MAIN PAPER

Nitrogen excretion in dairy cow, beef and veal cattle, pig, and rabbit farms in Northern Italy

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ABSTRACT

Reference values for N excretion of different livestock production systems are required for the application of the Nitrate Directive (91/676/EC). A survey aimed to estimate N excretion from on-farm measurements of feed consumption and performance of dairy cows (104 herds, 9,984 cows), growing cattle (40 farms, 40,157 young bulls), veal calves (34 farms, 49,206 calves), growing pigs (39 farms, 161,278 pigs) and rabbits (54 farms, 65,664 reproducing does) was conducted in Veneto from 2002 to 2003. N excretion was computed as the difference between N consumption and N retained in animal products. Dairy cow yielded 8,366 ± 1,646 kg/year of milk, consumed 6,600 ± 928 kg/year of DM, containing 2.45 ± 0.2 % DM of N, and excreted 116 ± 25 kg of N/year. No significant correlation was found between milk yield and N excretion, but the correlation between dietary N concentration and N excretion was significant (r=0.66). For growing cattle, the following mean values were achieved: daily gain 1.25 ± 0.19 kg/d; feed conversion ratio 6.9 ± 0.9 kg of DM/kg, rounds/year 1.66 ± 0.38. Nitrogen consumed, retained and excreted were, respectively, 68.7 ± 5.4, 11.4 ± 1.9 and 57.3 ± 4.9 kg/place/year. For veal calves, N consumed was 24.1 ± 1.9 kg/place/year, 12.1 ± 0.8 kg of which were retained in the body and 12.0 ± 1.5 kg were excreted. For heavy pig production, N consumed, per place and per year, averaged 19.0 ± 1.9 kg, N retained was 5.2 ± 0.5 kg and N excreted was 13.8 ± 0.4 kg. In the close-cycle rabbit farms, the doe and the relative growing rabbits (43 sold per year) consumed 11.2 ± 2.2 kg, retained 3.8 ± 0.7 kg and excreted 7.4 ± 1.5 kg N/doe/year. Nitrogen excretion estimated in this work can be considered as representative of some of the main animal production systems of the North-East of Italy. These values should not be considered as fixed, otherwise the implementation of the various strategies to reduce N excretion would not be possible. They should be considered as guidelines in the assistance both to public institutions and private enterprises in the evaluation of N excretion at farm level, favouring a more accurate quantification of the excretions, an increase of N retention efficiency and a better knowledge of the requirements of agricultural land. Moreover, a major extension of the agricultural land to be fertilised with manure should be promoted.

Key words: Nitrogen excretion, Dairy cattle, Beef cattle, Pigs, Rabbits.

RIASSUNTO

ESCREZIONE DELL'AZOTO NEGLI ALLEVAMENTI DI VACCHE DA LATTE, BOVINI DA CARNE E VITELLI A CARNE BIANCA, SUINI E CONIGLI DEL NORD ITALIA

L'applicazione della Direttiva Nitrati (91/676/EC) richiede la definizione di valori di riferimento di escrezione di N dei diversi sistemi di produzione zootecnica. Tra il 2002 e 2003 fu condotta un'indagine nella Regione Veneto per stimare l'escrezione azotata di vacche da latte (104 aziende, 9984 vacche), vitelloni (40 aziende, 40.157 capi), vitelli a carne bianca (34 aziende, 49.206 vitelli), suini (39 aziende, 161.278 capi) e conigli (54 aziende, 65.664 coniglie fattrici).

