [6]Use of a Personal Digital Assistant (price, €300).

Furthermore, Ait-Saidi et al. (2014b) estimated that the e-ID device (e-RB) price was responsible on average of 53.3% in implementation costs which were calculated in sheep meat farms; likewise in dairy farms, it represented 46.6% of implementation costs. In relation to HHR price's in the optional e-ID scenario, it represented 46.7 and 53.4% of total costs in meat and dairy sheep farms, respectively. Moreover, when the e-RB cost was removed from the calculation, due to the e-ID compulsory scenario, the HHR price was responsible of the greatest extra-costs in both meat (91.0%) and dairy (93.5%) sheep farms. Consequently, the critical HHR price was evaluated in the range of €200 to 800 to reach the break-even point in the cost-benefit study.

As a result, in the optional scenario, calculated HHR prices for the typical sheep flock size (400 ewes) in dairy farms (×1 and ×2) were lower (−58.2 and −34.2%, respectively) than the standard price used in the study (€600). With regard to the extensive and intensive sheep meat farms (700 ewes), HHR prices were also −60.8 and −19.8% lower than the standard price of €600 used, respectively. According to Ait-Saidi et al. (2014b), these results indicated a real need for offering cheaper HHR to sheep farms.

However, in the mandatory scenario, the calculated critical HHR prices increased +29.0 and +52.7% from the standard price to reach the BEP for the typical sheep flock size (400 ewes in ×1 and ×2 dairy farms, respectively). Likewise for sheep meat farms (700 ewes in extensive and intensive), HHR prices increased +44.3 and +104.0%, respectively. Consequently, under the mandatory scenario currently adopted in the EU, the use of e-ID is cost-effective and fully justified according to results of cost-benefit analysis at farm level by Ait-Saidi et al. (2014b).

Regarding the use of PDA at farm level, calculated extra-costs covered more than 100% of the implementation costs in all type farms, indicating that it is cost-effective for sheep performance recording.

6.5 Additional Uses of Electronic Identification at Farm Level

Utilization of transponders is a cost-effective system for farm management (Geers et al., 1997; Saa et al., 2005; Ait-Saidi et al., 2014b). Electronic identification is combined with equipment for on farm management practices, such as electronic scales (Hua et al., 2012; Ait-Saidi et al., 2014a) and dynamic reading in conventional race-ways equipped with frame antennas and stationary reading units (Stewart et al., 2007; Barge et al., 2013). Moreover, the use of electronic readers with memory and communication ports facilitates a fast and accurate data transfer from farms to data bases, and eliminates the associated errors of manual data transcription (Fallon et al., 2001; Ait-Saidi et al., 2008; 2014a). In the other hand, there are different types of sensors able to collect an increasingly wide range of information (i.e., temperature, movement, pH) but they require a permanent supply of energy (batteries) to operate. Passive transponders used for e-ID are activated once placed in the antenna field of RF readers and do not use batteries. Moreover, different developments of ID transponders integrated sensors which allowing animals to be monitored on farm conditions. Also, when farm tasks are automated, they permit a reduction in time spent observing the animals; especially in the case of temperature and activity monitoring systems which supervised parameters of physiology and behavior.

At nowadays, most industrialized livestock farms are equipped with integrated monitoring systems which collect information from a variety of sources, including sensors and data bases. They process data and provide outputs that may be used as recommendations for the producer or to make direct control actions.

6.5.1 Dynamic Reading Efficiency

Under commercial dairy conditions, Stewart et al. (2007) used 498 Holstein cows to evaluate the ability of a panel reader system to read ISO compliant e-ET devices (HDX, n =

334 and FDX-B, n = 182). Results demonstrated that the panel system can achieve high detection rates of HDX e-ET devices (99.9%) and meet the needs of the most demanding management applications. However, the FDX-B detection rate was not enough performant (93.8%). They conclude that the lower FDX-B reading rate may be due to the particular panel reader utilized or to its fine-tuning.

In another study, Wallace et al. (2008) used 82 heifers to compare the readability of 13 e-ET scanned by 3 different stationary readers. As a result, when the readers were fully adjusted and upgraded, readability did not differ ($P > 0.05$) for the 3 stationary readers (99.5% on average) as well as for the RFID technology (HDX, 98.2%; FDX-B, 96.5%). All the stationary readers agreed the U.S. Department of Agriculture 95% readability standards when they are fully adjusted and upgraded.

