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ECONOMIC WEIGHTS IN RABBIT MEAT PRODUCTION

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Abstract: A profit function was designed for an industrial commercial rabbitry with the most common management in industrial rabbit production. The incomes, costs, and profit function were calculated and economic weights of the traits were estimated. The variable costs (feeding, artificial insemination, health and replacement) represented 62% of the total costs, and the fixed costs (labour, utilities, amortisation and administration) represented 38% of the total costs. Major costs were feeding of fattening kits and labour cost, at 26% and 18% of the total cost, respectively. The economic weights were feed conversion rate during fattening (–20.2 €/[g feed/g liveweight]), number of kits born alive (15.7 €/kit), pregnancy rate (1.7 €/percentage unit), weaning survival (1.7 €/percentage unit), fattening survival (2.0 €/percentage unit), daily feed intake (–0.50 €/(g feed/d)), daily gain during fattening (1.33 €/(g weight/d)), and replacement rate (–0.29 €/percentage unit). When varying the prices of kg of fattening feed and kg of liveweight, only the economic weights of feed conversion rate during fattening in the first case and the number of kits born alive in the second case changed considerably. Changes in labour cost produced appreciable changes in the whole production cost. Although economic weights are robust to changes in prices, these weights should be recalculated after some generations of selection, because changes in the mean of the traits due to selection can also change economic weights.

Key Words: economic weights, profit function, rabbit production.

INTRODUCTION

The breeding goals in an animal breeding programme are commonly established according to the economic importance of the traits. In a selection index, the economic weights are defined as the economic value of a unit of the trait (Falconer and Mackay, 1996), although more accurate definitions can be proposed for specific cases (see Blasco, 1995, for a full review on economic weights[1]). In the simplest case, economic weights can be computed from a profit function, depending on a set of traits, a set of market prices, the variable costs and the fixed costs of production. Normally the prices and the costs (both fixed and variable costs) are considered constant whatever the size of the farm; i.e., there is no scale factor on costs and prices. This means, for example, that a farm of 1500 does will have twice the costs of a farm with 750 does and the prices of food and live rabbits will be the same. In a very large scale production operation, this is not always the case; for example, a very large company may obtain better prices for food; but the assumption of no scale factor on costs and prices works well for most of the common industrial farms. The profit function is, under these assumptions, a function of only the traits considered.

Another common hypothesis is that the profit function is a linear combination of the traits. In this case, the profit can be calculated as the difference between income and costs per unit of trait. As this is not often the case, an approximation can be done by linearising the profit function using Taylor series; i.e.: if $P=f(x_1,x_2, \dots ,x_n)$ is the profit function and $x_1,x_2, \dots ,x_n$ are the traits.

$$P \approx k+\left[\frac{\partial f}{\partial x_1}\right]_{x_i=\bar{x}_i,\forall i} \cdot x_1+\left[\frac{\partial f}{\partial x_2}\right]_{x_i=\bar{x}_i,\forall i} \cdot x_2+\cdots+\left[\frac{\partial f}{\partial x_n}\right]_{x_i=\bar{x}_i,\forall i} \cdot x_n \quad (1)$$

[1] An English translation of this paper is available from the author by request.

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Where $\bar{x}_i$ is the average of the trait *i* at the moment of selection and $x_i = \bar{x}_i, \forall_i$ means that the partial derivative is calculated at the means of all traits. It seems logical to call 'economic weights' the quantities that multiply the traits, since the profit is proportional to them. They are approximately equal to an increment in profit when a small increment of the trait is produced; this is usually correct because increments due to selection are small (Smith, 1984). This way of computing economic weights entails that they should be recalculated after few generations of selection, since the approximation may not work well if the means of the traits have changed too much by selection.

Economic weights can be computed in different ways. For example, the ratio income/costs can be considered instead of considering the difference between income and costs, but both perspectives lead to the same results under certain assumptions (Smith *et al.*, 1986). Other more complex approaches need market studies; for example, Amer and Fox (1992) derive economic weights from marginal costs curves, and De Vries (1989) considers the market quota of a breeding company. These approaches need information that is not usually available in rabbit production, so the economic weights were derived using the more classical approach discussed above.

Economic weights will be used later in selection indexes. A selection index predicts the economic value of the offspring of a candidate for selection. This economic value, often called "aggregate genotype" is, for each animal: $A_E = w_1 \cdot A_1 + w_2 \cdot A_2 + \ldots + w_n \cdot A_n$ where w_i is the economic weight of trait *i* and A_i is the breeding value of trait *i*; i.e., the prediction of the value of the offspring of the candidate of selection for this trait. The units in which the economic weights are expressed should be the same as the units of the breeding values; for example, if A_1 is the breeding value of slaughter weight expressed in kg, the economic weight w_1 should be expressed in €/kg; if A_2 is the breeding value for food conversion rate expressed in (kg food / kg liveweight), w_2 should be expressed in €/(kg food / kg liveweight), so that A_E is expressed only in €. By doing this, we select the animals that will have descents producing the highest profit, independently on whether they do that because they are particularly good in trait 1 or in trait 2. The breeding values A_i are often estimated simultaneously by means of an index, and they are not necessarily the same as the traits measured; for example, food conversion rate can be included in the aggregate genotype due to its economic interest, but not measured due to the high cost of recording; in this case the trait is improved through the genetic correlations with other traits actually measured. The procedure can be found, for example, in Falconer and Mackay (1996).