L'escrezione di N fu calcolata su base aziendale come differenza tra N consumato e N ritenuto nei prodotti animali. Le vacche evidenziarono in media una produzione di 8366 ± 1646 kg/anno di latte, un consumo di 6600 ± 928 kg/anno di s.s. di alimenti contenenti in media 2,45 ± 0,2% s.s. di N, e un'escrezione di 116 ± 25 kg N/anno. La correlazione tra produzione di latte aziendale e escrezione azotata non risultò significativa, mentre quella tra concentrazione di N della dieta ed escrezione di N fu significativa (r=0,66). Per i bovini da carne si osservarono i seguenti dati produttivi medi: accrescimento 1,25 ± 0,19 kg/d; indice di conversione 6,9 ± 0,9 kg s.s./kg, cicli/anno 1,66 ± 0,38. L'azoto consumato, ritenuto ed escreto risultò rispettivamente pari a 68,7 ± 5,4, 11,4 ± 1,9 e 57,3 ± 4,9 kg/posto/anno. Per i vitelli a carne bianca si misurarono un consumo di 24,1 ± 1,9 kg, una ritenzione corporea di 12,1 ± 0,8 kg e un'escrezione di 12,0 ± 1,5 kg N/posto/anno. Per la produzione di suino pesante, l'N consumato, ritenuto ed escreto fu in media 19,0 ± 1,9 kg, 5,2 ± 0,5 kg e 13,8 ± 0,4 kg/posto/anno. Negli allevamenti a ciclo chiuso di conigli, la fattrice con i relativi conigli prodotti (43 venduti/anno) evidenziò un consumo di 11,2 ± 2,2 kg, una ritenzione di 3,8 ± 0,7 kg e un'escrezione di 7,4 ± 1,5 kg N/anno. L'escrezione azotata stimata in questo lavoro può essere considerata rappresentativa di alcuni dei principali sistemi produttivi zootecnici del Nord-Est italiano. Questi valori non devono essere considerati fissi, altrimenti l'applicazione di possibili strategie finalizzate alla riduzione dell'escrezione azotata non sarebbe possibile. Questi dati possono tuttavia rappresentare valori di riferimento nell'attività di assistenza sia alle istituzioni pubbliche che alle imprese private nella valutazione dell'escrezione di N a livello aziendale, favorendo una più accurata quantificazione delle escrezioni, un aumento dell'efficienza di ritenzione azotata e una maggiore conoscenza dei fabbisogni di azoto dei terreni agricoli. Si dovrebbe inoltre favorire l'aumento dell'estensione dei terreni agricoli fertilizzabili con le deiezioni animali.

Parole chiave: *Escrezione azotata, Bovine da latte, Bovini da carne, Suini, Conigli.*

Introduction

An excessive application to soil of nitrogen (N) from chemical fertiliser and manure represents a threat for the quality of water, air and soil (Tamminga, 2003; Oenema, 2004). The European Directive 91/676/EC, aiming to prevent or reduce the nitrate pollution of surface and underground water, stated that each member state must identify the vulnerable areas where the load of N of livestock origin cannot exceed 170 kg/ha/year. A reliable definition of standard values for N in manure from each species and category of livestock is required for the implementation of this directive. The European Commission proposed a methodology to assist public institutions and individual producers in the computation of N in manure, taking into account the main livestock species, categories, feeding systems and management (ERM/AB-DLO, 1999). According to this methodology, N excretion is quantified as the difference between N consumption and N retention in animal products; N in manure is then calculated assuming a percentage of N lost in atmosphere during waste removal and storage. If national or regional information for the computation of N in manure is lacking, reference values proposed by ERM/AB-DLO (1999) could be used as standard values in national regulations. However, ERM reference values have been defined mainly on the basis of North Europe data and it is well known that the N in manure largely differ among European countries according to the production and feeding systems (Børsting *et al.*, 2003; Rotz, 2004). Therefore, the definition of N excretion values proper to specific local conditions is a strategic issue from environmental, economical, and social points of view.

The Italian government supported the "Interregional project on N excretion from livestock", involving Veneto, Emilia Romagna, Lombardia and Piemonte, aimed to quantify N excretion and identify the source of variation for the main national husbandry systems. This paper summarizes the main results obtained in the Veneto Region from a large survey on 271 dairy and beef cattle, pig and rabbit farms.

Material and methods

Farm data collection

Dairy cows. Data were collected in 104 dairy farms selected from the official national breeders database, representative of different breeds (60% Holstein Friesian, 20% Brown Swiss, 11% Italian Simmenthal, 9% Rendena), herd size (96 ± 63 cows/herd) and milk yield (8366 ± 1636 kg/cow/year). Dairy herds were visited by the same operator who collected feeding information according to an analytic feeding card. Data on milk yield were achieved from the official national database (AIA, 2004).

