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Technical efficiency and economic viability of different cattle identification methods allowed by the Brazilian traceability system

Eficiência técnica e viabilidade econômica de diferentes métodos de identificação de bovinos permitidos pelo sistema de rastreabilidade brasileiro

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Abstract

We aimed to evaluate the technical efficiency and economic viability of the implementation and use of four cattle identification methods allowed by the Brazilian traceability system. The study was conducted in a beef cattle production system located in the State of Mato Grosso, from January to June 2012. Four identification methods (treatments) were compared: T1: ear tag in one ear and ear button in the other ear (eabu); T2: ear tag and iron brand on the right leg (eaib); T3: ear tag in one ear and tattoo on the other ear (eata); and T4: ear tag in one ear and electronic ear tag (eael) on the other. Each treatment was applied to 60 Nelore animals, totaling 240 animals, divided equally into three life stages (calves, young cattle, adult cattle). The study had two phases: implementation (phase 1) and reading and transfer of identification numbers to an electronic database (phase 2). All operating expenses related to the two phases of the study were determined. The database was constructed, and the statistical analyses were performed using SPSS® 17.0 software. Regarding the time spent on implementation (phase 1), conventional ear tags and electronic ear tags produced similar results, which were lower than those of hot iron and tattoo methods, which differed from each other. Regarding the time required for reading the numbers on animals and their transcription into a database (phase 2), electronic ear-tagging was the fastest method, followed by conventional ear tag, hot iron and tattoo. Among the methods analyzed, the electronic ear tag had the highest technical efficiency because it required less time to implement identifiers and to complete the process of reading and transcription to an electronic database and because it did not exhibit any errors. However, the cost of using the electronic ear-tagging method was higher primarily due to the cost of the device.

Key words: Automation. Cattle farming. Electronic identification. SISBOV.

Resumo

Objetivou-se avaliar a eficiência técnica e a viabilidade econômica da implantação e utilização de quatro métodos de identificação de bovinos, permitidos pelo sistema de rastreabilidade brasileiro. A pesquisa foi realizada em um sistema de produção de gado de corte, localizado no Estado de Mato Grosso, de janeiro a junho de 2012. Foram comparados quatro métodos de identificação (tratamentos): T 1: brinco auricular em uma orelha e *botton* auricular na outra (brbo); T 2: brinco auricular e marca a fogo na perna

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direita (brmf); T 3: brinco auricular em uma orelha e tatuagem na outra (brta); T 4: brinco auricular em uma orelha e brinco eletrônico (arruela eletrônica auricular) (brde) na outra. Cada tratamento foi aplicado em 60 animais da raça Nelore, totalizando 240 animais, igualmente divididos em três categorias animais (bezerros, novilhos e vacas adultas). A pesquisa teve duas fases: implantação (fase 1) e leitura dos números de identificação e sua transferência para um banco de dados eletrônico (fase 2). Foram levantadas todas as despesas operacionais referentes às duas fases da pesquisa. A construção do banco de dados e as análises estatísticas foram realizadas utilizando o *software* SPSS® 17.0. Quanto ao tempo gasto na implantação (fase 1), o brinco convencional e a arruela eletrônica auricular apresentaram resultados semelhantes, e menores que o ferro quente e tatuagem, que apresentaram tempos diferentes entre si. No que diz respeito ao tempo necessário para leitura dos números dos animais, bem como a sua transcrição para um banco de dados (fase 2), foi verificado que a arruela auricular eletrônica foi o mais rápido, seguido pelo brinco convencional, ferro quente e tatuagem. Dentre os analisados, o método que apresentou maior eficiência técnica, em função de necessitar de menor tempo na implantação dos dispositivos de identificação, bem como na leitura e transcrição para um banco de dados eletrônico, e não ter apresentado nenhum erro foi a arruela auricular eletrônica. No entanto, o custo da utilização deste dispositivo foi mais elevado, principalmente em função da aquisição do equipamento, que possibilitou uma leitura dos números mais rápido.

Palavras-chave: Automação. Bovinocultura. Identificação eletrônica. SISBOV.

Introduction

With globalization and the creation of economic blocs, the food production system must be prepared for the inclusion of its products in a highly demanding consumer market. A traceability system is needed in the beef supply chain due to the new labeling rules of European importing countries (LOPES et al., 2013a). Such a system requires the accurate identification of the origin of products that have beef as a component. To meet this demand, the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA) established the Brazilian System of Beef and Buffalo Meat Identification and Certification (SISBOV), which set out a new operating structure, revoking the previous normative instructions and ordinances and renaming SISBOV as Cattle and Buffalo Supply Chain Traceability Service (BRASIL, 2002, 2006).