Economic weights of the main traits have been calculated by Armero and Blasco (1992) and Prayaga and Eady (2000) in rabbit meat production. However, industrial rabbit production has changed considerably in recent decades. Advances in management, nutrition, genetics, reproduction and marketing have modified the prices and costs of the profit function, and have also introduced new traits into the function; for example, nowadays the use of artificial insemination and reproduction management in batches is common in industrial production. Manual labour has changed, since one person can manage more than twice the number of does as 20 yr ago. Investments are also different nowadays, as farms are technically better. The aim of this study is to compute the economic weights in modern rabbit industrial production.

MATERIALS AND METHODS

Production system

A simulation was performed considering a typical industrial rabbitry that can be managed by one person. The rabbitry had 750 does housed in 2 bays. Each bay had 750 multipurpose cages for does and fattening animals plus 105 replacement cages. The management characteristics were based on of the national Spanish rabbit survey (MAGRAMA, 2008). The rabbitry was environmentally controlled and, as mentioned above, was managed by one person. Crossbreed does for replacement were purchased from a multiplier at 9 wk of age. The reproductive does had their first artificial insemination at 18 wk of age and were managed in a single batch. All does were artificially inseminated 11 d post-partum, i.e., with subsequent cycles of 42 d. The suckling kits were weaned at 35 d and sold to the slaughterhouse at 2.2 kg of liveweight. Replacement and reproductive does were fed with feed made for reproductive dams. Replacement does were feed-restricted. Reproductive does were fed *ad libitum* during the lactating, overlapping (both lactating and gestating) and gestating periods, and restricted during the empty periods. Kits consumed the doe feed *ad libitum* from 17 to 35 d of age, and a feed for fattening *ad libitum* until slaughter. The mean values assumed for the variables of the profit function are shown in Table 1.

Table 1: Mean values assumed for the variables of the profit function.

Parameter		Source
Pregnancy rate (%)	78.2	bdcuni[1]
Number of kits born alive per kindling	9.4	bdcuni [1]
Lactation survival (%)	88.1	bdcuni [1]
Fattening survival (%)	92.9	bdcuni [1]
Replacement rate (%)	120	Ramon and Rafel, 2002
Replacement mortality (%)	9.3	Rosell and de la Fuente, 2009
Feed intake of the replacement doe (kg/period)	8.8	Cervera and Pascual, 2006[2]
Daily feed intake of lactating doe (g/d)	282	Adapted from Pascual *et al.,* 1999
Daily feed intake of overlapping doe (g/d)	339	Adapted from Pascual *et al.,* 1999
Daily feed intake of empty doe (g/d)	167	Adapted from Pascual *et al.*, 1999
Daily feed intake of pregnant doe (g/d)	199	Adapted from Pascual *et al.,* 1999
Daily feed intake of suckling kit (g/d)	22	Blas E., personal communication
Daily feed intake during the fattening period (g/d)	105	Orengo *et al.*, 2009
Daily gain during lactation (g/d)	35.0	Alagón, 2013
Daily gain during the fattening period (g/d)	40.1	Orengo *et al.*, 2009
Weight at 17 d (kg)	0.31	Alagón, 2013
Weaning weight at 35 d (kg)	0.9	Alagón, 2013
Slaughter weight (kg)	2.2	bdcuni [1]

[1]Mean for rabbitries with a single batch management and insemination 11 d post-partum; bdcuni (database of technical management in Spanish rabbit sector), personal communication.
[2]Assuming 140 g/d from 9 to 18 wk of age.

Profit function

The profit function was expressed as $P= R-C$ where, P, R, C were the profit, returns and costs, respectively. The profit was expressed per doe and per year. Details of the profit function are shown in Annexes 1, 2 and 3. The only return considered was the income from selling fattening kits. Prices and costs assumed are shown in Table 2.

The fixed costs were the sum of labour, utilities, administration and amortisation costs. These costs were divided per doe, replacement doe or litter weaned per year. The labour cost was established as twice the Spanish national minimum agricultural salary (MEYSS, 2012). This labour cost was increased 36% to cover holidays and weekends, according to the working calendar in Spain, in which 270 working days are considered in a contract.

Table 2: Prices and costs used in the profit function.

