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Sustainability of intensive beef production system in North-East Italy: relationships between phosphorus supply and productive performance

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ABSTRACT

The beef sector of the Veneto Region is based on young bulls imported mainly from France and reared intensively using total mixed rations based on maize silage and concentrates. While nitrogen excretion of the sector is regulated by Nitrate Directive, the excretion of phosphorus (P) is less studied, despite of its potentially great impact on environment. This study aims at analysing the relationships between productive and economic performances and P content of the diet in 14 farms of the region. For a whole productive year feed consumption, ingredients and chemical composition of diets were monthly collected. Average Daily Gain (ADG), Feed conversion ratio (FCR), daily gross profit (DGP), and P balance were calculated. ADG, FCR, and DGP were analysed with a mixed model using arrival season, arrival weight, class of dietary content of P, protein and starch as fixed effects and farm as random effect. Average daily gain was 1.39±0.08 kg/d, FCR was 0.14±0.01 kg/kg, and DGP 2.5±0.40 €/d . The P dietary content was on average high (0.38±0.04, % DM), which resulted in P intakes and excretions of 13.49±1.94 and 9.85±1.92 kg/head/place, respectivel y. None of the productive and economic traits was affected by phosphorus content of the diet. As a consequence, the phosphorus supplementation can be reduced without the risk of weakening productive and economic performances.
(Keywords: Beef cattle, intensive farms, environment, Charolais breed, P excretion)

INTRODUCTION

Livestock production has complex interactions with the natural environment, especially for nitrogen (N) and phosphorus (P) excreted by animals (*Gerber et al.*, 2013). In the recent years, the research has mainly focused on human-related nitrogen impacts on environment, whereas phosphorus impacts have been less studied (*Schipanski and Bennet*, 2012).

The beef sector of the Veneto Region (North-East Italy) represents an important contributor to the national beef production. It is based on young bulls imported mainly from France (especially Charolais breed), and intensively reared for 7-8 months using total mixed rations (TMR). The most important feeds used are maize silage and concentrates (*Xiccato et al.*, 2005). In the last years, the sector has met the European Union's thresholds about nitrogen application on agricultural fields imposed by the Nitrate Directive (n.676/92). However, although manure application is carried out to meet crops N requirements, and also to respect the EU nitrogen thresholds, P surpluses

in soils are observed, since the N/P ratio required by plants is higher than that in manure (*Kissinger et al.*, 2005).

Due to the affinity of phosphorus compounds with soil's elements (*James et al.*, 1996), and the practice to concentrate the application of manure nearby their production sites in intensive farming systems (*Defra*, 2004), these surpluses have led to soil P accumulation in various areas of Europe (*Hooda et al.*, 2001*; Ott and Rechberger*, 2012). The resulting reduction of soil capacity to adsorb phosphorus could cause an increase of leaching rates to groundwater bodies (*Pautler and Sims*, 2000), and also of phosphorus loss with runoff events, carrying to a greater eutrophication risk of surface water resources (*James et al.*, 1996).

Overfeeding of beef cattle with P is common in the practice, partly because is frequent the inclusion in the diet of feeds naturally high in P, partly because additional P supplementation may occur irrespective of the actual P content of the diets (*Vasconcelos et al.*, 2007). This study aimed to analyse the effects of phosphorus supply on animal productive performances in the North-East Italy intensive beef sector, in order to evaluate whether P excretion could be reduced without consequences on productive and economic performances.

MATERIAL AND METHODS

Data for this study originated from 14 specialized fattening herds located in the Veneto region and associated to AZoVe (Associazione Zootecnica Veneta, Ospedaletto Euganeo, Italy), a large cooperative of beef producers. The reference unit for data collection was the batch, defined as a group of stock calves homogeneous for genetic type, origin, finishing herd and fattening period. For each batch the following data were acquired: average BW at arrival and at sale (kg); fattening length (d); purchase and sell price per head (€/head). These data were used to compute the following traits: average daily gain (ADG, kg/d), calculated as (live weight at sale – live weight at arrival)/fattening length; feed conversion ratio (FRC, kg/kg), calculated as (live weight at sale – live weight at arrival)/total feed DM intake in fattening period; daily gross profit (DGP), calculated as value at sale - value at purchase, and expressed per day of fattening (€/d). Herds were visited monthly during the whole year, diet formulations and a sample for TMR were collected for each batch, and the weight of total mixed ration (TMR) uploaded into the manger for each batch was recorderd. Two subsequent intake observations were averaged to obtain the mean daily dry matter intake (DMI). Diets were chemically analysed for determination of dry matter (*AOAC method 934.01*, 2003), crude protein (*Kjeldahl, AOAC method 976.05*, 2003), ash (*AOAC method 942.05*, 2003), Neutral Detergent Fiber according to *Van Soest* (1991), starch (HPLC method; *Bouchard et al.*, 1988) and phosphorus content (*AOAC 999.10*, 2000 and ICP-OES).
Only batches with Charolais breed and more than four month samples were considered in the study. The final data set included 126 batches, 8545 animals and 105 diets.

