A partial budget simulation to evaluate the Return of Investment of improved calving management in Italian beef cattle, family-run farms

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SUMMARY

Dystocia, defined as prolonged or difficult birth, negatively affects the dam and calf survival, health and welfare together with the economy of the farm. The main income in beef industry is represented by calves to be grown for meat production. However, stillbirth and dam mortality due to dystocia represent an economic and welfare issue and even if their incidence could be reduced by obstetrical and neonatal assistance, some farmers seem passively accept a certain death rate. The aim of this study was to simulate the Return of Investment of improved calving monitoring and assistance in family-run beef farms representative of central Italy breeding system. We set partial budget simulations for Chianina, Marchigiana and Limousin breeds. We considered a primiparous to multiparous ratio of 1:10 or 1:5, and herd size of 40 and 100 dams, respectively, together with various market scenarios. We assumed that monitoring all parturient cows prevented 75% of stillbirth and 50% of dam mortality due to dystocia. Additional profit in simulations derived from more calves to be sold, dams saved from culling and reduced replacement. Considering a primiparous to multiparous ratio of 1:10, simulated farms showed a yearly income increase from € 2,516.50 in Limousin to € 4,610.30 in Chianina farms, respectively, in smaller herds, and from € 6,891.26 to € 12,125.75 in Limousin and Chianina farms, respectively, in larger herds. Unfavorable market condition was simulated by increasing feeding costs and decreasing live weight values, respectively. However, even those simulations showed positive incomes in farms using a remote calving alarm system. Those results showed as implementing calving monitoring and assistance with estimated amortization period of 5 years could be sustained both by smaller and larger farms with a positive effect on herd economic balance. We are confident that this estimate will motivate farmers to improve on-farm practices for calving and newborn management.

KEY WORDS

Beef cattle; calving monitoring system; calving management; neonatal mortality; budget simulation.

INTRODUCTION

Dystocia, defined as prolonged or difficult birth, negatively affects dam and calf survival, health and welfare together with the economy of the farm[1]. The prevalence of dystocia is variable based on breeding systems, breed, parity etc. Reports concerning Italian beef breeds showed an overall dystocia prevalence of 4.4%[2]. Odds for calf death during the first 48 hours of life (stillbirth) are increased after the occurrence of a difficult birth, due to negative effects on fetal physiology exerted by prolonged compression within the birth canal. Dystocia is a painful event and even if recognition of pain in cattle is increasing in importance, the administration of analgesia is still limited[3,4].

In beef industry one of the main incomes is represented by the delivery of a live calf to be grown for meat production, so that "calving ease" is considered as one of the characteristics to be included in genetic selection programs. However, calf losses are still representing an economic and welfare issue worldwide, with a reported incidence of 1.4-9.5% in European extensive systems[5,6].

Mee[7] estimated that 90% of stillborn calves were actually alive at the moment of delivery and asserts that those losses could be reduced by improving obstetrical and neonatal assistance. Yet, the identification of the exact beginning of parturition in order to ensure calving assistance is difficult, especially during the night or in extensive grazing systems, and some farmers seem to passively accept that a certain percentage of calves is inevitably going to die.

In order to overcome this phenomenon, an increasing effort of researchers is aiming at improving automatic systems for calving detection in large ruminants[8-11]. Palombi et al.[12] and Choukeir et al.[13] reported a decrease in both stillbirth and uter-

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ine postpartum disease together with improved fertility in dairy cows assisted at calving. Evaluating the Return of Investment (RoI) of improved calving assistance also in beef herds could be useful in focusing the attention of both farmers and veterinarians on this issue.
Beef farming in Central Italy is characterized by small-dimension, family-conducted farms (30-40 beef dams) which mainly raise Chianina, Marchigiana and Limousin breeds. The first two breeds are autochthonous and are used to obtain a protected geographical indication (PGI) meat, which is restricted to be produced in the Apennine mountains of Central Italy. The productive cycle of those farms is represented by cow-calf line, with dams being housed in free-stall barns, while calves are raised with mothers until weaning and then reared to the final slaughter weight. Due to the reduced number of workers in this kind of farms, optimization of workload such as offered by a calving monitoring system which is able to detect the expulsive phase (stage II of labour) could be advantageous to ensure prompt resolution of dystocia and first neonatal care.
The aim of this study was to develop a cost and income simulation to evaluate the Return of Investment (RoI) of improved calving management in beef farms located in Central Italy.