Parameter		Source
Price per kg of liveweight (€)	1.81	ASESCU, 2012[2]
Price of replacement doe (€/crossbreed doe)	9.00	Sector companies
Price per kg of fattening feed (€/kg)	0.29	COAVRE, 2012[3]
Price per kg of doe feed (€/kg)	0.30	COAVRE, 2012[3]
Price of artificial insemination[1] (€/dose)	1.00	Sector companies
Health costs of doe (€/doe)	11.33	Rosell and Fluvià, 2008
Health costs of replacement doe (€/replacement doe)	0.50	Sector companies
Fixed cost of the doe (€/doe yr)	42.46	Own estimation
Fixed cost of the replacement (€/doe yr)	13.05	Own estimation
Fixed cost of the offspring (€/doe yr)	22.62	Own estimation

[1]Hormonal treatment included.
[2]Average of 2012.
[3]Average of 2012, coccidiostats and value added tax (10%) included; no antibiotics, transport and bonuses included.

The utilities costs, which included water, power, phone, maintenance and nesting material were estimated from restricted data from 2012 provided by 21 typical industrial farms included in the bdcuni[2] management programme (database of technical management in Spanish rabbit sector). The administrative costs considered were clerical costs, agricultural insurances (ENESA, 2012) and contributions to rabbit producers associations (BOE, 2010).

The investment cost was estimated as the cost of the building plus the cages. The depreciation period of this capital was 30 yr for the building and 15 yr for the cages. It was assumed that in real situations the farmer will need a loan for the investment, so the cost of a loan was added to the investment costs. Based on actual data, a loan with a constant interest rate of 6% repayable in 10 yr was assumed. An average inflation rate of 3% was also considered when calculating the annual payments of the loan, so that the actual amount returned was lower than the amount obtained when considering these quantities at constant monetary value. The opportunity cost was calculated, on current bank data, as the return obtained when investing the costs of the investments in a fixed term at 2.5%.

Economic weights

The absolute economic weights of the different traits were estimated as in formula (1), calculating the partial derivate of the profit function with respect to the traits, and substituting the traits by their average values. The traits considered were pregnancy rate (percentage of kindlings with respect to inseminations), number of kits born alive (kits born alive per kindling), lactation survival (percentage of kits weaned with respect to kits born alive), fattening survival (percentage of growing rabbits at slaughter age with respect to kits weaned), replacement rate (percentage of replacement does with respect to reproductive does per year), daily feed intake during fattening, daily gain during fattening and feed conversion rate during fattening. The relative economic weights of all traits were expressed with respect to the economic weight of the highest of all of them, which was the feed conversion rate during fattening. Prices and costs were assumed to be constant because no scale effect on the size of the farm was expected; however, changes of prices of the main inputs and outputs could modify the economic weights. In order to assess whether this was the case, a sensitivity analysis was performed by changing feed and rabbit liveweight prices. Economic weights were recalculated taking the means of the minimum and maximum prices between 2009 and 2012, which were in Spain 0.22 and 0.33 €/kg of feed (COAVRE, 2012), and 1.50 and 2.17 €/kg of rabbit liveweight (ASESCU, 2012). Economic weights were also recalculated varying the labour costs between one and three times the national minimum agricultural salary in Spain (BOE, 2011).

RESULTS

Profit function

Tables 3 and 4 show the costs per doe and year and per kg of liveweight, and the percentage of each item with respect to the total cost. Feeding represents almost half of the total costs. Feeding the offspring takes almost 30% of the total costs, showing the importance of feed conversion rate during fattening in the profit.

[2] Data provided by the Valencia Institute of Agricultural Research (IVIA).

Table 3: Distribution of the feeding costs of the rabbitry.

	€/doe and year	€/kg liveweight sold	% total[1]
Replacement doe	3.5	0.03	1.7
Reproductive doe	29.2	0.25	14.2
Pregnancy	2.8	0.02	1.4
Overlapping	16.5	0.14	8.0
Lactation	6.3	0.05	3.1
Empty period	3.6	0.03	1.8
Offspring	60.5	0.53	29.4
Lactation kits	7.2	0.06	3.5
Fattening kits	53.3	0.46	25.9

[1]Percentage of the cost with respect to the total cost of production.

Table 4: Distribution of the rabbitry costs.

	€/doe and year	€/kg liveweight sold	% total[1]
Feeding	93.2	0.81	45.2
Utilities	14.4	0.13	7.0
Artificial insemination	8.69	0.08	4.2
Replacement	11.8	0.10	5.7
Health	14.3	0.12	6.9
Labour	37.3	0.32	18.1
Administration	6.3	0.06	3.1
Amortisation	20.2	0.18	9.8

[1]Percentage of the cost with respect to the total cost of production.

Labour is an important cost due to the size of the enterprise, because total income of the products managed by a single man for a year is only 154,500 € (Table 5). If rabbits are slaughtered at heavier liveweights, as in France or in the North of Italy, this effect is mitigated because labour cost is approximately the same and the return increases. In total, fixed costs (labours, amortisations, utilities and administrative) represent 38% of the cost.

