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EXPERIMENTAL BALANCE TO ESTIMATE EFFICIENCY IN THE USE OF NITROGEN IN RABBIT BREEDING

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Absctract: Defining the composition and properties of manure in livestock production is critical in order to minimise possible environmental impacts stemming from its management. In this study, a nitrogen balance was carried out during two identical fattening periods (Experiments 1 and 2) in growing rabbits from weaning (age 28 d and live weight about 0.6 kg) to slaughter (age 61 d and live weight about 1.8 kg). The breeding conditions were typical for Spanish rabbit production. The objectives were to quantify the total nitrogen excreted by the animals and to estimate the average efficiency in the use of this nutrient, in comparison to other species. Animal weight, feed intake, and the production of faeces and urine were monitored weekly in a set of eight cages with nine rabbits in each, performing weekly analyses for nitrogen content in feed, urine and faeces. The overall nitrogen excretion was 50.2 g N per animal in Experiment 1 and 46.9 g N per animal in Experiment 2, which corresponded to about 58% of the total nitrogen intake. Urine and faeces contributed to overall nitrogen excretion in approximately the same proportions. The nitrogen excretion ratio was 40 grams per kilogram of animal produced. According to this ratio, rabbit breeding is less efficient in the use of nitrogen than raising broilers, but more than fattening pigs.

Key words: fattening rabbits, nitrogen, excretion, balance, manure.

INTRODUCTION

Nitrogen (N) is a key nutrient in both natural and agricultural ecosystems, since it is related to many biological processes, especially those associated with plant and microbial metabolism (Schulten and Schnitzer, 1997). Intensive animal production has become a central issue in the anthropogenic modifications of the N cycle because of the increase in manure production: the animals use only a part of the nitrogen in the protein they consume, and therefore a major part is lost as faeces and urine (Van der Hoek, 1998). The most appropriate manure management system is to use it as a fertiliser to recycle the nutrients, but this is not always possible depending on land availability and acceptance of manure by farmers.

What is more, livestock production is regarded in the European Union as a polluting activity because of the possible impacts on water (e.g. nitrate pollution), soils (e.g. eutrophication, accumulation of salts and heavy metals) and air resources (e.g. pollutant gases, aerosol formation, odours), and it is therefore subject to several regulations (for example N-Directive 91/676/CEE and Ceilings Directive 81/2001/EC).

Considering all these possible impacts, it seems necessary to quantify and characterize manure production in relation to two main aspects. On one hand, a reliable estimation of nitrogen excretion is essential to use

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manure more efficiently, and to avoid environmental impacts. On the other hand, nitrogen excretion is a crucial input to estimate ammonia and nitrous oxide emissions in relation to the national gas emission inventories (EMEP-CORINAIR, 2003; IPCC, 2006).

A difference should be made between excreted nitrogen and the nitrogen in manure: as much as one half of the total ammoniacal nitrogen can be volatilised within a few days (Misselbrook *et al*., 2005), and this has two main consequences. Firstly, ammonia is emitted, which can affect animal and human health (Roney *et al*., 2004) and contributes to eutrophication and acidification processes (Krupa, 2003); and secondly, there is a loss in the fertilizing value of the manure (Burton and Turner, 2003), which should be considered when planning the fertilization programme.

The objective of the study presented in this paper was to quantify the excretion of nitrogen in rabbits throughout the whole fattening period, and to evaluate the efficiency in the use of nitrogen by animals under standard management.

MATERIALS AND METHODS

General approach

A mass balance was proposed to evaluate the components of the nitrogen balance in the production of fattening rabbits. The balance is based on the principle that the nitrogen intake by animals is partly accumulated in animal tissues, but is also partly lost as faeces and urine. The balance can be formally expressed as follows:

$$M_{N\ feed} = M_{N\ tissue} + M_{N\ urine} + M_{N\ faeces} \quad (1)$$

Where $M_{N\ feed}$, $M_{N\ tissue}$, $M_{N\ urine}$ and $M_{N\ faeces}$ correspond to the nitrogen mass ingested by an animal, accumulated in the animal tissues, and excreted in the urine and faeces, respectively. This balance was evaluated weekly in the production of fattening rabbits using measured and bibliographic data as follows.

Two experiments (Experiment 1 and Experiment 2) were carried out on the farms corresponding to the Universidad Politécnica de Valencia (Spain). Experiment 2 was a repetition of Experiment 1, in order to confirm the results obtained there. The nitrogen balance was studied at animal level in eight cages with nine animals in each. The animals corresponded to the UPV line V, selected to improve litter size at weaning (Khalil and Baselga, 2002; Baselga, 2004). The balance was performed weekly during a complete fattening cycle, from weaning (28 d of age) to slaughter (61 d), using *ad libitum* conventional feeding for rabbits. No distinction between males and females was made. Both experiments were carried out at the beginning of summer, in 2005 (Experiment 1) and 2006 (Experiment 2).