MATERIALS AND METHODS

Description of the breeding system

We considered beef farms which were representative of Central Apennine breeding systems. Farm personnel is usually constituted by the owner family, and the mean herd size is 30-40 dams, with average primiparous to multiparous ratio varying from 1:10 to 1:5; rarely farm dimension reaches up to 100 dams, as showed by the annual reports published by various Italian Institutions (ANABIC, National Association of Italian Beef Cattle Breeders, 2020[14]; CREA, Council for Agricultural Research and Agricultural Economics Analysis, 2009[15]; ISMEA, Italian Institution for Agro-Food Market Services, 2020[16]). Those farms are characterized by cow-calf line where calves are raised under their dams without milk replacers and weaned when they are 5 to 6 months old. Then they are reared within the same farm until the final weight. Due to the uneven and semi-mountainous terrain, animals are housed in free-stall barns with external paddocks and are fed farm-produced forages, silages, leguminous-derived flours and purchased concentrates. Thus, the daily feeding cost for pregnant dams and growing veal is generally lower compared to intensive beef farming, where a greater concentrate to forage ratio is used[17]. Pasture is rarely used due to the limited availability of grass during the dry season (from June to September). Main cattle breeds are represented by Chianina and Marchigiana, which are slaughtered at a later age (18 months on average) and greater weight (from 650 to 750 kg) when compared to other breeds such as Limousin. However, Chianina and Marchigiana breeds are used for the production of a PGI meat, which generates an added value at the marketplace.
Prepartum areas are generally represented by multiple boxes with straw bedding; calving is usually unmonitored, especially during the night hours. Assistance to both the dam and the neonate calf depends on the visual appraisal of dystocia.

Table 1 - Herd composition, incidence of dystocia, calf death and dam mortality due to difficult birth in Central Italy beef farms used to build budget simulations.

	Primiparous	Multiparous	Reference
Herd composition (ratio)	1 1	10 5	ANABIC[14] CREA[15] ISMEA[16-18]
Dystocia incidence (%)	10.7	3.75	De Amicis et al.[2]
Stillbirth due to dystocia (%)	45.5	21.8	
Dam mortality due to dystocia (%)	14.3	32.7	
Calf male to female ratio	50	50	

Epidemiology data

Epidemiology data concerning the incidence of dystocia, stillbirth and dam's mortality due to dystocia are synthesized in Table 1. We considered a mean incidence of 10.7% and 3.75% of dystocia in primiparous and multiparous cows, respectively, as showed by De Amicis et al.[2] in Italian herds. The incidence of calf loss and dam mortality due to dystocia were extrapolated from the aforementioned report, by re-calculating rates specifically, based on attitude and parity. We did not consider the use of sexed semen and set the male to female ratio for calves at 50:50.

Remote calving alarm system

We herein assumed the purchase of a remote calving alarm system which is able to identify the expulsive phase of parturition, as described by various authors[8,12,19]. Those devices are represented by intravaginal sensors; once expelled from the birth canal, at the beginning of the stage II of labor, farm personnel are advised through a phone call. The costs/year and cost/delivery we considered in this work are resumed in Table 2.

Table 2 - Market prices for three different beef breeds (Chianina, Marchigiana, Limousin). Unless differently specified, all cost items and other information were extrapolated from ISMEA (Italian Institution for Agro-Food Market Services, 2021)[16-18].