It is interesting to note that the costs of replacement and feeding the replaced doe account for only 7.4% of the costs, which implies that longevity is not going to be an important economic trait. In general, all costs affecting the reproductive stock are divided by the total litter produced, and they represent a small part of the cost of the product, i.e. the rabbit sold to the slaughterhouse. In the present study we considered a replacement rate of 120% and a pregnancy rate of 78.2% (Table 1), which implies an average of 5.7 parities per doe. Having 9.4 kits born and with the survival rates shown in Table 1, each doe will have 7.7 rabbits sold per parity, which means that each doe produces about 44 rabbits in its productive life. Therefore, all costs on the doe should be divided by 44 to obtain the cost per rabbit sold. Notice that these figures are real data and not theoretical proposals; they are averages of actual results of the farms included in the bdcuni management programme.

Amortisation costs are relatively high. There are several reasons for this. First, a rabbit farm is a relatively expensive investment per doe for the same reason that fixed costs are higher in rabbit (38%) than in other intensive animal production (22% in swine, SIP, 2012; 24% in broiler, ENESA, 2009). Apart from this, it was considered a real situation in which the farmer has no savings and needs to ask for a loan to build up the farm. To reproduce as accurately as possible real situations, the loan was considered to be returned within 10 yr, although the cost was divided by the whole period of amortisation (30 yr for the building and 15 yr for the cages), which means that in practice the farmer will apparently have less profit at the beginning of this period and more profit later.

Only sold rabbit liveweight from fattening rabbits was considered as returns. Manure is almost not paid; its return is compensated by the cost of collection, transport and elaboration. The same happens with the income from culled does. Rabbit fur has some value, but slaughterhouses pay for the live rabbit, without dividing fur and carcass. Corrections of the liveweight price have occasionally been proposed according to carcass yield, but it is not a common practice, so liveweight is finally the only return in rabbit meat production.

Table 5 shows the total costs, income and benefits of the rabbit farm. It is noticeable that the benefits are near zero, a common situation in small animal production industries, in which the farmer obtains the benefits through self-employment.

Economic weights

The economic weights of the traits are shown in Table 6 expressed in €/unit of the trait. Not surprisingly, the highest economic weights were the feed conversion rate during fattening and the number of kits born alive. Note that, as

Table 5: Costs, returns and profit of the rabbitry.

	€/doe yr	€/kg liveweight sold	€/yr
Costs	206	1.79	154,500
Returns	208	1.80	156,000
Profit	1.69	0.01	1,500

Table 6: Absolute (EW) and relative (REW) economic weights of the main traits of the profit function in €/unit of the trait.

Trait	EW	EW[1]	REW	REW[1]
Pregnancy rate	1.7	-	–0.09	-
Number of kits born alive	15.7	30.7	–0.78	–0.89
Lactation survival	1.7	3.6	–0.08	–0.10
Fattening survival	2.0	4.2	–0.10	–0.12
Replacement rate	–0.3	–0.8	0.01	0.02
Daily feed intake during fattening	–0.5	–0.7	0.02	0.02
Daily gain during fattening	1.3	2.7	–0.07	–0.08
Feed conversion rate during fattening	–20.2	–34.3	1.00	1.00

[1]Economic weights according to Armero and Blasco (1992) adjusted to constant Euros (Base 100=2012).

shown in Figure 1, if the profit function is linear, the economic weights are the same independently of the amount of the increase of the trait; for example, the economic weight is the same if the increment of food conversion rate is 0.1 or is 1 because in the first case the benefit will be 10 times lower than in the second case. As profit functions are not always linear and the increment of a trait expected by genetic improvement is low, observing the profit increment when a unit of the trait increases can help to understand the meaning of the economic weight, as shown in Table 7. This table also shows the increment in profit when the trait increases one phenotypic standard deviation. Profit changes considerably, but response to selection depends on several factors such as genetic parameters and intensity of selection, and it is much more difficult to improve 3.4 young rabbits than 0.25 g/g of food conversion rate.

Economic weights of survival and replacement rate were small. This does not mean that survival or mortality are not important traits, but it should be taken into account that these traits are near their optimum, so only small increments can be expected. Whereas one rabbit more is near to a 10% increase in litter size, achieving this increase would put the survival rate of young rabbits at close to 100%. As these figures are the average of real farms from a management programme, it can be concluded that when a farm is far from these values, this farm has a management problem that should be solved by means other than genetics.

The economic weight of replacement rate was low compared to the economic weights of other traits. This economic weight can be considered as an estimation of the economic weight of longevity. It may be argued that the reproductive doe has an unproductive period before it is culled whose cost (feeding, sanitary costs, etc.) should be considered, but this unproductive period represents only 1.8% of the total cost of the doe, and apart from this, in our case it is actually included in the costs of the reproductive doe, because we considered all costs throughout the reproductive life of the doe. Some authors considered the economic weight of longevity as the period between first mating and death or culling time (Eady and Garreau, 2007), but this is equivalent to including the replacement rate in the profit function.