Components of the balance

The nitrogen balance was evaluated measuring the total weight corresponding to feed consumption, animal growth and the production of faeces and urine. On the other hand, the nitrogen content of each component was taken into account, and thus the Equation (1) was in practice evaluated as follows:

$$M_{feed} \times N_{feed} = M_{tissue} \times N_{tissue} + M_{urine} \times N_{urine} + M_{faeces} \times N_{faeces} + Rest \quad (2)$$

Where M is the fresh mass of each component of the balance expressed in kilograms, and N is the respective nitrogen content expressed in grams per kilogram (on a fresh basis); the term Rest is the error as regards inaccuracies in determining the balance. These components were determined as follows.

Feed consumption and animal growth were controlled weekly in each cage, whereas the production of urine and faeces were measured every two days for practical reasons. Urine and faeces were collected

Figure 1: Schema and photo of the urine and faeces collecting device.

separately using a 4 mm mesh for faeces and a lower polyethylene layer collecting the urine into a 8 L bottle (see Figure 1). The device was easy to assemble and dismantle, but labour-demanding, since frequent weighing of faeces and urine was required.

The sampling protocol to determine the nitrogen content in feedstuff, urine and faeces was as follows: every week two samples of urine and two samples of faeces were taken for each cage and the nitrogen content was determined in duplicate using the Kjeldahl method. A single sample of feedstuff was also analysed weekly. Dry matter and ash content were also determined for all samples. The nitrogen content in animal tissues was estimated according to the recommendations made by Maertens *et al*. (2005). They found that the nitrogen content in the body of the animal corrected by the nitrogen gut content was 29 g N/kg live weight for a fattening rabbit with a standard weight of 2.5 kg. According to these authors, for lower animal weights, a correction of 0.08 g N per 100 g of live weight should be applied, since nitrogen content is lower in younger animals.

The nitrogen balance was expressed in terms of animal produced and kilogram increase in body weight. The nitrogen corresponding to dead animals was initially considered as nitrogen accumulated in the tissues because this nitrogen has been metabolised, but at the end of the balance this component was distinguished in order to account for this nitrogen loss.

Environmental conditions

Temperature and relative humidity were continuously recorded both indoors and outdoors, using a data logger (HOBO H8-004-002) and a weather station (HOBO Weather Station), respectively. The ventilation flow on the farm was also monitored, using two HOBO ON/OFF data loggers to monitor the operation time of the two exhaust fans installed in the target building.

Statistical analysis

The nitrogen balance was calculated using weekly average values for each cage. An analysis of variance was carried out to find out whether any significant differences between cages existed, in relation to the parameters involved in the nitrogen balance.

$$M_i = \mu + Cage_i + \varepsilon_i \quad (3)$$

$$N_i = \mu + Cage_i + \varepsilon_i \quad (4)$$

Where M_i is the measured mass of each component of the balance (g/week), and N_i is the nitrogen content expressed in g/kg. The model was tested using the GLM procedure of SAS (2002). This analysis was conducted to detect possible differences between cages, which would invalidate the use of a global average.

RESULTS AND DISCUSSION

The weights of the balance components, expressed per animal produced, are presented in Table 1. In experiment 1, initial and final average animal weights were 0.569±0.014 and 1.816±0.027 kg, respectively, whereas in experiment 2 they were 0.663±0.015 and 1.806±0.028 kg. These weights were normal for Line V rabbits (Khalil and Baselga, 2002), but slightly lower than the usual ones on Spanish commercial farms (approximately from 0.8 to 2.2 kg). The temperature inside the farm ranged from 20 and 28ºC, varying according to external temperature, which was normal for this part of the year (18-30ºC). The ventilation system worked properly during the two experiments.

An increase in the feed conversion ratio (FCR) is observed when the animals are older, and was on average 2.70 and 2.83 for experiments 1 and 2, respectively. The production of faeces was 2.11 and 2.26 kg per kg of animal produced. The production of urine, however, showed higher variability because water spillage by animals was collected together with urine. No differences between cages were observed in the nitrogen content and in the total mass of the components of the balance.

The animals consumed less feed during week 5 than in week 4 because the period corresponding to week 5 included only five days (from 29 to 33 d of the fattening cycle).

The nitrogen content of the components of the balance is shown in Table 2. The nitrogen content in both faeces and urine tended to decrease with animal age, and was found to be highly dependent on water spillage by the animals.