Recently, Barge et al. (2013) evaluated the readability of 40 pigs passing through the reading area of an antenna, placed at increased distance. As a result, reading rate was drastically decreased (−0.61 to −0.35 readings/s, on average) when multiple e-ID devices were present in the detection area of the antenna, demonstrating the collision effect, especially when devices of the same RF technology were used.

In sheep, Ait-Saidi et al. (2013) studied dynamic reading (DR) performances under on-farm conditions. They used 2 stationary readers in a 50 cm race-way. The study involved a total of 240 ewes which were separated in 4 groups according to e-ID device type and were read in quintuplicate in unique or mixed groups. As results, DR efficiency varied between 25.3 and 100% and the lowest value was obtained with e-RB of FDX-B. However, e-ID devices of HDX were read satisfactorily in most cases (unique or mixed groups) and were recommended as the most convenient tool for on-farm applications.

Moreover, in the Scottish pilot project report for sheep ID&R, SAOS (2011) mentioned that the variation in equipment specification and site conditions can affect the DR efficiency and reported that additional difficulty is caused by the absence of industry standards.

6.5.2 Estrus Detection

The common aspect of females in heat is the increased activity during this period. The most conventional methods used to detect estrus in cows are tail paint, chin-ball markers fitted to androgenized females or sterile bulls, heat-mount patches, video cameras as well as dogs trained to detect estrus by odor (Foote, 1975; Stevenson et al., 1996).

New electronic devices, as summarized in Table 6.4, were reported by Dohi et al. (1993) and Senger (1994), based on radio telemetry and on the use of pressure sensitive devices attached to the female rump and linked to computers (Figure 6.2). At-Taras and Spahr (2001) used electronic devices (heat mount sensor and electronic activity tag) to study mounting and physical activity. In all cases, more than 80% of efficiency to detect estrus in dairy cattle was obtained by the devices.

Table 6.4. Comparison of different devices used for estrus detection in dairy cows (Senger, 1994)

Requirement	Pedometer	Pressure		Impedance, implant
		Implant	External	
Continuous surveillance[1]	+	+	+	+
95% Accuracy[2]	+?	?	?	?
Lifetime of cow[3]	-	+	-	+
Minimized labor[4]	±	+	±	+
Automated ID[5]	+	+	-	+

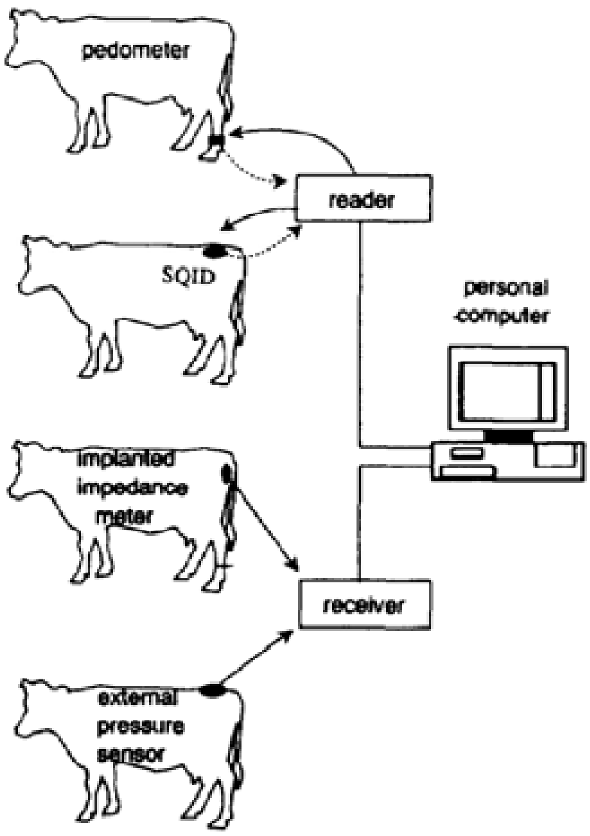
[1]Continuous means 24 h/d during the time that cow is eligible to be inseminated. [2]Ability to detect 95% of physiologic periods of estrus and to present 95% of cows for AI that are truly in estrus. [3]Functional in a single cow for her productive lifetime (at least 5 yr).[4]Eliminates need for transfer between cows, routine maintenance (battery replacement, etc.), individual cow manipulation, and observation. [5]Cows can be automatically identified by electronic means so that the need for manual or visual recording is eliminated.