	Chianina	Marchigiana	Limousin
Calf			
Final slaughter weight (kg)	700	650	580
Age at slaughter (months)	18	16	15
Value at slaughter (€/Kg)	3.76	3.27	2.75
Feeding cost (€/day)	2.16	2.16	2.26
Dam			
Adult average weight (Kg)	800	750	650
Value at slaughter (€/Kg)	1.28	1.25	1.21
Carcass disposal (€/Kg)	0.62	0.62	0.62
Feeding cost (€/day)	2.81	2.81	2.81
Replacing heifer			
Average weight (Kg)	750	700	600
Live value (€/Kg)	4.28	4.28	2.90
Calving monitoring system[2]			
Intravaginal device (€/delivery)	2.17	2.17	2.17
Central Unit (€/year)	400	400	400

[1] From Crociati et al. (2020)[20].

Market prices

Market prices for economic estimations are reported in Table 2. Feed and live weight prices, average slaughter weight and mean age at slaughter for Chianina, Marchigiana and Limousin veal were retrieved by ISMEA, Italian Institution for Agro-Food Market Services annual reports for the beef industry sector[16,18].

Preliminary assumptions

In beef industry there is paucity of studies reporting the entity of reduction in stillbirth and dam mortality after the improvement of a systematic calving assistance. Mee[7] for example stated that 90% of neonatal calf death is preventable through appropriate calving assistance. In a previous investigation we evaluated the effect of a timely calving assistance on calf losses and early culling in a dairy herd[20]. We achieved an 100% and 84% reduction in stillbirth together with a 70% and a 44% reduction in early culling in monitored primiparous and multiparous cows, respectively. Due to difference in breed attitude and in order to be conservative, we assumed that monitoring all parturient cows from the beginning of stage II could prevent 75% of neonatal losses (Red_{still}) and 50% of dam death (Red_{DD}) due to dystocia in beef herds.

Development of the economic model

For each breed, we set simulations as follows: #1 considering a primiparous to multiparous ratio of 1:10 together with a herd size (HERD) of 40; #2 with a primiparous to multiparous ratio of 1:10 and herd size of 100 dams; #3 with a primiparous to multiparous ratio of 1:5 with a herd size of 40 dams. Since market prices are volatile, we also evaluated #4 and #5 simulations by setting feeding costs at +35% and live weight values at slaughter for veal, dams and replacing heifers at -10% compared to simulation #1, respectively.

As our aim was to provide an annual balance applicable for long-term investment evaluations, we decided not to round the results of the number of events to whole numbers, but to keep the decimals.

In order to calculate how many stillbirth (N_{still}) and dam death (N_{DD}) events occurred yearly, we applied the following formulae in primiparous (N_p) and multiparous (N_m) cows, respectively:

N_p = HERD x 10 / 100

N_m = HERD x 90 / 100

in simulations with primiparous to multiparous ratio of 1:10, and:

N_p = HERD x 20 / 100

N_m = HERD x 80 / 100

in simulations with primiparous to multiparous ratio of 1:5.

$N_{still} = (N_p \times I_{dyst\_p} \times I_{still\_p}) + (N_m \times I_{dyst\_m} \times I_{still\_m})$

$N_{DD} = (N_p \times I_{dyst\_p} \times I_{DD\_p}) + (N_m \times I_{dyst\_m} \times I_{DD\_m})$

where I_{dyst_p} and I_{dyst_m} was the incidence of dystocia in primiparous and multiparous cows while I_{still_p} and I_{still_m} was the incidence of stillbirth in calves born from dystocia in primiparous and multiparous cows, respectively, as shown in Table 1. I_{DD_p} and I_{DD_m} was the incidence of dam mortality due to dystocia in primiparous and multiparous cows, respectively, as shown in Table 1.

Feeding cost for a calf to be grown until slaughter was calculated as:

$Cost_{feed} = Daily_{feed\_calf} \times 30 \text{ days} \times Age$

where $Daily_{feed\_calf}$ was Feeding cost (€/day) shown in Table 2 and Age was the average age at slaughter (months) for each breed. For animals lost due to stillbirth this amount was set as positive, while in the second section of the simulation this amount was set as negative.

Similarly, the feeding cost for a pregnancy ($Cost_{pregn}$) was obtained by multiplying the daily feeding cost (Table 2) for the average length of pregnancy in beef cattle (284 days):

$Cost_{pregn} = 284 \times Daily_{feed\_dam}$

This cost was considered negative when stillbirth occurred, due to the fact that no calf will be raised for meat production and sold to pay back the maintenance cost of the mother.