Beef cattle. Data on growth, feed consumption and diet composition were collected on 40 intensive beef cattle herds and concerned 585 production cycles involving 40,157 beef bulls of Charolaise (50%), Limousine (34%) and Polish Friesian (5%) breeds and French crossbreds (11%).

Veal calves. Data from 34 intensive veal herds involving 49,206 calves of different breeds (mainly Polish and Italian Friesian and a lesser proportion of Simmenthal and crossbreds) were used in the present study. Information was collected by the same operator who visited the farms in collaboration with public institutions and private associations.

Growing pigs. A sample of 39 heavy pig farms was identified in collaboration with various producer associations, private industries and farmers to be representative of different farm sizes, feeding techniques and territorial distribution. Detailed information concerning the farm input-output movements of feeds and animals was collected from the period 1997 to 2003. Data concerned 141 production cycles involving 161,278 pigs.

Rabbits. A sample of 54 rabbit farms was selected, representative of the Veneto distribution and management systems. Ninety percent of the farms included both reproduction and fattening sectors (close cycle), 10% of the farms had either reproduction or fattening sector (open cycle). The close-cycle units counted on average more than 1200 reproducing does with a daily presence of about 7500 growing rabbits. The average number of rabbits sold per year was 55,000, ranging from 5000 to 234,000.

Chemical analyses and nitrogen balance

Samples of rations and compound feeds were collected in each farm to be analysed for dry matter (DM) and N concentrations (AOAC, 1990). Nitrogen balance was calculated according to ERM/AB-DLO (1999). An average N concentration of milk of 0.53% was obtained from the official national database of dairy farm control (AIA, 2004). Nitrogen concentration of live weight (LW) gain was assumed equal to 2.7% for young bulls (ERM/AB-DLO, 1999), to 3.0% for veal calves (NRC, 2001), to 2.4% for growing pigs (Bittante et al., 1990; Fernández et al., 1999) and to 3.1% for growing rabbits (Szendro et al., 1998). Nitrogen in manure was calculated assuming a 28% N lost in atmosphere during waste removal and storage for all species and categories, instead of using different values (10 to 40%) proposed by ERM/AB-DLO (1999) but not proven for the waste management systems in our country as stated by the Committee of the Interregional project on N excretion from livestock.

Results and discussion

Dairy cows

Productive performance of dairy cattle, N balance and a comparison with ERM/AB-DLO (1999)

Table 1. Productive performance and N balance of dairy cattle and ERM/AB-DLO (1999) default values.

		Present study		ERM/AB-DLO
		Mean	SD	(1999)
Cows/farm	n.	96	63	-
DM consumed/cow/year	kg	6600	928	5950
N concentration of rations	% DM	2.45	0.2	2.8
Milk yield/cow/year	kg	8366	1646	7000
N concentration of milk	%	0.53	0.02	0.53
N consumed/cow/year	kg	162.1	28.2	166
N retained/cow/year	"	46.1	8.4	39.0
N excreted/cow/year	"	116.0	24.5	128
Assumed N loss	%	28		10
N in manure/cow/year	kg	83.5		114

default values are given in Table 1. Average DM consumption was 6600 kg/cow/year, considering both the milking and the dry periods. Dietary N concentration averaged 2.45% DM, and the milk yield was 8366 kg/cow/year. The amounts of N consumed, retained in animal products (milk, gain of cow and fetus), excreted and remaining in the manure averaged 162.1, 46.1, 116.0 and 83.5 kg/cow/year, respectively. When compared with the values of ERM/AB-DLO (1999) and Poulsen and Kristensen (1998), our results indicated that the average cows consumed larger amounts of DM with a lower N concentration and produced higher amounts of milk. Despite the higher DM consumption, the mean N excretion per average cow was comparable to the value proposed by ERM/AB-DLO (1999). These excretion levels can be explained considering that the diets used in Veneto dairy herds, based mainly on corn silage, presented lower N concentrations with respect to the value given by ERM/AB-DLO (1999).