Arazi et al. (2010) suggested the integration of computerized herd management systems to automatically collect the behavior data, allowing to monitor cow welfare and to improve heat detection ability as well as to the early diagnosis of sick cows.

Electronic pedometers are used for detection of cows in estrus period. Attached on the neck of on a foreleg, the sensor measures variations in the increased walking activity associated with estrus cycle (Kiddy, 1977; Brehme et al., 2008). Data recorded in the pedometer are interrogated remotely in the milking parlor by a reader and then uploaded to the computer (Figure 6.2). Afterwards, they are analyzed and classified according to cow's activity. The accuracy of detection of estrus by pedometers varies from 22 to 100% (Senger, 1994).

Saumande (2002) tested the DEC system (IMV Technologies, France) which is an electronic device designed to detect estrus in the cattle. It is based on the electronic detection of standing mounts accepted by cows in estrus. The criteria (number, length and interval between mounts) are analyzed by a microprocessor associated with the sensor and give a definition of the onset of estrus. The continuous (24 h a day) surveillance of the cows represents one of the main advantages of electronic devices when detecting estrus.

Figure 6.2. Types of estrus detection systems available for dairy cow producers. SQID = Subcutaneous implantable device (Senger, 1994).



De Mol et al. (1997) have proposed more qualitative measured variables combined to increased activity, reduced milk yield, increased milk temperature and decreased feed intake in order to take more reliable decisions on estrus detection. Biosensors were also used for measurements of progesterone by continuous milk assay in the milking parlor to detect estrus (Claycomb and Delwiche, 1998).

In sheep, Bocquier et al. (2006) have developed a new method enabling the simple and reliable detection of ewes in estrus within a flock. At each mounting, the male equipped with a RFID reader, activates the electronic transponder of the ewe (e-IT) and its identity number, as well as the time of which it was read, are recorded. Then, data are transmitted remotely (Bluetooth connection) to the computer for analysis and to be compared with other data generated from video recordings. Collected data were interpreted to predict the onset of estrus as early as possible. As a result, the use of this detector allowed to plan the reproduction (directed matting) and insemination within needing to use hormonal methods, and can increase fertility rate as well as to be compatible with organic livestock systems.

6.5.3 Sorting Gate

In dairy cow farms, Trevarthen and Michael (2007) studied the adoption of e-ID systems by using RFID readers linked to sorting gates at entering or leaving the milking parlor. The reader identified each cow's number and sent their numbers to the computer database which derived the information of the direction to which the cow was addressed. At the exit of the milking parlor, the installed sorting gates directed specific cows (according to their database information) to the grazing area or to holding pens. Additional separation space, blocking gates and visual detection devices were used as preventive systems for the well rooting of the cows.

In the study of Champion et al. (2005), e-ID system was coupled with non-return gates to study the motivation of sheep to obtain resources at pasture. After training periods, sheep learn to use non return gates and moving between short races. Additionally, the system allowed automatic monitoring of the periods spent by the sheep in limited areas.

A more modernized system was described by Maton et al. (2006) for sorting sheep. They adopted a sorting gate system making an exit toward 2 directions. They installed the system in a pre-existing conventional race-way to automate the sheep sorting. When sheep walked through the race-way, the individual e-ID number is read by a stationary reading unit which sends the e-ID code to a computer. Installed software on the computer assigns the direction of the animal read and activates the driver commanding the right gate. When the read animal approximates the rooting system, one of the two gates opened and the animal can join the lot at which is assigned. Additionally, a set of sensors is placed at different sites in the race-way to confirm the sheep passage.

6.5.4 Body Temperature Monitoring

A physiological parameter easy to measure from the technical point of view is the temperature. Lambooij (1991) reported, in agreement with many authors, that a variability of about 2°C in animal body temperature can be related to circadian activities, reproductive functions, physical activities and transport stress.

In order to detect diseases, estrus and stress, physical sensors for measuring body temperature can provide useful information (Geers, 1994). Moreover, Geers et al. (1997) reported the use of telemetric device injected into the ear base of pigs' for measuring body temperature, although their precision was not enough.

Monitoring body temperature, food intake and effective environmental temperature, as well as animal activity, need to be measured to give a correct interpretation of their body and physiological conditions. Transponders equipped with a temperature sensor (Nelson, 1988; Geers et al., 1997) or in combination with activity tracking (Artmann, 1999) have an accuracy of about 0.2°C. However, medical telemetry systems have a greater precision in the range of 0.1°C (Eigenberg et al., 2008). Difficulties in the interpretation of results lie in problem of accuracy. There are not absolute values, but the relative changes contain the significant variation of information. Currently, the measuring devices are miniaturized, and the period of measuring is determinant in order to get real data and possible interpretation of variations.