The value at slaughter for calves sold for meat production were calculated by multiplying the value (€/Kg) at the marketplace for the corresponding average weight (Table 2):

$Value_{calf} = Value_{market\_calf} \times Weight_{calf}$

While when accounting for dams dead due to dystocia, loss was calculated as the value of a dam no more sold for meat production together with the carcass disposal fee as follows:

$Value_{dam} = (Value_{market\_dam} + Disposal) \times Weight_{dam}$

where Disposal represented the average cost (€/kg) needed to remove and dispose the carcass of a dead dam and $Weight_{dam}$ represented the average adult weight of a dam based on breed, as shown in Table 2.

Concerning replacement of primiparous and multiparous dams dead due to dystocia, we considered that farmer had to buy new pregnant heifers from another farm or to avoid selling heifers to convert them to reproduction. In both cases, the value of those heifers was added in the final budget as negative. This expense was calculated by multiplying the market value of a beef heifer (Table 2) for the average weight of a ready-to-calve heifer:

$Value_{heifer} = Value_{market\_heifer} \times Weight_{heifer}$

Cost due to the purchase of the remote calving alarm system was added in each simulation. The Central Unit cost was set at € 2,000 with estimated amortization in 5 years and an overall yearly cost of € 400, as calculated in Crociati et al.[20]. Similarly, the intravaginal probe was reusable for 30 calving and a cost for each use of 2.17 euros was attributed. The cost of the intravaginal device/delivery was multiplied for the number of calving/year based on the herd size:

$Cost_{probes} = Cost_{calving} \times HERD$

Simulations were then repeated for each breed and herd size, but considering the effect of the remote calving alarm system.

In order to calculate the number of events (stillbirth and dam death) prevented, we applied the following formulae:

$Saved_{still} = N_{still} - [N_{still} \times (1 - Red_{still})]$

$Saved_{DD} = N_{DD} - [N_{DD} \times (1 - Red_{DD})]$

Saved incomes due to prevention of stillbirth and dams death were calculated as follows:

$€_{saved\_stillbirth} = Saved_{still} \times Value_{calf}$

$€_{saved\_DD} = Saved_{DD} \times Weight_{dam} \times Value_{market\_dam}$

Partial budget simulation

A partial budget method[21] was used to evaluate costs and incomes deriving from the implementation of a calving alarm system in family-run beef farms, as typical of Central Italy. The partial budget model simplifies calculations and emphasizes only outcomes deriving by a certain intervention. Thus, in our case, we ignored costs associated with feeding, housing, veterinary, and farm workload for routine farm operations, together with other disposable materials, as they would have resulted the same in farm without and with a calving alarm system. The time required for insertion of the intravaginal device was limited to few minutes. Cost of application was represented by one disposable rectal palpation glove, warm water, few milliliters of iodine solution, and small quantity of lubricant gel. Those costs were then considered as negligible. The final result was represented by an estimation of additional income from more calves to be grown for meat production and dams saved from culling, together with money saved from purchasing new late-gestating heifers for replacement, and reduced expenses for carcass disposal. Incomes (positive) and losses (negative) were summed, thus obtaining a final budget. Simulations were then compared for each breed and herd size and the real net return achievable by the farm was represented by the difference between economic simulation with and without a remote calving alarm system.

RESULTS

Results from the simulations with and without a remote calving alarm system are shown in Tables 3 to 7 for Chianina, Marchigiana and Limousin breeds, respectively. The greater income is achieved in Chianina farms, where the value of meat is highest, while in case of Limousin breed no PGI-fare is applied. Considering a primiparous to multiparous ratio of 1:10 in farms using a remote calving alarm system, the economic simulation shows an income increase from € 2,516.50 in Limousin to € 4,616.30 in Chianina farm per year, respectively, in smaller herd, and from € 6,891.26 to € 12,125.75 in Limousin and Chianina farms, respectively, in larger herds. Simulations #4 and #5 (Tables 6 and 7) considered unfavorable market condition by increasing feeding costs and decreasing live weight values, respectively. However, even those simulations showed positive incomes in farms using a remote calving alarm system.