SISBOV establishes a series of procedures and controls for animal identification, which must be dual, and one of the following options may be adopted: a) a SISBOV standard ear tag in one ear and a button on the other; b) a SISBOV standard ear tag in one ear and an electronic device; c) a SISBOV standard ear tag in one ear and a tattoo on the other with the SISBOV management number; or d) a SISBOV standard ear tag in one ear and the SISBOV management number branded with a hot iron on the right hind limb (LOPES; SANTOS, 2007).

Brazil has been raising both yield and exportation of beef in the latest years. In 2008, it past to lead the ranking of the greatest exporters of beef in the world, reaching, in 2015, the total of 1.4 million of tons of the exported product (ABIEC, 2016). In this context, it is stressed that the intensification of the change of foodstuffs among countries of all over the world has led to the development of joint technical standards, based upon the establishment of rules which take into account the right to the access to information by means of labeling and tracking. Specifically in relation to the labeling, it is stood out that the search for information about credibility attributes in beef has increased in the latest years, mainly in Europe and, more recently in the United States and in other parts of the world, such as Brazil (LOUREIRO; UMBERGER, 2007). For instance, the European Union, aiming to increase the food security of the products, food production occurs, mainly, in particular regions, especially those with a reputation of high quality, making, this way, the quality control by official bodies easier (LAGERKVIST et al., 2014).

Thus, considering the importance of animal identification; that the legislation allows the use of different identification methods; that each method has different prices, advantages and limitations; that electronic methods have been developed; and that there is a lack of studies that have addressed this issue, especially regarding economic viability and technical efficiency, the need for more studies becomes evident.

Therefore, we aimed to evaluate the technical efficiency and economic viability of the implementation and use of four cattle identification methods allowed by SISBOV as well as to discuss some advantages and limitations of each one, aiming to provide information that supports technicians and livestock producers when choosing the most efficient method to identify cattle.

Materials and Methods

The study was conducted in a cattle production system that develops the pre-weaning, post-weaning and finishing stages (full cycle), in a grazing regime, located in Mato Grosso, Brazil, from January to June 2012. Four identification methods (treatments) allowed by SISBOV were compared: T1: ear tag in one ear and ear button in the other ear (eabu); T2: ear tag and iron brand on the right leg (eaib); T3: ear tag in one ear and tattoo on the other ear (eata); and T4: ear tag in one ear and electronic ear tag (eael) in the other. Each method was applied to 60 Nelore animals (60 replicates), totaling 240 animals, divided equally into three life stages (calves, young cattle, adult cattle). Of this total, 80 were suckler calves aged five to eight months; 80 were young cattle aged 14 to 20 months; and 80 were adult cattle aged four to six years. The study had two phases: implementation of the identification devices (phase 1) and reading of the identification numbers and transfer of data from various identification devices to a microcomputer (phase 2). In each method, the duration of animal restraint, implementation of identifiers, data reading and data transfer were measured.

In phase 2, i.e., identification number reading, the animals were taken to the management pen and restrained in a squeeze chute, where the identification devices were read. Regarding the electronic method, animal data read and stored in the reader/collector were downloaded to software, and the time needed for this activity was recorded. The time began to be counted when we began to set up the device and ended with the end of the disassembly process, which occurred after the data were downloaded to the computer.

Regarding the conventional methods, the numbers read were recorded in a field notebook and subsequently entered into a spreadsheet created in Excel®. The time spent reading, typing and verifying data (to check for typing errors) were timed by two researchers.

To compare the different identification methods evaluated between life stages (calf, young cattle and adult cattle) as a function of the time spent on implementation and reading and transcribing the data to the worksheet or computer, two-factor analysis of variance (ANOVA) was performed, followed by Bonferroni's multiple comparison test. ANOVA was used due to its high robustness (ability to maintain the strength of the test) and when the sample was sufficiently large and balanced between treatments (MAROCO, 2010), as observed in the present study. Moreover, the interaction was unfolded, i.e., differences in the means of the dependent variables for a factor were evaluated considering each level of the other factor separately by ANOVA followed by Bonferroni's multiple comparison test.