By combining Tables 1 and 2, a weekly estimation of the nitrogen balance was obtained. Figure 2 represents the accumulated components of the nitrogen balance in the two experiments. In both cases, the proportion of the nitrogen in the tissues was higher in the first weeks of the fattening period, which is in accordance with the lower FCR during these weeks. At the end of the cycle, however, only about one third of the nitrogen is present in the animal tissues.

The term Rest corresponds to the nitrogen mass that is not taken into account with the components of the balance considered. It can be seen that this term is larger during the first experiment, and this was attributed to a particular malfunction in the urine collecting system. These problems were solved in the

Table 1: Weekly fresh mass of the components involved in the nitrogen balance expressed as g/animal (average±SE), including feed consumption, increase in body weight, the production of urine and faeces (all as g/period), and the feed conversion ratio (FCR).

	Experiment 1					Experiment 2				
Week	Feed	Body	Faeces	Urine	FCR	Feed	Body	Faeces	Urine	FCR
1	441±18	255±12	260±12	397±27	1.73	362±11	236±6	191±6	540±59	1.55
2	643±18	302±14	461±27	697±55	2.13	633±12	244±13	421±18	1,041±134	2.55
3	740±32	273±20	572±40	904±68	2.71	724±25	249±9	556±30	1,505±212	2.92
4	843±22	275±19	697±44	1032±123	3.07	797±25	226±35	723±26	1,809±284	4.11
5	713±24	146±7.5	657±40	1425±218	4.89	611±26	193±11	617±22	1,873±272	3.39
Total	3,380±87	1,250±33	2,647±141	4,456±430	2.70	3,131±82	1,148±27	2,506±78	6,778±918	2.83

Table 2: Nitrogen content of the components of the N-balance (average±SE), expressed in grams per kilogram of fresh matter.

	Experiment 1				Experiment 2			
Week	Feed	Body*	Faeces	Urine	Feed	Body*	Faeces	Urine
1	26.1±0.3	27.7	9.5±0.2	5.7 ±0.2	25.7±0.2	27.7	9.2±0.3	4.7±0.7
2	26.1±0.3	27.9	7.8±0.2	3.9 ±0.4	25.7±0.2	27.9	10.0±0.5	4.1±0.4
3	26.1±0.3	28.1	8.1±0.2	3.8±0.1	25.7±0.2	28.1	8.0±0.2	3.2±0.4
4	26.1±0.3	28.3	8.3±0.3	2.9±0.1	25.7±0.2	28.3	8.0±0.4	2.5±0.3
5	26.1±0.3	28.5	8.4±0.4	2.8±0.1	25.8±0.2	28.5	8.5±0.3	2.3±0.1

*Nitrogen content in tissues was estimated according to Maertens *et al.* (2005).

design of the Experiment 2, and as a result the term Rest was reduced considerably. Another possible cause of this imbalance was the nitrogen loss from the urine and faeces collected, caused by the volatilisation of ammonia. This volatilisation can be easily minimised by adding an acid to the bottle collecting the urine, as usual in digestibility experiments, since urease activity is considerable within few hours (Udert *et al.*, 2003).

The components of the overall nitrogen balance during the entire fattening cycle are shown in Table 3. In this table, the mass corresponding to dead animals (8 animals in each experiment) has been distinguished from the slaughtered animals (tissues).

Overall transformation of nitrogen intake to tissues was 43.1% and 41.8% in Experiments 1 and 2, respectively. Approximately 7.7% of the nitrogen converted to tissues was also lost as dead animals which did not reach slaughtering age. The efficiency in the use of the nitrogen is still lower than the 59% found by Guiziou and Béline (2005) for broiler production, but it is similar to pig production (Dourmad *et al.*, 1999; Xiccato *et al.*, 2005), and higher than the nitrogen efficiency in mink production (Pedersen and Sandbol, 2002).

The proportion of nitrogen excreted by faeces (24.9% and 26.6%) is closely related by definition to the apparent digestibility of the crude protein (75.1% and 73.4%, respectively) during the whole fattening period. Pascual *et al.* (2007) found a similar crude protein digestibility (75.0 %) for rabbits of the same line and age. However, the proportion of nitrogen in the faeces in the present study varied with animal age (see Figure 2), which is in accordance with the results obtained by Fernandez *et al.* (1994) who reported a digestibility of the crude protein of 85.6% in recently weaned rabbits (21 d of age), which decreased to 76.1% in rabbits of 8 weeks of age. Gutierrez *et al.* (2003) reported a crude protein digestibility between 77% and 78% using different protein sources, in rabbits between 32 and 36 d of age.