DISCUSSIONS

Live and healthy calves grown for meat production represent the major income in beef farms. At the same time neonatal losses still show important incidence worldwide, and although it is generally accepted that improved calving management is fundamental for reducing stillbirth, some farmers passively accept a certain calf death rate[7]. In this study we analyzed the economic effort needed to improve a remote calving alarm system in family-run farms typical of Central Italy. The aim was to evaluate the economic sustainability of using a remote calving alarm for delivery surveillance to improve both animal welfare and farm economy.

In the last decades, substantial effort has been made by research in improving available method for calving prediction; however the sensitivity, specificity, local tolerability and ability to specifically predict calving are sometimes non-optimal[10,11,13,22]. Obstetric assistance should be provided "at the right time"; however, the identification of the exact beginning of expulsive phase is challenging and sometimes assistance is provided too early, with negative effects on both the dam and the calf[23]. Similarly, when cows deliver unmonitored and unassisted, prolonged parturition could result as the expulsion of a living calf, but the prolonged compression within the birth canal can induce metabolic acidosis and negatively influence colostrum assumption and the amount of immune-globulins absorbed by the intestinal tract[24].

Table 3 - Simulation #1. Economic evaluation of one year of improved calving management through a remote calving monitoring system in Chianina, Marchigiana and Limousin family-run, beef farms. In this simulation, herds were composed by 40 dams with a primiparous to multiparous ratio 1:10. The reduction of stillbirth and dam death events due to dystocia in farms using a remote calving alarm system were set at 75% and 50%, respectively.

	Simulation #1					
HERD (n)	**40**					
Primiparous:multiparous	**1:10**					
Breed	**Chianina**		**Marchigiana**		**Limousin**	
Remote calving alarm	no	yes	no	yes	no	yes
Dystocia (n)	1.78	1.78	1.78	1.78	1.78	1.78
Stillbirth (n) *	0.48	0.37	0.48	0.37	0.48	0.37
Dam mortality (n) *	0.50	0.25	0.50	0.25	0.50	0.25
Calf						
Value at slaughter (€)	-1287.15	965.36	-1039.45	779.59	-780.02	585.01
Feeding (€)	570.42	-427.81	507.04	-380.28	497.35	-373.02
Dam						
Value and disposal (€)	-764.03	257.36	-704.97	235.62	-597.91	197.67
Feeding pregancy (€)	-401.14	-401.14	-401.14		-401.14	
Replacing heifer						
Live value (€)	-1613.52	806.76	-1505.95	752.98	-874.62	437.31
Calving monitoring system						
Intravaginal device (€)		-86.80		-86.80		-86.80
Central Unit (€)		-400.00		-400.00		-400.00
Final Budget/year (€)	-3495.43	1114.87	-3144.48	901.11	-2156.33	360.18
Difference (€)	**4610.30**		**4045.59**		**2516.50**	

* In columns relative to a farm which uses a remote calving monitoring system, the number reported represents the amount of calves and dams prevented from dying due to dystocia and economics were calculated based on animals saved from loss.

Table 4 - Simulation #2. Economic evaluation of one year of improved calving management through a remote calving monitoring system in Chianina, Marchigiana and Limousin family-run, beef farms. In this simulation, herds were composed by 100 dams with a primiparous to multiparous ratio 1:10. The reduction of stillbirth and dam death events due to dystocia in farms using a remote calving alarm system were set at 75% and 50%, respectively.