The database was constructed, and the statistical analyses were performed using SPSS® 17.0 software. The statistical model used in the present study was: $Y_{ijkl} = \mu + t_i + c_j + tc + \varepsilon_{ijk}$, where Y_{ijkl} = observation, μ = global mean, t_i = effect of identification method i, c_j = effect of animal category (life stage) j, tc = effect of the interaction between treatment i and animal category j, and ε_{ijk} = error associated with each observation.

To estimate the costs of the four methods, all operating expenses for their implementation and the cost of reading the identification numbers were recorded by calculating the labor cost, given by the hourly rate paid to workers involved in the activity. Variable costs, i.e., those that varied depending on the number of animals, and fixed costs, which referred to the depreciation of devices used for identification (LOPES; SANTOS, 2007), were quantified considering that these devices will be used in several production cycles. The depreciation was calculated using the straight line method (HOFFMANN et al., 1981).

After surveying the implementation costs and the costs of reading the numbers from the animals and transferring the data to an electronic database, we performed an analysis of the economic viability of the investment to be made in the acquisition of an electronic reader. The net present value (NPV), the internal rate of return (IRR) and the payback were estimated according to Casarotto Filho and Kopittke (2010).

Based on the identification, reading and data transfer costs, we developed two mathematical equations by which we estimated the minimum number of animals needed for the electronic identification to be economically viable and the number of times that the numbers must be read in a given cattle production system to make the adoption of the electronic animal identification method economically viable.

The present study was approved by the Ethics Committee on Animal Use and was conducted according to the Ethical Principles for Animal Experimentation, under protocol No. 081/11 of the Deanship of Research of the Federal University of Lavras (UFLA)/Standing Committees.

Results and Discussions

Keeping records about raising conditions and about the performance of the herds is an important management tool and can be used to increase the efficiency of livestock production, the individual identification of the bovines being a step for any information record system (SCHMIDEK et al., 2009). The most common identification methods for bovines are tattoo, earring (conventional or electronic) and branding by heated iron. Each has its advantages and limitations in its use and the efficiency is directly related to the form by which are utilized in the identification of the animals (SCHMIDEK et al., 2009; MACHADO; NANTES, 2000). In the present study which sought to compare the efficiency of these methods permitted in Brazilian legislation, it was found that were significant differences ($P<0.01$) between the different categories and methods of cattle identification, time spent in the implementation of identification devices (phase 1) and time required to read the numbers and transcribe them to a database (phase 2). In addition, there was an interaction between the factors, indicating that the time spent on identification methods was different between the animal life stages studied.

Regarding the time spent on implementation, conventional ear tags and electronic ear tags exhibited similar results ($P>0.05$) (Table 1). This result was expected because the shape of the devices was similar and the method of application was exactly the same. However, the time to implement these methods was different from the hot iron and tattoo methods ($P<0.05$), which differed from each other ($P<0.05$). Such differences resulted from the greater detail required and the peculiarities of each method at the time of implantation, especially the tattoo, when compared with the ear identification devices. Among the different life stages, there was a difference in the mean implementation time between calves, young cattle and adult cattle, and the implantation of identification in young cattle took the shortest time ($P<0.05$) (Table 1).

Table 1. Time spent on the implantation, reading and transcription to a microcomputer of numbers using different identification methods in Nellore cattle, per animal and life stage category.

Phase 1: Implantation		Phase 2: Data reading and transfer	
Factor	Mean* (seconds)	Factor	Mean* (seconds)
Calf	88.6±47.8[A]	Calf	37.5±18.5[A]
Heifer	67.9±45.0[B]	Heifer	39.0±22.0[AC]
Cow	99.9±58.0[C]	Cow	41.1±20.3[C]
Conventional ear tag	40.1±11.2[a]	Conventional ear tag	44.2±13.2[a]
Electronic tag	40.3±8.4[a]	Electronic tag	11.0±4.8[b]
Hot iron	121.2±27.7[b]	Hot iron	43.9±9.8[a]
Tattoo	149.4±21.3[c]	Tattoo	57.8±11.2[c]

Phase 1: time spent on implantation of identification devices; phase 2: time required for reading the identification numbers on animals, as well as their transcription to a database. *Means followed by different letters in the same column differ by the Bonferroni test.

When the time necessary for reading the numbers from animals and transcribing the data into a database was evaluated, we observed that the electronic tag was the fastest method and that the tattoo method was the most time-consuming. The identification of adults was more time-consuming than the identification of young cattle and calves (P<0.05) (Table 1).