The term Rest was particularly high during Experiment 1, partly due to losses in the urine collection system which were reduced in Experiment 2. It can therefore be considered that the amount urine nitrogen

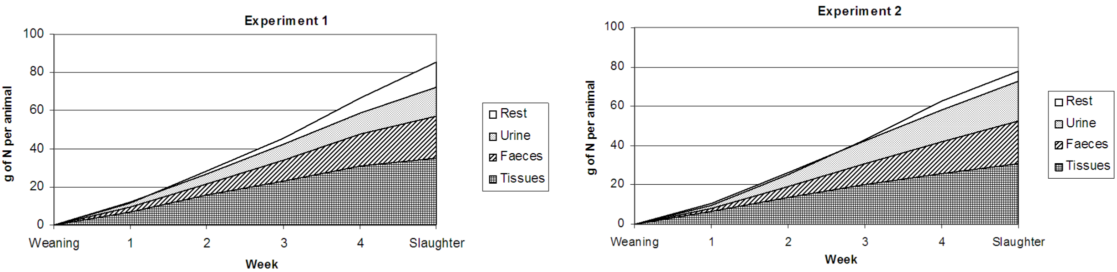

Figure 2: Accumulated nitrogen balance in fattening rabbits from weaning to slaughter.

Table 3: Overall nitrogen balance in the production of fattening rabbits, expressed per animal produced.

Experiment		Feed	Body	Dead	Faeces	Urine	Rest
1	N (g)	88.22	35.10	2.95	22.00	15.40	12.76
	% of feed	100	39.8	3.3	24.9	17.5	14.5
2	N (g)	80.50	31.05	2.56	21.44	20.48	4.98
	% of feed	100	38.6	3.2	26.6	25.4	6.2

was similar to the nitrogen in the faeces (25 and 27%, respectively). Nitrogen is present in the urine mainly as urea (Bristow *et al*., 1992), whereas faeces contains organic nitrogen compounds (Kirchmann and Witter, 1992), and this is of fundamental importance in the ammonia emission dynamics, since urea nitrogen is readily available to form ammonia (Beline *et al*., 1998). The proportion and type of nitrogen also determine the design of manure treatment systems, particularly the composting (Hao *et al*., 2004).

The total nitrogen excreted, expressed per place and year, depends on the number of cycles within a year. If we assume that the Rest corresponds to losses in the determination of faeces and urine, then the nitrogen excretion includes these three terms. Values of nitrogen excretion expressed per animal produced and per place and year are shown in Table 4. This table also shows the nitrogen excreted per kilogram increase in body weight and the excretion per place and year, considering 9 batches per year.

The nitrogen excretion obtained in this study is representative for rabbits produced in Spain, but it is lower than the result obtained by Maertens *et al*. (2005) for fattening rabbits from 0.8 to 2.5 kg of live weight, based on the input-output balance (94 grams of nitrogen per rabbit produced, and 658 grams of nitrogen per fattening place and year). In Spain, the market demands lower animal weights at slaughter (2 to 2.2 kg), and this difference in the final weight explains the discrepancy in nitrogen excretion, since the production of heavier animals involves a higher nitrogen excretion.

The relative nitrogen excretions obtained in this study (40.1 and 42.4 grams of nitrogen per kilogram produced) were similar to the 38 grams reported by Maertens *et al*. (2005) for fattening rabbits, but they show a lower efficiency in the utilization of this nutrient comparing to poultry production. In broiler production the nitrogen excretion is 22 grams of nitrogen per kilogram produced (Guiziou and Béline, 2005). However, in pig production the nitrogen excretion is higher, between 49 and 53 grams of nitrogen per kilogram produced (Dourmad *et al*., 1999).

CONCLUSIONS

The main conclusions of this study are related to the characterisation of the nitrogen cycle for fattening rabbits in Spain:

(1) The average nitrogen efficiency in the production of the fattening rabbits studied here is over 40% of the ingested nitrogen. This efficiency drops sharply with animal age.

(2) The losses of nitrogen in urine and faeces were similar, and accounted for more than 25% of the nitrogen intake each.

Table 4: Nitrogen excretion expressed per animal produced and per animal place and year, considering 9 batches per year.

	g N/animal	g N/kg produced	g N/place and year
Experiment 1	50.2	40.1	451
Experiment 2	46.9	42.4	422

(3) The nitrogen excretion was approximately 40 grams of nitrogen per kilogram of rabbit produced. The annual excretion of nitrogen depends on the number of fattening cycles per year.