	Simulation #2					
HERD (n)	**100**					
Primiparous:multiparous	**1:10**					
Breed	Chianina		Marchigiana		Limousin	
Remote calving alarm	no	yes	no	yes	no	yes
Dystocia (n)	4.45	4.45	4.45	4.45	4.45	4.45
Stillbirth (n) *	1.23	0.92	1.23	0.92	1.23	0.92
Dam mortality (n) *	1.25	0.63	1.25	0.63	1.25	0.63
Calf						
Value at slaughter (€)	-3217.88	2413.41	-2598.64	1948.98	-1905.05	1462.54
Feeding (€)	1426.04	-1069.53	1267.59	-950.69	1243.38	-932.54
Dam						
Value and disposal (€)	-1910.09	643.40	-1762.43	589.05	-1494.77	494.17
Feeding pregancy (€)	-1002.84		-1002.84		-1002.84	
Replacing heifer						
Live value (€)	-4033.80	2016.90	-3764.88	1882.44	-2186.54	1093.27
Calving monitoring system						
Intravaginal device (€)		-217.00		-217.00		-217.00
Central Unit (€)		-400.00		-400.00		-400.00
Final Budget/year (€)	-8738.57	3387.18	-7861.20	2852.77	-5390.82	1500.44
Difference (€)	**12125.75**		**10713.97**		**6891.26**	

* In columns relative to a farm which uses a remote calving monitoring system, the number reported represents the amount of calves and dams prevented from dying due to dystocia and economics were calculated based on animals saved from loss.

Table 5 - Simulation #3. Economic evaluation of one year of improved calving management through a remote calving monitoring system in Chianina, Marchigiana and Limousin family-run, beef farms. In this simulation, herds were composed by 40 dams with a primiparous to multiparous ratio 1:5. The reduction of stillbirth and dam death events due to dystocia in farms using a remote calving alarm system were set at 75% and 50%, respectively.

	Simulation #3					
HERD (n)	**40**					
Primiparous:multiparous	**1:5**					
Breed	Chianina		Marchigiana		Limousin	
Remote calving alarm	no	yes	no	yes	no	yes
Dystocia (n)	2.06	2.06	2.06	2.06	2.06	2.06
Stillbirth (n) *	0.65	0.49	0.65	0.49	0.65	0.49
Dam mortality (n) *	0.51	0.26	0.51	0.26	0.51	0.26
Calf						
Value at slaughter (€)	-1713.64	1285.23	-1383.87	1037.90	-1038.47	778.85
Feeding (€)	759.42	-569.56	675.04	-506.56	662.15	-496.61
Dam						
Value and disposal (€)	-782.51	236.58	-722.02	241.32	-612.36	202.45
Feeding pregancy (€)	-410.84		-410.84		-410.84	
Replacing heifer						
Live value (€)	-1652.53	826.27	-1542.36	771.18	-895.77	447.88
Calving monitoring system						
Intravaginal device (€)		-86.80		-86.80		-86.80
Central Unit (€)		-400.00		-400.00		-400.00
Final Budget/year (€)	-3800.10	1318.72	-3384.05	1057.32	-2295.29	445.77
Difference (€)	**5118.82**		**4441.37**		**2741.07**	

* In columns relative to a farm which uses a remote calving monitoring system, the number reported represents the amount of calves and dams prevented from dying due to dystocia and economics were calculated based on animals saved from loss.

Table 6 - Simulation #4. Economic evaluation of one year of improved calving management through a remote calving monitoring system in Chianina, Marchigiana and Limousin family-run, beef farms. In this simulation, herds were composed by 40 dams with a primiparous to multiparous ratio 1:10. The reduction of stillbirth and dam death events due to dystocia in farms using a remote calving alarm system were set at 75% and 50%, respectively. Feeding costs are increased by 35% compared to simulation #1.

	Simulation #4					
HERD (n)	**40**					
Primiparous:multiparous	**1:10**					
Breed	**Chianina**		**Marchigiana**		**Limousin**	
Remote calving alarm	no	yes	no	yes	no	yes
Dystocia (n)	1.78	1.78	1.78	1.78	1.78	1.78
Stillbirth (n) *	0.48	0.37	0.48	0.37	0.48	0.37
Dam mortality (n) *	0.50	0.25	0.50	0.25	0.50	0.25
Calf						
Value at slaughter (€)	-1287.15	965.36	-1039.45	779.59	-780.02	585.01
Feeding (€)	770.06	-577.55	684.50	-513.37	671.43	-503.57
Dam						
Value and disposal (€)	-764.03	257.36	-704.97	235.62	-597.91	197.67
Feeding pregancy (€)	-541.54		-541.54		-541.54	
Replacing heifer						
Live value (€)	-1613.52	806.76	1505.95	752.98	-874.62	437.31
Calving monitoring system						
Intravaginal device (€)		-86.80		-86.80		-86.80
Central Unit (€)		-400.00		-400.00		-400.00
Final Budget/year (€)	-3436.18	965.14	-3107.41	768.01	-2122.65	229.62
Difference (€)	**4401.32**		**3875.43**		**2352.27**	

* In columns relative to a farm which uses a remote calving monitoring system, the number reported represents the amount of calves and dams prevented from dying due to dystocia and economics were calculated based on animals saved from loss.