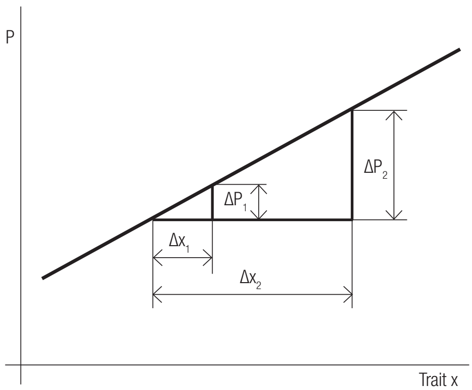

Figure 1: Linear profit (P) function. Economic weight=$\Delta P_1/\Delta x_1=\Delta P_2/\Delta x_2$ are the same using any increment of the trait.

Sensitivity analysis

The sensitivity analysis of absolute and relative economic weights is shown in Tables 8 and 9. Economic weights look quite robust, but appreciable changes occur in the economic weight of food conversion rate when there is a large variation in the price of fattening feed, and the same happens to the economic weight of the number

Table 7: Increase in profit (€/doe yr) derived from a change in the mean value of a trait. A: Change of profit caused by the improvement of one unit of the trait. B: Change of profit caused by the improvement of one phenotypic s.d.

	Mean	s.d.	A(€)	B(€)
Pregnancy rate (%)	78	7.7[1]	1.7	13
Number kits born alive (kits)	9.4	3.4[1]	15.7	53
Lactation survival (%)	88	3.4[1]	1.7	6
Fattening survival (%)	93	4.5[1]	2.0	9
Replacement rate (%)	120	29[1]	0.3	8
Fattening daily feed intake[a] (g/d)	105	21[2]	0.5	10
Fattening daily gain (g/d)	40	7.9[2]	1.3	10
Feed conversion rate during fattening[a] (g/g)	2.6	0.25[2]	20.2	5

[1]bdcuni (database of technical management in Spanish rabbit sector), personal communication.
[2]Orengo *et al.,* 2009.
[a]Estimated from the whole consumption of the cage.

of kits born alive when large changes occur in the sold liveweight price of the rabbit, independently of whether we consider the absolute or relative economic weight.

When varying the salary between one and three times the national minimum agricultural salary, the labour cost, which is 18.1% of the production costs in our model (Table 4), ranged from 10.7% to 23.5% and the production cost, 1.79 €/kg of liveweight in our model (Table 5) varied between 1.65 and 1.94 €/kg of liveweight. This shows that the production cost is sensitive to large changes in the labour cost.

DISCUSSION

Profit function

Our model represents a typical modern industrial farm managed by one person. The number of does managed per person has increased in the last years due to advances in reproduction and management such as the implementation of artificial insemination or management in batches. Some processes have become mechanised, like the feeding and manure elimination systems (Mugerza *et al.*, 1995; Rodríguez, 2007). At present, one person is considered to manage between 675-750 does (Jentzer-Azard, 2009; Serrano *et al.*, 2012; Rafel *et al.*, 2013). As explained in the Introduction section, we assumed that there is no scaling factor in prices and costs, so our results can be applied to rabbitries of different sizes.

The variable costs (feeding, artificial insemination, replacement and health) were 62.1% of the total cost, while fixed costs (labour, amortisations, utilities and administrative) were 37.9%. These results were within the range obtained in 2010 by Pascual *et al.* (2011) and Serrano *et al.* (2012).

Table 8: Economic weights in €/unit of the trait obtained with minimum and maximum price of fattening feed and sold liveweight.

Trait	Fattening feed price		Liveweight price	
	Min	Max	Min	Max
Pregnancy rate	1.9	1.6	1.4	2.3
Number of kits born alive	17.1	15.0	13.0	20.2
Lactation survival	1.9	1.6	1.4	2.2
Fattening survival	2.0	1.9	1.7	2.4
Replacement rate	–0.3	–0.3	–0.3	–0.3
Daily feed intake during fattening	–0.4	–0.5	–0.5	–0.5
Daily gain during fattening	1.0	1.5	1.3	1.3
Feed conversion rate during fattening	–15.0	–22.5	–20.2	–20.2

Table 9: Relative economic weights obtained with minimum and maximum price of fattening feed and sold liveweight.