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REFERENCES

Beline F., Martinez J., Marol C., Guiraud G. 1998. Nitrogen transformations during anaerobically stored N-15-labelled pig slurry. *Bioresour. Technol., 64: 83-88.*

Bristow A. W., Whitehead D. C., Cockburn J. E. 1992. Nitrogenous constituents in the urine of cattle, sheep and goats. *J. Sci. Food Agric., 59: 387-394.*

Baselga M. 2004. Genetic improvement of meat rabbits. Programmes and diffusion. *In Proc.: 8th World Rabbit Congress, 7-10 September, 2004. Puebla, Mexico, 1-13.*

Burton, C. H., Turner C. 2003. Manure Management: Treatment strategies for sustainable agriculture. *2nd Edition. Lister & Durling Printers. Silsoe, Bedford, UK.*

Dourmad J. Y., Seve B., Latimier P., Boisen S., Fernandez J., Peet-Schwering C., Jongbloed A. W. 1999. Nitrogen consumption, utilisation and losses in pig production in France, The Netherlands and Denmark. *Livest. Prod. Sci., 58: 261-264.*

EMEP-CORINAIR. 2003. Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook. *Third Edition. European Environment Agency. Copenhagen, Denmark.*

Fernandez C., Cobos A., Fraga M. J. 1994. The Effect of Fat Inclusion on Diet Digestibility in Growing Rabbits. *J. Anim. Sci.: 72, 1508-1515.*

Guiziou F., Béline, F. 2005. In situ measurement of ammonia and greenhouse gas emissions from broiler houses in France. *Bioresour. Technol., 96: 203-207.*

Gutierrez I., Espinosa A., Garcia J., Carabano R., de Blas C. 2003. Effect of protein source on digestion and growth performance of early-weaned rabbits. *Anim. Res., 52: 461-471.*

Hao X. Y., Chang C., Larney F. J. 2004. Carbon, nitrogen balances and greenhouse gas emission during cattle feedlot manure composting. *J. Environ. Qual., 33: 37-44.*

IPCC. 2006. Emissions from Livestock and Manure Management. *In: 2006 IPPC Guidelines for National Greenhouse gas Inventories. Volume 4: Agriculture, Forestry and other Land Use. Hayama, Japan.*

Khalil M.H., Baselga M. 2002. Rabbit genetic resources in Mediterranean countries. *CIHEAM Serie B: Etudes et recherches No. 38. Zaragoza, Spain.*

Kirchmann H., Witter D. 1992. Composition of fresh, aerobic and anaerobic farm animal dungs. *Bioresour. Technol., 40: 137-142.*

Krupa S. V. 2003. Effects of atmospheric ammonia (NH3) on terrestrial vegetation: a review. *Environ. Pollut., 124: 179-221.*

Maertens L., Cavani C., Petracci M. 2005. Nitrogen and phosphorus excretion on commercial rabbit farms: Calculations based on the input-output balance. *World Rabbit Sci., 13: 3-16.*

Misselbrook T. H., Nicholson F. A., Chambers B. J. 2005. Predicting ammonia losses following the application of livestock manure to land. *Bioresour. Technol., 96: 159-168.*

Pascual J.J., Borgoñon P., Ródenas L., Martínez E., Moya V.J., Blas E., Cervera C. 2007. Potential use of Ceratitis Capitata exhausted diets in growing rabbit diets. *World Rabbit Sci., 15: 189-198.*

Pedersen S., Sandbol P. 2002. Ammonia emission and nitrogen balances in mink houses. *Biosyst. Eng., 82: 469-477.*

Roney N., Llados F., Little S. S., Knaebel D. B. 2004. Toxicological Profile of Ammonia. *U.S. Department of Health and Human Services. Agency for Toxic Substances and Toxic Registry. Atlanta, U.S.A.*

SAS. 2002. SAS User's Guide: Statistics (Release 8.2) SAS® Institute Inc. Cary NC, USA.

Schulten H. R., Schnitzer M. 1997. The chemistry of soil organic nitrogen: a review. *Biol. Fert. Soils, 26, 1-15.*

Udert K.M., Larsen T.A., Biebow M., Gujer W. 2003. Urea hydrolysis and precipitation dynamics in a urine-collecting system. *Water Res., 37: 2571-2582.*

Van der Hoek K. W. 1998. Nitrogen efficiency in global animal production. *Environ. Pollut., 102: 127-132.*

Xiccato G., Schiavon S., Gallo L., Bailoni L., Bittante G. 2005. Nitrogen excretion in dairy cow, beef and veal cattle, pig, and rabbit farms in Northern Italy. Ital. *J. Anim. Sci., 4: 103-111.*