The electronic ear tag had the shortest implementation time as well as the shortest time for data reading and transcription, followed by conventional the ear tag, hot iron and tattoo methods in most categories (Table 2). Similar results were obtained by Lopes et al. (2013a) in Holstein calves in the southern Minas Gerais state, Brazil. The tattoo method required the most time for data reading and transcription (P<0.05).

Table 2. Time spent, per animal, on the implantation, reading and transcription of four animal identification methods of Nellore cattle in different life stage categories.

Category	Method	Phase 1	Phase 2
		Mean* (seconds)	Mean* (seconds)
Calf	Conventional	42.9±3.8[a]	41.8±8.4[a]
	Electronic tag	42.5±5.9[a]	10.0±1.8[b]
	Hot iron	126.3±8.7[b]	42.5±6.4[a]
	Tattoo	142.7±19.0[c]	55.6±11.4[c]
Heifer	Conventional	32.0±7.0[a]	50.7±17.3[a]
	Electronic tag	40.9±12.6[a]	10.3±1.9[b]
	Hot iron	91.0±6.3[b]	45.0±11.2[c]
	Tattoo	143.5±15.0[c]	57.09±10.6[d]
Cow	Conventional	53.3±9.0[a]	37.3±4.6[a]
	Electronic tag	37.7±4.0[b]	15.3±10.1[b]
	Hot iron	146.4±24.8[c]	45.5±13.1[c]
	Tattoo	162.0±23.9[d]	65.4±8.5[d]

Phase 1: time spent on the implantation of the identification devices; phase 2: time required for reading the identification numbers on animals, as well as their transcription to a database. * ANOVA P<0.001; means followed by different letters in the same column in each identification method differ by the Bonferroni test.

Conventional ear tags and electronic ear tags exhibited similar implantation times between calves and young cattle (P>0.05) (Table 2). These results indicate that if the producer chooses a temporary identification method (conventional ear tag or electronic ear tag), regardless of the life stage, both will require similar implantation times. If the producer opts for a permanent method (hot iron and tattoo), the one that required less time was the hot iron method.

The advantage of the electronic ear tag in total time spent reading and transferring the identification numbers to the computer (Tables 1 and 2) (P<0.05 compared to all other methods), which was expected, could be even greater as the number of animals increased (which would occur in an actual farm) because the time required for setting up and preparing the electronic device and connecting it to the computer was included in the calculation. This time was added to the reading time and divided by the small number of animals (20). As the number of animals with identification numbers to be read increases, the time spent on setting up and preparing the electronic reading device per animal will decrease even further, justifying the use of automation. Although the number of animals was small, the time spent reading the conventional ear tag was 318.0, 392.2 and 143.7% greater than the time spent reading the electronic ear tag in calves, young cattle and adult cattle, respectively. From the management point of view, this difference is important because the shorter the time spent reading, the less labor spent on this activity, reducing its cost.

The electronic identification of the animals enables to feed a computerized data system, adapting the farm management processes through faster and safe decisions (MACHADO; NANTES, 2000). In fact one advantage of electronic reading is the elimination of typos, observed in the present study with the conventional ear tag, thus providing greater reliability of data collected during the management practices and during the transfer of information from the reader to the software. Some typos may be serious and cause serious consequences. According to Machado et al. (2000), in the animal identification process, the quality and accuracy of the data collection process should be considered. Correctly recording and transcribing information into a computer are obstacles to overcome in the automation of a farm.

Electronic identification of cattle may also be better utilized if associated with electronic scales and management and monitoring software, which eliminates reading errors, errors of transcription to spreadsheets or individual records and typing errors, reducing the task time and increasing reliability, resulting in improved efficiency of the system as a whole. As a disadvantage, electronic identification of cattle has a higher fixed cost, which highlights the need to optimize the device because these costs do not depend on the number of animals identified. The higher cost of the electronic ear tag method, due to the cost of the reading device itself, may hinder its implementation in many farms (LOPES et al., 2013b). To make the implementation of the device feasible, the technological level and the number of animals on the farm must be evaluated to ensure that the costs from using the device are justified by the optimization of labor usage.