Trait	Fattening feed price		Liveweight price	
	Min	Max	Min	Max
Pregnancy rate	0.13	0.07	0.07	0.11
Number kits born alive	1.14	0.67	0.64	1.00
Lactation survival	0.12	0.07	0.07	0.11
Fattening survival	0.13	0.09	0.08	0.12
Replacement rate	0.01	0.01	0.01	0.01
Daily feed intake during fattening	0.02	0.02	0.02	0.02
Daily gain during fattening	0.07	0.07	0.07	0.07
Feed conversion rate during fattening	1.00	1.00	1.00	1.00

Labour cost was considered as twice the national minimum agricultural salary (28,543 €/yr, including taxes) because the producer is supposed to have background and experience in rabbit production management, so it is not possible to apply a salary of an unqualified worker. This salary is within the range considered by other technical management programmes in Spain and France (Jentzer-Azard, 2007; Jentzer-Azard, 2009; BOE, 2011; ITG, 2012).

Longevity has been proposed as a trait of strong economic interest by some authors (Piles *et al.*, 2006; Sánchez *et al.*, 2008), but according to our results it is of low importance, and the same result was found by Eady and Garreau (2007). All costs placed on the reproductive stock are divided by the number of rabbits produced, leading to low economic weights and low profits when increasing the traits related to these costs. All costs on the doe should be divided by the 44 kits produced in their reproductive life to obtain the cost per rabbit sold. The same reasoning can be applied to all costs related to artificial insemination or related to males; they will always be low and will have no interest for selection, despite the claims of some authors based only on the heritabilities of these traits (Lavara *et al.*, 2011; Tusell *et al.*, 2012).

Benefits are near zero. This is common in small sized agricultural industries due to competence, and the farmer obtains the return on capital invested after costs by self-employment with a reasonable salary, as we have seen before.

Economic weights

There are only 2 former studies on economic weights in rabbit, Armero and Blasco (1992) and Prayaga and Eady (2000). In a context of restricted feeding, Eady and Garreau (2008) also calculate economic weights for some traits of rabbit meat production. Table 6 shows the results of Armero and Blasco (1992) in €/unit of trait, corrected for inflation. The relative economic weights look remarkably similar, but there are obvious differences for the absolute economic weights. Number of kits born alive halved its economic weight in the last 20 yr, and even at its maximum price (Table 8) it was far away from the weight given by Armero and Blasco (1992). As the economic weight of number of kits born alive is directly related with the price of sold rabbit liveweight, prices 20 yr ago should have been higher, and indeed they were. Correcting for inflation, the price of rabbits in 1992 was 3.27 €/kg liveweight compared to the current 1.81 €/kg liveweight. The decrease in fattening food prices has been much less dramatic, from 0.33 to 0.29 €/kg, but here comparison is more difficult, since Armero and Blasco (1992) considered weaning at 28 d; nevertheless, a reduction in the economic weight is expected if the price of food decreases (Table 8). The reduction of liveweight price has been compensated by reducing labour costs through a great increase in the number of females managed by one person. In the 1990s one person was assumed to be able to manage 300 females (Baselga and Blasco, 1989), whereas now one person manages more than twice this figure. Rabbit production has become an intensive farming industry similar to swine or poultry. In Australia, the economic weights of litter size and food conversion rate were also important, although the infant industry is much less productive than European systems (Prayaga and Eady, 2000; Eady, 2003). In France, Eady and Garreau (2008) stress that using restricted feeding will reduce feeding costs more than feeding ad lib. Restricted feeding is used generally for a better control of enterocolitis, but it can be an interesting trait in rabbit production *per se*. Research is needed to determine whether the genetic progress under restricted feeding would be more efficient for decreasing food conversion rate than *ad libitum* feeding, and whether this would compensate a lower growth. An experiment of selection under restricted feeding is now being carried out (Drouilhet *et al.*, 2013).

The economic weights of lactation and fattening survival had a low value, agreeing with results reported by Prayaga and Eady (2000). In spite of this, Eady (2003) suggested that pre-weaning mortality can be an important trait to be included in a selection index in these conditions. However, the reason for the importance of this trait was its high phenotypic deviation (σ_P=22.7%), much higher that the value obtained in the Spanish industry (3.37%; bdcuni, personal communication). This means that mortality was much higher than it should be on many farms, and this should not be solved by selection. One condition for the estimation of the economic weights is that the resources have to be used efficiently (Smith *et al.*, 1986), as genetic progress is slow and changing management is a much more efficient solution when the performances are suboptimal.

Although economic weights have shown some sensitivity to changes in the extremes of some prices, a result observed before (Vandepitte and Hazel, 1977; Bright, 1991), selection indexes are quite robust to variations in the values of economic weights (Smith, 1983), thus the normal fluctuation of prices should not affect the results of selection indexes when the economic weights are included. It is nevertheless recommended to re-estimate them after some generations of selection in order to see how the changes in the means produce changes in the economic weights. We have seen how in the last 20 yr great changes have taken place in the economic weights of litter size and feed conversion rate during fattening.