Table 7 - Simulation #5. Economic evaluation of one year of improved calving management through a remote calving monitoring system in Chianina, Marchigiana and Limousin family-run, beef farms. In this simulation, herds were composed by 40 dams with a primiparous to multiparous ratio 1:10. The reduction of stillbirth and dam death events due to dystocia in farms using a remote calving alarm system were set at 75% and 50%, respectively. Market prices for live animals (€/kg) were decreased by -10% compared to simulation #1.

	Simulation #5					
HERD (n)	**40**					
Primiparous:multiparous	**1:10**					
Breed	**Chianina**		**Marchigiana**		**Limousin**	
Remote calving alarm	no	yes	no	yes	no	yes
Dystocia (n)	1.78	1.78	1.78	1.78	1.78	1.78
Stillbirth (n) *	0.48	0.37	0.48	0.37	0.48	0.37
Dam mortality (n) *	0.50	0.25	0.50	0.25	0.50	0.25
Calf						
Value at slaughter (€)	-1158.44	868.83	-935.51	701.63	-702.02	526.51
Feeding (€)	570.42	-427.81	507.04	-380.28	497.35	-373.02
Dam						
Value and disposal (€)	-712.56	231.62	-657.85	212.06	-558.37	177.90
Feeding pregancy (€)	-401.14		-401.14		-401.14	
Replacing heifer						
Live value (€)	-1452.17	726.08	-1355.36	677.68	-787.16	393.58
Calving monitoring system						
Intravaginal device (€)		-86.80		-86.80		-86.80
Central Unit (€)		-400.00		-400.00		-400.00
Final Budget/year (€)	-3153.89	911.92	-2842.82	724.29	-1951.33	238.18
Difference (€)	**4065.81**		**3567.10**		**2189.51**	

* In columns relative to a farm which uses a remote calving monitoring system, the number reported represents the amount of calves and dams prevented from dying due to dystocia and economics were calculated based on animals saved from loss.