Brown-Brandl et al. (2003) used a temperature telemetry system for automatic recording of body temperature in cattle and swine. The system is based on telemetry transmitters and mobile receivers. Core body temperature measurement and respiration rate give true information on feeding swine behavior (Eigenberg et al., 2008). Temperature measurement in cattle can be done with rectal or tympanic membrane probe. However, temperature sensors can be implanted, ingested or applied as tympanic probe in pigs.

Castro-Costa et al. (2014) used 16 Murciano-Granadina dairy goats, carrying rumen boluses with wireless sensors of pH and temperature, previously introduced by surgery to measure the evolution of ruminal pH and temperature. The system used RFID technology which allows the transmission of recorded data from the ruminal bolus to the computer using transmitter and receptor devices. The experiment showed marked differences in temperature and pH of rumen according to feeding and environment (heat stress vs. thermoneutral) conditions.

6.5.5 Welfare and Behavior Monitoring

Animal behavior such as decreasing activity (i.e., disease) and gathering (i.e., cold environment) can be a clear indicator of its physiological or ambient state. The measuring of body temperature with injectable devices (Geers et al., 1997) and assessment of real time computer vision (Shao and Xin, 2008) would give the right information on the welfare condition of pigs.

In order to improve health control or disease extending, all farm animals should have an unequivocal ID number. A computer on the farm combined with individual intelligent biosensors on the animals make possible to monitor automatically selected physiological (i.e. body temperature), behavioral (i.e., image analysis) and performance (i.e., milk and meat production) traits from each animal (Lambooij, 1991).

An additional advantage of reliable e-ID is facilitating the use of automated housing systems. This development would improve labor conditions of the workers (Geers, 1994) because animals do not need to be restrained for ID, as for reading ear tags or tattoos, and operators spend less time working under unpleasant physical conditions (i.e., sound, dust).

6.5.6 Transportation and Movement Recording

Transport of animals and their products are both important to husbandry trade and to most countries economy. In addition, consumers put more importance on animal welfare, on the quality of husbandry and transport systems.

For prevention of disease introduction, it is crucial that risk transports and vehicles can be intercepted before entering a disease-free country or region. Hence, on-line information on animal transports is of utmost importance. Current systems used for the ID&R of animal movements supply information only after the events have already occurred. It is necessary to develop systems detecting the introduction and spread of contagious diseases at the earliest moment possible.

Another important issue related to transport is animal welfare. The EU rules on the protection of animals during transport were laid down in Council Directive 91/628/EEC, recommended by Commission Decision 2001/298/EEC. Regulation state that records on environmental conditions (particularly temperature) should be available to the competent authority.

A new system for on-line surveillance of animal transports including telemetry and wireless data communication was proposed by Geers et al. (1998). The system allows on-line data collection on the lorry transport respect to animal ID, body temperature and geographical position.

Finally, to integrate housing, handling and transport of pigs, Goedseels et al. (1990) developed a sensor for temperature measuring and implanted in the pigs' ear base for welfare evaluation during transport. Transmission of information was received by a decoder linked to a data-acquisition system. This system allows multiple measuring points without entering the lorry compartments. Before transport, the ear base temperature ranged from 36.9 to 37.8°C. During transport, it ranged from 37.6 to 38.3°C. Body temperature information is certainly useful for the driver of the truck, so that will be able to adjust the driving style and truck temperature and ventilation to avoid stress and mortality of the pigs.

It is important to collect and to store sufficient temperature data before transport, to have a reference value for comparison during and after transport. Indeed, malignant hyperthermia and mortality during transport may be avoided by taking appropriate measures (i.e., automatic regulation of ventilation).

6.5.7 Spatial and Temporal Location of Animals

The global positioning system (GPS) technology offers a mean for studying how spatial and temporal variability of animal, forage, soil and landscape features affect grazing behavior and forage utilization. Moreover, GPS technology has the advantage of obtaining detailed data of animal behavior and position with little restriction on time and location of observers.