Which traits should be considered for inclusion in a selection index? There is no straightforward answer to this question. Some traits have a direct effect on the profits (e.g. litter size), but if the heritability of a trait is very low, no economic progress will be obtained by selection. Intensity of selection is not the same for all traits. Some traits are highly variable and some are not, and the selection response is proportional to variability. Some traits have no effect on the profit function, but may be included in it for other reasons, for example future expectations (e.g. meat quality). Some traits are recorded in both sexes and some in only one sex (e.g. pregnancy rate), some traits are expressed before animals should go the slaughter house (e.g. growth rate) and some are not observed until adult life (e.g. litter size) so no data of the candidate for selection is available at the moment of selection and it should be selected using information of relatives. Some traits are difficult and expensive to be measured (e.g. food conversion rate) but are correlated with traits that are easier to gauge (e.g. slaughter weight), so they can be considered in the breeding objective but not measured in the selection index. Some traits allow repeated measurements (e.g. litter size) and some traits do not (e.g. daily gain).

Ponzoni and Newman (1989) have stressed that in practice selection will not necessarily be carried out based on indices, but economic weights identify the relevant traits to be included in the breeding objective. In our case, it seems clear that food conversion rate and litter size are the main objectives in rabbit breeding. Current breeding systems consider selection for litter size in dam lines and improvement of food efficiency through selection for growth rate in terminal sire lines, for practical reasons. If dam lines were also selected for growth rate, their adult weight would increase (Blasco *et al.*, 2003), their maintenance costs would also increase and their management would be more complex; moreover, the need for individual identification and recording of the offspring will also raise the costs of the programme. Direct measurement of the conversion index looks attractive, as it seems that the genetic correlation between food conversion rate and growth rate is lower than in other species (Piles *et al.*, 2004), but it is expensive and the industry has been reluctant to use this measurement.

Litter size and food conversion rate are still the most important traits in rabbit meat production. Litter size is difficult to improve by selection and intensive research is being carried out to increase it. Food conversion rate is expensive to measure, but further research is needed about implementing records of this trait in selection programmes; for example, food consumption may be measured only in males and in some preselected families, reducing the high cost involved.

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ANNEXES

Annex 1: Glossary of symbols.

Symbols	Description	Symbols	Description	Symbols	Description
A	Alive	Fd	Feeding	Pn	Perinatal
Ac	Acquisition	Ft	Fattening	Pr	Price
An	Annual	Fx	Fixed	Pt	Parities
AI	Artificial insemination	G	Gain	R	Returns
B	Born	H	Health	Ra	Rate
C	Cost	I	Intake	Re	Replacement
Ci	Reproductive cycle	La	Lactation	Sl	Slaughter
D	Day	N	Number	Su	Survival
Do	Doe	O	Overlap	To	Total
Em	Empty	Of	Offspring	W	Weight
En	Entrance	P	Profit	We	Weaning
F	Feed	Pg	Pregnancy		

Annex 2: Abbreviations.

Symbols	Description	Symbols	Description
AcCRe	Acquisition cost of replacement	HAnCRe	Health annual cost of replacement
AIC	Artificial insemination cost	HCDo	Health cost of the doe
AnReRa	Annual replacement rate	HCRe	Health cost of replacement
C	Cost	LaCOf	Lactation cost of offspring
DFI17-35	Daily feed intake between 17-35 days	LaD	Lactation days
DFIFt	Daily feed intake during fattening	LaSu	Lactation survival
DFIO	Daily feed intake during overlap	NBA	Number of kits born alive per kindling
DFIPg	Daily feed intake during pregnancy	NCi	Number of reproductive cycles
DFILa	Daily feed intake during lactation	ND_{17-35}	Number days between 17-35 d
DGFt	Daily gain during fattening	NPt	Number of parities
DGLa	Daily gain during lactation	OD	Overlap days
DoC	Doe cost	P	Profit
EmD	Empty days per year	PgD	Pregnant days
EnRa	Entrance rate	PgR	Pregnancy rate
FdCDo	Feeding cost of the doe	PnSu	Perinatal survival
FdCEm	Feeding cost of empty	Pr1	Price of kg of liveweight
FdCLa	Feeding cost of lactation	Pr2	Price of replacement
FdCO	Feeding cost of overlap	Pr3	Price per kg of doe feed
FdCPg	Feeding cost of pregnant	Pr4	Price of artificial insemination
FdCRe	Feeding cost of replacement	Pr5	Price per kg of fattening feed
FIRe	Feed intake during replacement	R	Returns
FtC	Fattening cost	ReC	Replacement cost
FtD	Fattening days	ReSu	Replacement survival
FtSu	Fattening survival	SlW	Slaughter weight
FxCDo	Fixed cost of the doe	ToNB	Total number of kits born per kindling
FxCFt	Fixed cost of fattening	W17	Weight at day 17
FxCRe	Fixed cost of replacement	WeW	Weaning weight
HAnCDo	Health annual cost of the doe	WG_{35-SlW}	Weight gain 35 d to slaughter