Conventional ear-tagging has the advantage of lower acquisition cost, does not require specialized labor for implantation or reading, is easily visually identified, is one of the most commonly adopted systems and can be used in large herds given that the scales used (numeric and alphanumeric) are infinite. One of its disadvantages is that it is subject to errors, and the numbers may become faded or illegible and covered in dirt, mud and dust, which are common factors in the field (SCHMIDEK et al., 2009). These factors can cause reading errors and errors in data recording, making them unreliable. In the present study, there were no such problems because there was no mud when the study was conducted. Another disadvantage of conventional ear-tagging is when the person who listens and writes down the numbers does not fully understand the numbers spoken. Of the 300 numbers read (five times in each of the 60 animals), the reading was repeated 47 times, which corresponded to 15.6% of the total, thus requiring more time. Even when readings were repeated, a wrong number was written down on 16 occasions (5.3%).

Regarding the advantages and limitations of hot iron branding, it is the method that requires the lowest spending on consumables (gas only) and a greater amount of labor. It causes leather injuries, thereby decreasing the sale price. In addition, it is a method which brings risk to the animals, being able when badly conducted, to cause grave lesions by burn, resulting into pain and suffering, counteracting, thus, animal welfare principles, in animal production (MACHADO; NANTES, 2000; SCHMIDEK et al., 2009). In addition, this method is also susceptible to annotation errors in the spreadsheet. In the present study, these errors occurred only five times (1.6%), and no number was incorrectly written.

The tattoo method requires low investment, primarily with the acquisition of the tattoo plier, which comes with a set of numbers. In the specific case of bovines, it requires higher consumption of labor because, in addition to the animal needing to be contained better and for longer (SCHMIDEK et al., 2009), the inner side of the ear must be cleaned to remove wax, and the ink must be well spread and pressed onto the holes. It is a painful process and often it does not have the desired outcome, especially when the high-quality ink is not used and when the inner side of the ear is not well cleaned. The large presence of hair in some breeds hinders identification (LOPES; SANTOS, 2007). Another disadvantage is when the person who writes down the numbers does not fully understand the correct numbers, which, in the present study, occurred 10 times (3.3%). Even after repeating the readings, a wrong number was noted six times (2.0%). The person who was reading the numbers could not read them on three occasions (1.0%) and had doubts four times (1.3%), needing help to verify the numbers.

Table 3 shows a description of the implementation costs of different cattle identification methods. The ear tag and the hot iron brand were the methods with the lowest effective operating cost (EOC) for implementation per animal (BRL$ 3.38), whereas when considering the total operating cost (TOC), the ear tag and the button were the least expensive (BRL$ 3.93). This difference was due to the lower representativity of the depreciation of the materials used in the ear tag and button identification methods compared with that of the materials used in the ear tag and hot iron brand identification methods. This fact shows the importance of a thorough cost estimation study and that not only the actual spending but also the equipment depreciation should be considered in the decision-making process. In both cases, the conventional ear tag and the electronic tag exhibited the highest values of the depreciation.

Table 4 shows a description of the costs relative to the time spent reading numbers from animals and their transcription to a database per cattle identification method. In all methods, except for the electronic ear tag, the EOC was equal to the TOC because they only required labor, without the use of depreciable equipment. Among all of the methods involved in the study, the electronic ear tag required the least amount of labor. However, this method requires the use of a computer and an electronic reader/collector, and these devices are subject to depreciation.

Table 3. Implementation costs of different cattle identification methods, in BRL$.

Specification	hb	ta	bu	ed
1 Total operating cost (2+3)	273.21	303.30	235.53	409.51
2 Total effective operating cost	202.63	214.32	224.35	398.33
3 Depreciation cost	70.58	88.98	11.18	11.18
4 Total cost (5+7)	293.83	324.60	245.61	424.82
5 Fixed costs (3+6)	91.20	103.85	14.53	14.53
6 Return on invested capital	20.62	14.87	3.35	3.35
7 Variable costs (8+9)	208.71	220.75	231.08	410.28
8 Effective operating cost without taxes	202.63	214.32	224.35	398.33
9 Return on working capital	6.08	6.43	6.73	11.95
10 Effective operating cost/animal (2/14)	3.38	3.57	3.74	6.64
11 Total operating cost/animal (1/14)	4.55	5.05	3.93	6.83
12 Total cost/animal (4/14)	5.00	5.41	4.09	7.08
13 Mean variable cost/animal (7/14)	3.48	3.68	3.85	6.84
14 Number of identified animals (heads)	60	60	60	60
15 % Fixed cost relative to the total cost	31.04	31.99	5.92	3.42
16 % Variable cost relative to total cost	71.03	68.01	94.08	96.58
17 Effective operating cost relative to total operating cost (%)	74.17	70.66	95.25	97.27

hb = hot iron branding; ta = tattoo; bu = button; ed = electronic device.