The mean presence of calves and heifers in the surveyed herds approached 0.9 heads/cow. The mean annual N excretion of young animals was close to 48 kg/head, corresponding to 33.7 kg of N in manure when volatilisation was taken into account.

A large variability among herds was observed for all investigated traits. No significant correlation between milk yield and N excretion was found (r = 0.32); this probably means that the dietary N concentration is established not only considering the theoretical nutrient requirements, but also taking into account the availability of home made feed ingredients, the market prices of feeds, the need of maintaining a low level of urea in blood and in milk. Conversely, a significant correlation (r = 0.66) was found between dietary N concentration and N excretion/cow/year, confirming that the reduction of the dietary protein is a main strategy for reducing N excretion from dairy farms (Børsting *et al.*, 2003).

Beef cattle

The initial and final LW averaged 340 and 600 kg, the daily weight gain was 1.25 kg/d, feed conversion ratio was slightly lower than 7.0 and the mean N concentration of rations was 2.31% DM (Table 2). Nitrogen consumption averaged 68.7 kg/place/year, N retention 11.4 kg/place/year and N excretion 57.3 kg/place/year. The value of N excretion was similar to that found by Smith and Frost

Table 2. Productive performance and N balance of beef cattle and ERM/AB-DLO (1999) default values.

		Present study		ERM/AB-DLO
		Mean	SD	(1999)
Place/farm	n.	412	399	
Initial LW	kg	342	62	
Final LW	"	608	78	
Average daily gain	kg/d	1.25	0.19	1.0
Rounds/year	n.	1.66	0.38	
DM feed conversion ratio	kg/kg	6.91	0.87	7.4
N concentration of rations	% DM	2.31	0.15	2.7
N concentration of LW gain	%	2.7		2.7
N consumed/place/year	kg	68.7	5.4	70
N retained/place/year	"	11.4	1.9	7
N excreted/place/year	"	57.3	4.9	63
Assumed N loss	%	28		10
N in manure/place/year	kg	41.3		

(2000) for large-size growing cattle of 1 to 2 years of age. The standard deviation of N excretion, close to 9%, was comparable with that reported by Poulsen and Kristensen (1998) and Smith and Frost (2000). A more detailed analysis, not reported here, evidenced significant differences due to the breed (Gallo *et al.*, 2004). Nitrogen excretion found in this research was about 10% lower than the value of 63 kg/place/year proposed by the ERM/AB-DLO (1999). Also in this case, this result can be ascribed to the lower N concentration of the rations with respect to the value of 2.8% DM indicated by ERM/AB-DLO (1999). This low dietary protein concentration can be explained by the widespread application of the total mixed ration technique, the frequent changes of dietary composition according to age (the number of rations in the growing period was 3.6), as well as the high proportion in the rations of corn silage, sugar beet pulp, cereals and the limited amount of soybean meal and legumes hay.

Veal calves

Places per herd averaged 681 with 2.1 cycles/year. As reported in Table 3, initial and final LW averaged 61 and 253 kg, respectively, and average daily gain was 1.19 kg/d. Performances were comparable with those previously reported by others (Andrighetto *et al.*, 1996; Xiccato *et al.*, 2002). The mean N concentration of the diet, mainly based on milk replacers, was 3.36% DM. Nitrogen concentration of LW gain was assumed to be 3.0% on the basis of previous comparative slaughter experiments (Andreoli *et al.*, 1996). Nitrogen consumption amounted 24.1 kg/place/year and 12.1 kg were estimated to be retained in the body; therefore, average N excretion was 12 kg/place/year. Assuming a N loss of 28%, the resulting N in manure was 8.6 kg/place/year. No data of N balance is provided by ERM/AB-DLO (1999) or other literature for veal calves. The resulting N retention efficiency (50%) is explained by the low feed conversion ratio (1.73 kg DM/kg) and it is comparable with values found for other monogastric species at young ages.

Growing pigs

Pig sector in Italy is peculiar with respect to other European countries, since it is driven by the production of certified (DOP) cured ham. The heavy LW (160 kg or more) and the minimum age (9 months) at slaughter imposed by DOP regulation

Table 3. Productive performance and N balance of veal calves (no default values are given by ERM/AB-DLO, 1999).