Phosphorus balance
Phosphorus balance was calculated following the ERM method (2001). The model estimates P excreted as P intake – P retention. Each element refers to 1 head/batch/year. The single elements are obtained as follows:

P intake = Intake* (P diet/100) (kg), where Intake is the total feed intake for head/batch/year

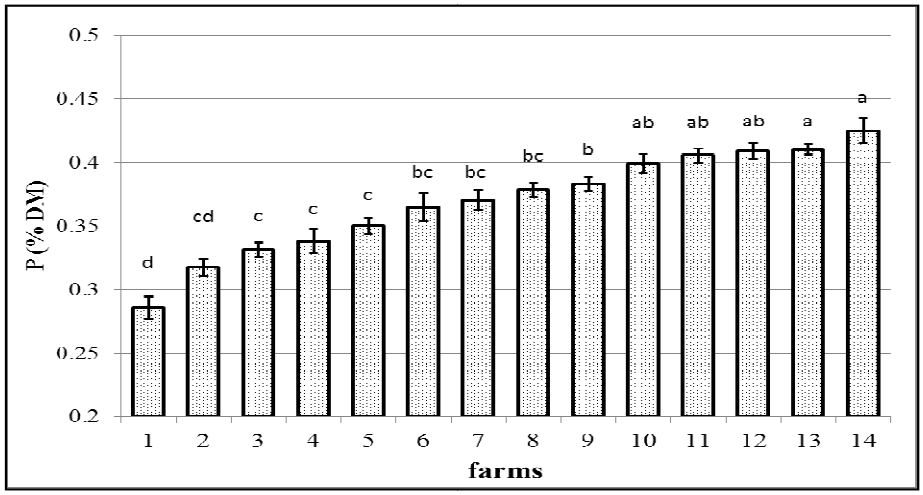
P retention = (LWf – LWi) * K_P (kg), where LWf and LWi are final and initial live weight respectively, and K_P is phosphorus retention per life weight unit coefficient, corresponding to 0.0075 kg/kg (*Whiters et al.*, 2001).

Statistical analysis

For statistical analysis, the database was edited as follows: the P content (% DM) of the diet was grouped in three classes (ClP) on the basis of 25th and 75th quartile; the same procedure was used for protein (ClPr) and starch (ClS) content. Season of arrival was classified as winter, spring, summer, autumn on the basis of arrival month of the batch; arrival weight was divided into three classes based on the mean±1SD. A preliminary analysis (GLM) showed a large variability among farms in P dietary content (Figure 1). The P content was correlated (r=0.41, P<0.001) with the proportion of feeds used to increase N dietary content (mix of oilseed by-products, corn distiller and maize gluten feed, and a commercial mineral-protein supplement), and the variability among farms can be explained with different feeding strategies and management practices. For this reason, we decided to use the farm as random effect in the final statistical model.

Figure 1

LSmeans for P content of diet (% DM) for farms



Average daily gain (ADG), feed conversion ratio (FCR), and daily gross profit (DGP) were analysed with mixed linear models (SAS, 1991), with arrival season, arrival weight class, protein class (ClPr), starch class (ClS), and P class (ClP) as fixed effect and farm as random effect.

RESULTS AND DISCUSSION

Mean initial and final body weight were 390 and 714 kg, respectively (*Table 1*), and the fattening period averaged 233 d. In this period, the mean daily DMI resulted of 10.2 kg/d, ADG was 1.39 kg/d, and FCR was 0.14 kg/kg, with a range of variation among batches wider for ADG than for FCR.

Table 1

Descriptive statistics for productive performances

Item	Unit	Mean	SD	Min	Max
Initial live weight	Kg	390.4	28.44	322.0	458.0
Final live weight	Kg	714.2	20.34	670.0	772.0
Duration	D	233	18	190	324
DMI	kg/head/d	10.22	0.79	8.27	11.73
ADG	kg/d	1.39	0.08	1.19	1.60
FCR	kg/kg	0.14	0.01	0.11	0.17
Daily gross profit	€/d	2.50	0.40	1.66	3.39

DMI: dry matter intake; ADG: average daily gain; FCR: feed conversion ratio

The ADG found was similar to those obtained for Charolais breed reared in Veneto Region (*Sturaro et al*., 2005). Moreover, ADG and FCR mean values were similar to those obtained in performance experiments using maize-based diets (*Mandell et al.*, 1997; *Arthur et al.*, 2001). About economic result, DGP was 2.50 €/d on average. A relevant variation among batches was recorded, with the maximum value being almost double than the minimum. A positive correlation existed between ADG and DGP ($n=123$, $r=0.56$, $P<0.001$).