Table 4. Costs associated with reading and transferring the cattle identification numbers to a computer as a function of the different identification methods, in BRL$.

Specification	hb	ta	bu	ed
1 Total operating cost (2+3)	26.92	35.44	27.10	180.38
2 Total effective operating cost	26.92	35.44	27.10	5.38
3 Depreciation cost	0.00	0.00	0.00	175.00
4 Total cost (5+7)	27.73	36.51	27.92	264.54
5 Fixed costs (3+6)	0.00	0.00	0.00	259.00
6 Return on invested capital	0.00	0.00	0.00	84.00
7 Variable costs (8+9)	27.73	36.51	27.92	5.54
8 Effective operating cost without taxes	26.92	35.44	27.10	5.38
9 Return on working capital	0.81	1.06	0.81	0.16
10 Effective operating cost/animal (2/14)	0.45	0.59	0.45	0.09
11 Total operating cost/animal (1/14)	0.45	0.59	0.45	3.01
12 Total cost/animal (4/14)	0.46	0.61	0.47	4.41
13 Mean variable cost/animal (7/14)	0.46	0.61	0.47	0.09
14 Number of identified animals (heads)	60	60	60	60
15 % Fixed cost relative to the total cost	0.00	0.00	0.00	97.91
16 % Variable cost relative to total cost	100.00	100.00	100.00	2.09
17 Effective operating cost relative to total operating cost (%)	100.00	100.00	100.00	2.98

hb = hot iron branding; ta = tattoo; bu = button; ed = electronic device.

The electronic ear tag was the method with lowest EOC per animal for reading (BRL$ 0.09), whereas when TOC was considered, the electronic tag was the most expensive (BRL$ 3.01) (Table 4). This value was higher because it included the electronic reader depreciation, which was divided by the small number of animals whose numbers were read. As the number of animals increases, as occurs in a cattle production system, the value related to depreciation per animal decreases. According to Lopes et al. (2006), the increase in the production scale significantly influences the representativeness of depreciation on fixed and total costs by optimizing the infrastructure of the farm.

The higher cost of the electronic ear tag method, due to the reading device, may hinder its implementation in many farms. According to Lopes et al. (2013a), to make the implementation of the device feasible, the technological level and number of animals on the farm must be evaluated to ensure that costs of equipment are justified by the optimization of the use of labor. Thus, a study of the economic viability of the investment was necessary.

Knowing the annual depreciation value of the electronic reading device, it is necessary to know if the purchase is economically viable. We developed Equation 1 to estimate the minimum number of animals whose numbers should be read so that the equipment acquisition is economically viable. To create the equation, we used the equilibrium point or leveling point equation. Thus, considering the difference between the amount spent on labor when the numbers were read from the animals using the conventional method and the electronic method and considering the number of times that these animals need to be read and the annual depreciation value of the reading equipment, we estimated the minimum number of animals. That is, the equation developed is a function of the annual depreciation of the reading equipment, of labor costs and of the number of times the numbers on the animals are read as a result of the animal husbandry practices used in the production system.

$$NA = \frac{\textbf{Annual depreciation}}{(LB\ conv.met. - LB\ ele.met) \text{x}\ NR} \quad (Equation\ 1)$$

where:

NA = minimum number of animals whose numbers must be read so that the acquisition of the reader is economically viable;

Annual depreciation = value of the annual depreciation of the device for reading the electronic ear tag, in BRL$;

LB conv. met. = cost of labor involved in reading number on animal, making annotation in field notebooks, and typing value in an electronic database, in BRL$;

LB ele. met. = cost of labor involved in reading the number on animal and transferring the data to an electronic database, in BRL$;

NR = number of times that the numbers on animals will be read, per year, as a function of the cattle production system management practices.

In the present study, considering the mean data collected from animals that were identified with conventional ear tags, hot irons and tattoos (Tables 2, 3 and 4) and the inclusion of the respective values into Equation 1, the minimum required number of animals whose numbers should be read to make the acquisition of the electronic reader economically viable would be 487 for hot iron branding and conventional ear tags and 350 for tattoos, if only one reading was performed per year (Figure 1). These values were the same because, coincidentally, the time spent on reading the numbers was similar. If two readings were performed per year, the minimum number of animals would be 244 and 175, respectively.