Annex 3: Development of the profit function.
Profit=Returns–Costs

Returns (R):

$R=34.51\times PgR\times NBA\times LaSu\times FtSu$

$R=8.69\times PgR\times NBA\times LaSu\times FtSu\times 2.2\times 1.81$

$R=NCi\times PgR\times NBA\times LaSu\times FtSu\times (WeW+WG_{35\text{-}SlW})\times Pr1$

$R=NCi\times PgR\times NBA\times LaSu\times FtSu\times SlW\times Pr1$

$R=NPt\times ToNB\times PnSu\times LaSu\times FtSu\times SlW\times Pr1$

Costs:

Replacement costs (ReC)

$ReC=13.05+AnReRa\times 13.39$

$ReC=13.05+AnReRa\times (1.10)\times (12.15)$

$ReC=13.05+AnReRa\times (1/0.907)\times ([9.0+8.82\times 0.3+0.50])$

$ReC=FxCRe+AnReRa\times (1/ReSu)\times ([Pr2+FIRe\times Pr3+HCRe])$

$ReC=FxCRe+AnReRa\times EnRa\times ([Pr2+FIRe\times Pr3+HCRe])$

$ReC=FxCRe+AnReRa\times EnRa\times Pr2+AnReRa\times EnRa\times FIRe\times Pr3+AnReRa\times EnRa\times HCRe$

$ReC=FxCRe+AcCRe+FdCRe+HAnCRe$

Doe costs (DoC)

$DoC=69.44+11.33\times AnReRa+14.64\times PgR$

$DoC=42.46+8.69+AnReRa\times 11.33+3.63\times PgR+21.21\times PgR+8.08\times PgR+18.29\times (1-PgR)$

$DoC=42.46+8.69\times 1+AnReRa\times 11.33+7\times 8.69\times PgR\times 0.199\times 0.3+24\times 8.69\times PgR\times 0.339\times 0.3+$
$+11\times 8.69\times PgR\times 0.282\times 0.3+365\times (1-PgR)\times 0.167\times 0.3$

$DoC=FxCDo+NCi\times Pr4+AnReRa\times HCDo+PgD\times NCi\times PgR\times DFIPg\times Pr3+OD\times NCi\times PgR\times DFIO\times Pr3+$
$+LaD\times NCi\times PgR\times DFILa\times Pr3+EmD\times DFIPg\times Pr3$

$DoC=FxCDo+AIC+HAnCDo+PgD\times NPt\times DFIPg\times Pr3+OD\times NPt\times DFIO\times Pr3+$
$+LaD\times NPt\times DFILa\times Pr3+EmD\times DFIPg\times Pr3$

$DoC=FxCDo+AIC+HAnCDo+FdCPg+FdCO+FdCLa+FdCEm$

$DoC=FxCDo+AIC+HAnCDo+FdCDo$

Lactation costs of offspring (LaCOf)

$LaCOf=0.52\times PgR\times NBA+0.52\times PgR\times NBA\times LaSu$

$LaCOf=1.04\times PgR\times NBA\times (0.5+0.5\times LaSu)$

$LaCOf=8.69\times PgR\times NBA\times (0.5+0.5\times LaSu)\times 0.022\times ([0.93-0.31]/0.035)\times 0.30$

$LaCOf=NCi\times PgR\times NBA\times (0.5+0.5\times LaSu)\times DFI_{17\text{-}35}\times ([WeW-W_{17}]/DGLa)\times Pr3$

$LaCOf=NPt\times NBA\times ([1+LaSu]/2)\times DFI_{17\text{-}35}\times ND_{17\text{-}35}\times Pr3$

$LaCOf=NPt\times ToNB\times PnSu\times ([1+LaSu]/2)\times DFI_{17\text{-}35}\times ND_{17\text{-}35}\times Pr3$

Fattening costs (FtC):

$FtC=22.62+(1.62\times PgR\times NBA\times LaSu\times (DFIFt/DGFt)+1.62\times PgR\times NBA\times LaSu\times FtSu\times (DFIFt/DGFt))$

$FtC=22.62+(2.55\times PgR\times NBA\times LaSu\times (0.5+0.5\times FtSu)\times (DFIFt\times (1.27)/DGFt))$

FtC=22.62+(8.69×PgR×NBA×LaSu×(0.5+0.5×FtSu)×(DFIFt×(2.2−0.93)/DGFt)×0.29)

FtC=FxCFt+(NCi×PgR×NBA×LaSu×(0.5+0.5×FtSu)×(DFIFt×(SIW−WeW)/DGFt)×Pr5)

FtC=FxCFt+(NCi×PgR×ToNB×PnSu×LaSu×([1+ FtSu]/2)×DFIFt×FtD×Pr5)

FtC=FxCFt+(NPt×ToNB×PnSu×LaSu×([1+FtSu]/2)×DFIFt×FtD×Pr5)

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