The TMRs of all the batches contained maize silage and soybean meal, and almost all contained also maize flour (89% of TMRs) and sugarbeet pulp (83% of TMRs); corn distiller, maize gluten feed, alfalfa hay, wheat straw, hydrogenated fat and mineral-protein supplement completed the mean diet; other ingredients were less important (data not shown).

The mean chemical composition of diets is shown in *Table 2*. Mean phosphorus level resulted 0.38% DM, with a relevant variability since the highest TMR content was 1.7 times the lowest one.

Table 2

Descriptive statistics for chemical composition of diet (% DM)

Item	Mean	SD	Min	Max
P	0.38	0.04	0.27	0.45
CP	13.86	0.74	11.48	15.55
Ash	5.93	0.37	5.06	6.62
Starch	33.89	3.90	27.06	42.74
NDF	32.03	2.98	24.31	38.23
NSC	44.75	3.20	38.54	53.05

CP: crude protein; NDF: neutral detergent fiber; NSC: not structural carbohydrates

The range of P dietary contents observed is higher, even in the lowest values, than the reference P requirements for beef NRC (2000), 27.6–52.7 g P/d observed vs 21–22 g P/d recommended, probably because of the practice of including P supplementation in the protein supplement without accounting for the basal diet content. Protein levels were on

average 1.42 kg/d, higher than the NRC (2000) recommendations of 1.07 kg/d CP, although also in this case there was a remarkable variability (range: 11.5–15.5% DM). Finally, contents of starch, which is an important source of energy for fattening young bulls varied from 27 to 43%.

The results of P balance are given in *Table 3*. The intake, depending on the combination of varying DM intakes and P (%DM) contents, varied more than the retention, which depended on a moderately variable growth rate. The resulting P excretion was close to 10 kg/head/d, with a wide variability; the same value, expressed as kg/day/1000 heads, was higher than that found for US intensive beef production (28.1 vs 23.1 kg) (*Cole and Todd*, 2009). Phosphorus efficiency was in the lowest values of the ranges reported in literature, and highy variable.

Table 3

Descriptive statistics for phosphorus balance

Variables	Unit	Mean	SD	Min	Max
P intake	kg/head/y	13.49	1.94	9.65	18.45
P retention	kg/head/y	3.64	0.21	3.12	4.20
P excretion	kg/head/y	9.85	1.92	6.05	15.11
P efficiency	%	27.55	4.20	18.09	37.31

The results of statistical analysis of ADG, FCR, and DGP are given in *Table 4*. The effect of arrival season was statistically significant for all variables, as expected from what usually observed in the practice of this fattening system: ADG, FCR and DGP were higher for batches arrived in summer than in winter (ADG: 1.41 and 1.36 kg/d; FCR: 0.14 and 0.13 kg/kg; DGP: 2.72 *vs* 2.2–2.1 €/d).

Table 4

Mixed model analysis for productive performances

Effect	ADG (kg/d)		FCR (kg/kg)		DGP (€/d)	
	F	P-value	F	P-value	F	P-value
Arrival Season	4.51	0.01	12.76	< 0.01	34.84	< 0.01
Arrival weight	3.41	0.04	4.23	0.02	1.75	0.18
ClP	0.43	0.65	1.20	0.31	0.90	0.41
ClS	3.18	0.05	2.26	0.11	3.90	0.02
ClPr	0.43	0.65	2.84	0.06	2.73	0.07
RMSE	0.05		0.01		0.25	

ClP: classes of P (%DM), ClS: classes of starch(%DM), ClPr: classes of protein (%DM)

Effects of arrival weight were less marked, and significant only for ADG, which decreased with increasing weight class (1.42 to 1.36kg/d, respectively for the light and heavy classes) and FCR, which observed the same trend with increasing weight class (0.14 to 0.13 kg/kg, respectively for the light and heavy classes). This was also expected since young bulls lower at arrival tend to grow faster (*Chambaz et al*., 2001). The levels

of P had no effect on ADG, FCR, and DGP. This is not surprising since P intakes were in general higher than requirements (see *Table 2*). Similarly, the class of dietary protein had no significant effects on productive and economic parameters. Class of starch influenced ADG, with better values for the high as respect to the low class (1.41 kg/d vs 1.35 kg/d), and DGP, with better values for intermediate class (2.55 €/d) and high class (2.50 €/d) as respect to low class (2.33 €/d).

CONCLUSIONS

The productive performances of intensive North-East Italy beef sector were not influenced by phosphorus content of diet. As a consequence, P content of most diets appeared in excess, and it could be reduced without impairing growth performances In relation with P environmental fate, and its impact on promoving eutrophication of surface waterbodies, this reduction can be an important tool to improve the relation between the local beef sector and the local environment.

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