Figure 1. Examples of the application of mathematical equation developed to estimate the minimum quantity of animals, whose numbers shall be read, to make economically feasible the acquisition of electronic reader.

$$NA = \frac{\textbf{Annual depreciation}}{(LB\ conv.met. - LB\ ele.met) \text{x}\ NR} \quad (Equation\ 1)$$

where:

NA = minimum number of animals whose numbers must be read so that the acquisition of the reader is economically viable; Annual depreciation = value of the annual depreciation of the device for reading the electronic ear tag, in BRL$; LB conv.

met. = cost of labor involved in reading number on animal, making annotation in field notebooks, and typing value in an electronic database, in BRL$; LB ele. met. = cost of labor involved in reading the number on animal and transferring the data to an electronic database, in BRL$; NR = number of times that the numbers on animals will be read, per year, as a function of the cattle production system management practices.

Hot iron

$$NA = \frac{175,00}{(0,45 - 0,09)x\ 1} = 487\ animals$$

Tatto

$$NA = \frac{175,00}{(0,59 - 0,09)x\ 1} = 350\ animals$$

Conventional ear tag

$$NA = \frac{175,00}{(0,45 - 0,09)x\ 1} = 487\ animals$$

Table 5. Estimate of the net present value, internal rate of return and payback of the investment in an electronic reader comparing scenarios in which different conventional cattle identification methods are replaced by the electronic method.

Scenarios	NPV (BRL$)	IRR (%)	PB (years)
		Conventional ear tag	
1 reading/year*			
Number of animals			
N = 487	-5,526.38	**	7.01
1,000	-715.22	1.68	3.11
2,000	8,663.28	43.21	1.05
2 readings/year*			
N = 244	-5,517.01	**	7.03
1,000	8,663.28	43.21	1.05
2,000	27,420.27	101.11	0.02
		Hot iron	
1 reading/year*			
Number of animals			
N = 487	-5,526.38	**	7.01
1,000	-715.22	1.68	3.11
2,000	8,663.28	43.21	1.05
2 readings/year*			
N = 244	-5,517.01	**	7.03
1,000	8,663.28	43.21	1.05
2,000	27,420.27	101.11	0.02
		Tattoo	
1 reading/year*			
Number of animals			
N = 350	-5,534.72	**	8.00
1,000	2,931.98	20.75	2.20
2,000	15,957.66	67.15	1.60
2 readings/year*			
QA = 175	-5,534.72	**	8.00
1,000	15,957.66	67.15	1.60
2,000	42,009.04	142.22	0.30

* Number of times that the identification numbers will be read using the electronic reader; N: minimum number of animals whose numbers must be read to make the acquisition of the electronic reader economically viable; **: Impossible to estimate due to the large negative value. NPV, net present value; IRR, internal rate of return; PB, payback.

Considering that the minimum number of animals whose numbers will be read is a function of the annual depreciation of the reading equipment, the amount spent on labor and the number of readings (Equation 1), the producer has some alternatives to reduce the number of animals read. The main measure would be to reduce the purchase price of the reading equipment, which reflects on the depreciation value, which can be done by researching the market (budgeting). In addition, another measure that is related to animal husbandry and management practices adopted in the production system is the number of times the animals are taken to the squeeze chute for reading and recording (Table 5).

Another important point is the TOC of implementation of the identification method (Table 3). The cost of the electronic ear tag was far greater than the cost of other methods. Considering only the TOC value, it seems unfeasible to use electronic devices. However, this method has advantages, including information reliability and shorter reading time, which will result in a reduction of labor costs.

Considering the highest value of the total operating cost of the implementation of the electronic device (in this study the electronic tag), when compared with conventional methods (Table 3) and knowing the savings gained from reducing labor costs, it is necessary to know whether the implementation of the electronic method is economically viable.

Subsequent to knowing the savings gained from reducing labor costs, it is necessary to know whether the implementation of the electronic method is economically viable. To estimate the minimum number of readings for the implementation of the method to be economically viable, we developed Equation 2. To create the equation, we used the equilibrium point or leveling point equation. Thus, considering the difference between the cost of the implementation of the electronic and the conventional methods and the difference between labor cost if the numbers on animals were read by the conventional and the electronic method, the minimum amount of time that the animals need to be read to make the adoption of the electronic method economically viable was estimated. This number is directly related to the animal husbandry practices adopted in the production system.

$$NR = \frac{TOC\ ele.met - TOC\ conv.met.}{LB\ conv.met. - LB\ ele.met} \quad (Equation\ 2)$$

where:

NR = number of times that the animals should be read, during their whole life, as a function of the cattle production system management practices, to make the adoption of the electronic animal identification method economically viable;

TOC ele. met. = total operating cost of the implementation of the electronic method, in BRL$;

TOC conv. met. = total operating cost of the implementation of the conventional method, in BRL$;

LB conv. met. = labor cost involved in reading the number on the animal, making annotations in a field notebook and recording the values in an electronic database, in BRL$;

LB ele. met. = labor costs involved in reading the number on the animal and transferring the data to an electronic database, in BRL$.