		Present study		ERM/AB-DLO
		Mean	SD	(1999)
Place/farm	n.	681	540	
Initial LW	kg	61	6.1	
Final LW	"	253	13.9	
Average daily gain	kg/d	1.19	0.06	
Cycles/year	n.	2.1	0.1	
DM feed conversion ratio	kg/kg	1.73	0.10	
N concentration of ration	% DM	3.36	0.03	
N concentration of LW gain	%	3.0		
N consumed/place/year	kg	24.1	1.9	
N retained/place/year	"	12.1	0.8	
N excreted/place/year	"	12.0	1.5	
Assumed N loss	%	28		
N in manure/place/year	kg	8.6		

strongly affect feeding practices and diet characteristics. Although this production has a large economic relevance, few systematic data on production traits and N balance are available (Schiavon *et al.*, 1997).

The main production traits and N balance are given in Table 4 and compared with values proposed by ERM/AB-DLO (1999) for other pig production systems (light pigs). Even though relevant differences for all production variables were observed, N excreted per place and year was similar to the values proposed by other references (ERM/AB-DLO, 1999; Fernández *et al.*, 1999; Smith *et al.*, 2000) and close to 13.5 kg. Restricted feeding and low protein diets used in heavy pig production are aimed to maintain average LW gain around 0.640 kg/d during the whole growth period and to avoid the risk of pigs too young and lean at the target slaughter weight (Bosi and Russo, 2004). Some studies showed the feasibility of a further reduction of N excretion by decreasing the dietary protein level and optimizing the amino acid profile (Piva and Mordenti, 1995). Performance and N balance concerning sow herds with or without piglets in the Veneto conditions (Ceolin *et al.*, 2005; Tagliapietra *et al.*, 2005) were in agreement with ERM/AB-DLO (1999).

Rabbits

The main productive data and N balance are given in Table 5. In the close-cycle farms, the N balance is referred to the reproducing doe (4 kg LW) and its offspring (43 rabbits/year sold at 2.5-2.6 kg). The doe and the relative growing rabbits consumed 11.2 kg N/doe/year and retained 3.8 kg N/doe/year. The doe and its offspring excreted yearly 7.4 kg N, that is 20% lower than the value proposed by ERM/AB-DLO (1999) and very close to the results of Maertens *et al.* (2005). ERM/AB-DLO (1999) assumed a 40% N loss in atmosphere, against 28% of our study, therefore suggesting similar quantity of N in manure (5.5 kg N/doe/year for ERM/AB-DLO and 5.3 kg for our study). When N excretion was expressed on different productive units, excreted N was 0.172 kg/sold rabbit and 0.069 kg/kg sold rabbit. These values are somewhat lower than those proposed by ERM/AB-DLO (1999), i.e. 0.184 kg/sold rabbit or 0.088 kg/kg sold rabbit, but differences can be at least partly explained considering different assumptions for N loss during manure removal and storage.

In the reproduction open-cycle farms with rabbit does weaning 47 kits per year at 0.9 kg LW, excreted N was 2.5 kg/doe/year, that is 1.8 kg/doe/year in manure. In the fattening open-cycle farms, with weaned rabbits bought at 0.9 kg LW and sold at 2.5 kg and 7 fattening cycles/year, excreted N resulted 0.80 kg/fattening place/year, that is 0.58 kg/fattening place/year in manure. Nitrogen excretion referred to the reproducing does was influenced mainly by the rabbit LW at slaughter (2.4 to 2.9 kg in the surveyed farms) and by the number of sold rabbits (35 to 60 per doe/year). Differently, total N excreted by the farm was main-

Table 4. Productive performance and N balance of growing pigs and ERM/AB-DLO (1999) default values.