The method for calving prediction herein considered is able to identify the stage II of labour and since the system sends a phone call and a message through GSM, the exact time of device expulsion from the vagina could be used to schedule farm personnel or veterinarian intervention. This could be particularly advantageous in family-run farms, where both the number of working units and the time that personnel can spend in observing and caring for animals are limited, especially considering that some calving occur during the night hours.
In this study, we simulated semi-intensive family-run farms which use to separate late-gestating cows in maternity areas, where the application of a remote calving alarm could be easily achieved. In case of extensive farming with access to pasture, GPS-collars and telemetry could be applied for the identification and localization of parturient animals[25,26]. However, in this second option, timely intervention for the resolution of dystocia would be hard to achieve due to factors such as distance, time needed to reach the cow, restraint equipment and working facilities.
We extrapolated the occurrence of stillbirth and dam mortality in Italian beef breeds from the report of De Amicis et al.[2], as we specifically re-calculated incidence of stillbirth for beef calves born from dystocia and the rate of beef dams dead due to dystocia; incidence we used in our simulation are in line with reports on beef cattle breeds from other studies[5-7].
We did not vary the dystocia rate in farms using a remote calving alarm. Henningsen et al.[19] reported a greater incidence of dystocia in cows which received a T-shaped calving alarm device, probably due to premature rupture of fetal sac caused by the device itself. Except for this report, devices for calving prediction have no effect on dystocia rate or resolution method. Since no difference would be seen in farms with or without a calving alarm system, these rates and associated costs were not included into the partial budget. Similarly, we did not consider the cost for veterinary intervention into the partial budget.
It should be taken into account that especially in family-run farms the veterinarian practitioner is not called for assistance in every calving, but preferably in case of severe dystocia or when cesarean section is necessary. In the investigation conducted by De Amicis et al.[2] the overall incidence of cesarean section in beef cattle reared in Italy accounted for 3.75% (8 out of 213) and for 0.16% (8 out of 4858) of difficult births and all deliveries, respectively. Another economic investigation on losses associated to stillbirth in UK dairy herds showed that the contribution of veterinary fees were limited[27]. In last instance, since dystocia and cesarean section rates are independent on the use of a calving alarm system as stated above, it could be definitively assumed that costs associated to practitioners would not affect the partial budget outcomes.
Concerning costs due to personnel in the evaluation herein described farms are run by owner and family members, including routine calving assistance and first neonatal care; thus, no additional costs or employment contracts for trained personnel were included into the partial budget. Moreover, as also stated in a previous investigation[20], the aim of remote calving monitoring systems is not to make the farmer's presence unnecessary, but to optimize the time and workload in the calving barn, thus avoiding continuous observation of the periparturient cows.
In the study conducted by Manhani et al.[28] concerning contribution to economic losses due to dystocia and calf death in dairy farms, the main item was represented by the value of the calf, followed by the cost of dystocia resolution and by the culling and replacement of the affected dam. In our evaluation we estimated the total loss due to calf death was represented by the failure to sell a veal for meat production, but we also considered that in case of death, that animal would not consume feed, thus the feeding cost for raising a calf until slaughter weight would be saved.
Similarly, in case of dam mortality, the farm will need to purchase a replacement heifer from its own herd (thus not selling it for life or for meat production) or from another farm and we considered the cost to buy an adult, ready-to-calve dam. In order to be applicable as a long-term evaluation of RoI, we propose not to round decimals even when considering animals. This also because farm incidence of dystocia, stillbirth and dam mortality could vary based on year, breeding plan and other unpredictable factors.
Even if the number of calves and dams saved from death could appear as limited during the course of a single year, summed losses could reach consistent values depending on the breed considered, even in small herds. The greater income was achieved in Chianina farm, where the value of meat is highest. Where farm apply a remote calving alarm system, the economic simulation shows an income increase from € 2,516.50 in Limousin to € 4,610.30 in Chianina farms per year, respectively, in case of smaller herds, and from € 6,891.26 to € 12,125.75 in Limousin and Chianina farms, respectively, per year. In our simulation, implementing a calving alarm system with estimated amortization period of 5 years could be sustained both by smaller and larger farms.
Obviously, our economic evaluation has some limitation. We did not consider differences in dystocia and stillbirth odds for male compared to female calves or twinning, as reported in other studies[28]. In the present economics simulation a 75% reduction in neonatal calf losses and 50% reduction in dam mortality were assumed, and our evaluations may be slightly underestimated. Moreover, primiparous to multiparous ratio could be variable based on factors such as farm culling policy and year. In order to overcome this weakness, we simulated two beef herd compositions: one representing farm characterized by a low culling rate (10% first-calving dams) and the other relative to a farm with greater percentage of young animals. This is likely to increase the external validity of our simulations. We also considered two unfavorable market conditions that is increasing feeding costs and decreasing live weight prices; in both cases the improvement of calving management and the maximization of calves raised showed positive effect on the farm economic balance. We are confident that this estimate will motivate farmers to improve on-farm practices for calving and newborn management, thus expanding our knowledge and allowing further studies under field conditions.

CONCLUSION

In conclusion, we conducted a budget simulation to analyze the economic effort needed to implement a remote calving alarm system in Chianina, Marchigiana and Limousin family-run farms. The aim was to evaluate the economic sustainability of using a remote calving alarm for delivery surveillance to improve both animal welfare and farm economy.
Even if the number of calves and dams saved from death could appear as limited during the course of a single year, summed losses could reach consistent values even in small herds. The results of the study showed as implementing a calving alarm system with estimated amortization period of 5 years could be sustained both by smaller and larger farms with a positive effect on herd economic balance.

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