Regarding the assessment of the implementation of the electronic method, considering the mean data collected from animals that were identified with conventional ear tags, hot irons and tattoos (Tables 2, 3 and 4), and the insertion of the respective values into Equation 2, the number of times that the numbers must be read to make the adoption of the electronic animal identification method economically viable would be seven for hot iron branding, four for tattoos and eight for conventional ear tags (Figure 2). The number of readings can be reduced because, according to Machado et al. (2000), some electronic identification devices can be recovered from the animals at slaughter and reused at least 10 times without affecting the accuracy of the reading.

Figure 2. Examples of application of mathematical equation developed to estimate the amount of times the numbers of animals should be read during the life time of the animal, to make economically feasible the adoption of the electronic method of animal identification.

$$NR = \frac{TOC\ ele.met - TOC\ conv.met.}{LB\ conv.met. - LB\ ele.met}\ (Equation\ 2)$$

where:

NR = number of times that the animals should be read, during their whole life, as a function of the cattle production system management practices, to make the adoption of the electronic animal identification method economically viable; TOC ele. met. = total operating cost of the implementation of the electronic method, in BRL$; TOC conv. met. = total operating cost of the implementation of the conventional method, in BRL$; LB conv. met. = labor cost involved in reading the number on the animal, making annotations in a field notebook and recording the values in an electronic database, in BRL$; LB ele. met. = labor costs involved in reading the number on the animal and transferring the data to an electronic database, in BRL$.

Hot iron

$$NR = \frac{6,83 - 4,55}{0,45 - 0,09} = 6,33 = 7\ readings$$

Tatoo

$$NR = \frac{6,83 - 5,05}{0,59 - 0,09} = 3,56 = 4\ readings$$

Conventional ear tag

$$NR = \frac{6,83 - 3,93}{0,45 - 0,09} = 8,05 = 8\ readings$$

The equations developed are of great importance because the livestock producers, in possession of the necessary data collected in their production systems, can calculate the values and obtain information that will assist them in decision-making processes.

Some economic indicators (payback (PB), or time to return of the invested capital; net present value (NPV); and internal rate of return (IRR)) of the investment in an electronic reader were estimated by comparing scenarios in which different conventional cattle identification methods were replaced by the electronic method (Table 5). Considering only payback and reading and recording of the numbers once a year, the adoption of an electronic identification method over tattoos is justified based on a minimum of 350 animals. If the reading is performed twice a year, this number decreases to 175 (Table 5). The values are lower when this method is used because, according to Lopes et al. (2013b), due to some peculiarities and details of the method, it demands a greater amount of labor and time. Compared to other methods studied, the minimum numbers are 487 and 244 animals, for one and two readings per year, respectively. The values show that the more labor an activity requires, the more automation is justified.

The results show that as the number of animals increases, the economic viability indicators increase considerably, justifying the investment in technology because the internal rates of return were higher in scenarios with 2,000 animals than in those with 1,000 animals and both were higher than the hurdle rate, which in the present study was estimated at 6% per year. In investment analysis, according to Casarotto Filho and Kopittke (2010), internal rates of return higher than the minimum hurdle rate indicate that the investment is economically viable. In all scenarios with 1,000 animals and in those with two readings per year, the NPV was positive, which also demonstrates the economic viability of the investment.

Conclusions

Among the methods analyzed, the electronic ear tag showed the highest technical efficiency because it required less time for implantation in the animal as well as for reading and transcribing the numbers to an electronic database and because it was not associated with any reading error, even when the numbers were transferred to an electronic database. The cost of using this device was higher primarily due to the cost of the device itself. The results show that as the number of animals increases, the economic viability indicators improve considerably, justifying the investment in this technology.

The mathematical equations developed will help technicians and livestock producers estimate, with accuracy and considerable speed, the minimum number of animals and the minimum times that the numbers must be read to make the adoption of the electronic animal identification method economically viable.

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