The GPS tracking collars have been incorporated in research on the ecology and management of grazing systems in sheep (Rutter et al., 1997; Hulbert et al., 1998) and cattle (Turner et al., 2000; Ganskopp, 2001). By using GPS units in conjunction with geographic information systems (GIS), animal distribution and movement can be related to landscape features. Ganskopp (2001) used this technology to evaluate the results of salt and water distribution for affecting cattle localization.

Monitoring combined with e-ID may help to improve the development of geographic information systems to assess the potential for transmission of infectious diseases between herds. In the long term, knowledge of relative risks would allow the prevention of disease outbreak within eradication programs for intensive and extensive husbandry systems (Geers, 1994).

Kampers et al. (1999) developed a system using ID combined to computation technologies to identify the owner of an animal founded somewhere. Once the animal ID number read, the code is transferred to a computer which is connected to a global network. From the country or manufacturer’s code, the computer can automatically ask the master database in which the ID code was stored. Looking up the individual ID code in this database will provide an address of the computer with the intermediate database. The name and address of the owner can be retrieved. This process can be automated completely and will take only seconds to complete.

CHAPTER 7

Conclusions

CHAPTER 7.

CONCLUSIONS

The main conclusions obtained by the different experiments carried out during this Doctoral Thesis are the following:

7.1 Milk recording in dairy goats

The use of the semi-automatic milk recording system, based on electronic boluses for e-ID and handheld reader for automatic reading and data transfer to a computer, demonstrated advantages of reading and transferring milking data in dairy goats (9% of total time reduction). Implementation of the semi-automatic system allowed reducing 40% of labor costs for milk recording and increased accuracy of milk recording data, avoiding confusion and errors during data transfer. Advantages of the system were expected to be greater when operators are well trained and when the semi-automatic system is used in large goat herds.

7.2 Performance recording in dairy and meat sheep farms

When manual or semi-automatic milk recording systems were compared in dairy sheep, recording time and data errors did not differ during the milk recording under our milking parlor and flock size conditions. Nevertheless, when data transfer was included, time was markedly longer (+75%) for the manual system. Moreover, no errors were detected when the semi-automatic system was implemented. On average, 19% of the total milk recording time was saved when the semi-automatic system was used instead of the manual system.

As shown in our study, implementation of a semi-automatic system was time-effective for milk recording in dairy ewes, saving more than 1 h of labor time for a flock size of 400 ewes milked in a parallel 2 × 12 stalls milking parlor.

Furthermore, use of e-ID for semi-automatic (lambing data recording) and automatic (body weight recording) performance recording in meat and dairy sheep farms, saved approximately 50% of the time required and increased the reliability of the collected data.

7.3 Cost-Benefit Analysis of Electronic Identification Use in Sheep Farms

When the analysis of cost-benefit was performed for semi-automatic system implementation, additional equipments were required (i.e., e-ID devices and readers) which resulted in an increase of performance recording costs. In our study, calculated extra-costs depended mainly on farm type (i.e., meat or dairy), conditions (i.e., extensive or intensive), scenario (i.e., optional or mandatory e-ID), flock size (number of sheep), test-days per day (×1 and ×2 milk recordings) and per year, as well as on reader price.

As a consequence, 15 to 70% of the investments made for the e-ID system in the optional scenario were paid by the savings when using e-ID for performance recording. In the case of mandatory e-ID, as currently used in the EU and in which the bolus costs were excluded; the savings paid 100% of the extra-costs in all farm types and conditions. In both scenarios, handheld reader price was the most important extra-cost (40 to 90%) of e-ID implementation.

Alternatively, use of a personal digital assistant reduced (−50%) the cost of implementing a semi-automatic performance recording system. Calculated extra-costs of using the personal digital assistant covered more than 100% of the implementation costs in all type of farms, indicating that this device was cost-effective for sheep performance recording.

Finally, the use of e-ID proved to be cost-effective under the e-ID mandatory scenario currently adopted in European Union, but not when e-ID was considered optional. Other uses (i.e., management, selection, veterinary treatments) or the reduction in the price of the readers should be necessary for fully paying the e-ID extra-costs.

7.4 Recommendations

In the dairy industry, user friendly procedures are needed especially for immediate performance recording data transfer. As well, use of the handheld reader system is preferred not only to avoid mistakes in ewe and goat ID but also to implement automated systems for performance recording.

Use of personal digital assistant devices for data management is a recommendable option for semi-automatic performance recording in many productive scenarios of the current sheep industry; especially for medium sheep flock size where automated systems based on RFID technology are not indispensable.

CHAPTER 8

References

CHAPTER 8.

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APPENDIX