		Present study		ERM/AB-DLO
		Mean	SD	(1999)
Place/farm	n.	1289	1037	
Initial LW	kg	28.5	4.7	25
Final LW	"	163.4	5.3	105
Cycles/year	n.	1.60	0.17	3.0
Feed conversion ratio	kg/kg	3.64	0.26	2.9
N concentration of feeds	% DM	2.73	0.11	2.8
N concentration of LW gain	%	2.4	2.5	
N consumed/place/year	kg	19.0	1.87	19.5
N retained/place/year	"	5.19	0.46	6.0
N excreted/place/year	"	13.81	0.44	13.5
Assumed N loss	%	28		26
N in manure/place/year	kg	9.96		10.1

Table 5. Productive performance and N balance of rabbits (reproduction + fattening farms) and ERM/AB-DLO (1999) default values.

		Present study		ERM/AB-DLO (1999)
		Mean	SD	
Reproducing rabbits/farm	n.	1216	885	
Rabbits sold/year/farm	"	54,441	44,357	
Final LW	kg	2.65	0.11	2.10
Feed conversion ratio	kg/kg	3.82	0.19	4.00
Rabbits sold/doe/year	n.	42.8	8.7	50.0
LW rabbit sold/doe/year	kg	113.1	22.4	105.0
N concentration of feeds	% DM	2.88	0.11	2.94
N concentration of LW gain	%	3.1		3.0
Feed intake/doe/year	kg	431	81	420
N consumed/doe/year	"	11.17	2.16	12.3
N retained/doe/year	"	3.77	0.70	3.1
N excreted/doe/year	"	7.40	1.48	9.2
Assumed N loss	%	28		40
N in manure/doe/year	kg	5.33		5.5

ly influenced by the number of reproducing does, even if the estimation of farm N excretion was improved when the total weight of rabbits sold per year was included in the predicting equation. Nitrogen excretion values calculated in this study were notably higher than the values currently assumed by Italian national and regional legislation. An overall decrease of dietary N concentration and the application of feeding plans characterized by protein decreasing with age may permit a substantial reduction of N excretion without impairment of growth performance and meat quality (Maertens *et al.*, 1997; Trocino *et al.*, 2000).

Conclusions

Several strategies aimed to reduce the excretion of N and other nutrients from livestock have been proposed in the literature for different species (Piva and Mordenti, 1995; Maertens *et al.*, 1997; Satter *et al.*, 2002). All these strategies aim to increase the efficiency of retention of the dietary nutrients in animal products. The reader can found more details in the reviews of Tamminga (1996) and Maertens (1999).

The promotion of these strategies at practical level is strictly depending on the constraints settled by regulations. In our opinion, the adoption of reference coefficients for computing farm N excretion based exclusively on the number of heads would not promote the on-farm application of strategies aimed to reduce the excretion per head. This kind of approach simply acts to reduce the number of livestock unit/ha, with serious risks of a strong decrease in the number of livestock farms, particularly in the areas vulnerable to nitrate pollution.

The results of our study can contribute to a more precise estimation of nitrogen excretion of livestock as a function of productive management and feeding systems, and in particular:

1) the values of N excretion determined in the present study are representative of some livestock production systems currently applied in the Northern Italy and can be useful as reference val-

ues to setup regional or national regulations;

2) for some species, namely dairy cows, beef cattle and rabbits, the average values of N excreted are somewhat higher than the values currently assumed by local regulations. Therefore, in many areas there could be an excess of N from manure, while in other cases the exclusive use of chemical fertilizer results in a reduction of the organic matter content of the soil, with negative consequences on its structure, texture and fertility;

3) the adoption of farm protocols for recording feed consumption, feed composition and production performance would promote a better identification of the critical points of husbandry and a more accurate quantification of excretions as well as the need of agricultural land;

4) the methodological approach followed in this study and the set of values found for the different traits of production and N balance, both in terms of mean and variability, can be used as reference for the assistance in the evaluation and control of N excretion at farm level.

In conclusion, besides the increase of agricultural land involved in the use of manure, the application of feeding and management techniques capable of increasing N retention efficiency and reducing N excretion per animal product unit should be promoted. Moreover, a better definition of the chemical and physical characteristics of manure, as a result of feeding and housing systems and manure removal, treatment, storage, is also needed in order to promote the correct application of animal waste on agricultural land and to reduce the risks of environmental pollution.

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