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Original article

Effect of dietary cimaterol on performance and carcass traits in bulls and on aspects of digestion in cattle and sheep *

LO Fiems **, CV Boucqué, BG Cottyn, G Van de Voorde ***

National Institute for Animal Nutrition, Agricultural Research Centre – Ghent, Scheldeweg 68, B-9090 Melle-Gontrode, Belgium

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Summary — Forty-eight finishing Belgian White-blue bulls were used to examine the effect of 4 ppm cimaterol on liveweight gain, feed efficiency and carcass traits. Cimaterol was incorporated in a complete dry feed, which was fed *ad libitum* for 225 d. The digestibility and the rumen fermentation pattern of the diet were determined with wethers fed near maintenance. Digestibility was also determined with growing bulls fed to appetite. During the first half of the production trial, cimaterol improved growth rate and feed efficiency. During the second part, daily gain and feed efficiency were decreased by cimaterol. Cimaterol significantly increased dressing percentage and EUROP conformation score and altered carcass composition towards more meat and less fat. Other than a decrease for crude fibre, digestibility coefficients were not affected in cimaterol-treated sheep. In bulls fed *ad libitum*, the digestibilities of dry matter, organic matter, crude fibre and energy were reduced by cimaterol. Rumen fluid of cimaterol-treated sheep contained a significantly higher level of acetic and propionic acid and a significantly lower level of butyric acid.

cimaterol / growth / feed intake / carcass quality / digestion

Résumé — Effet du cimatérol sur les performances et les caractéristiques de la carcasse des taurillons à l'engrais et sur les aspects de digestibilité chez des bovins et des moutons. *Nous avons comparé la croissance, l'efficacité alimentaire et la composition de la carcasse de 48 taurillons blanc-bleu belges recevant une ration concentrée à satiété, comportant 0 ou 4 ppm de cimatérol pendant 225 jours. De plus, la digestibilité de cette ration et la composition du jus ruminal ont été examinées sur des moutons nourris à l'entretien. En outre, la digestibilité était aussi déterminée avec des taurillons en croissance nourris à satiété.*

Pendant la première période de l'essai de production, le cimatérol a entraîné une amélioration de la croissance et de l'efficacité alimentaire, tandis que le gain de poids et l'efficacité alimentaire étaient inférieurs ensuite. Le cimatérol a augmenté significativement le rendement à l'abattage et la conformation selon le classement EUROP. La proportion de muscle a été augmentée alors que la proportion de gras a été diminuée.

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*** Working group for Meat Production and Carcass Classification Faculty of Agricultural Sciences, State University of Ghent

Chez les moutons nourris à l'entretien, le cimatérol n'a pas influencé la digestibilité, excepté la cellulose brute. Chez les taurillons nourris à volonté, la digestibilité de la matière sèche, la matière organique, la cellulose brute et l'énergie ont été diminuées par le cimatérol. Chez les moutons, le cimatérol provoquait une augmentation significative des acides acétique et propionique et une réduction significative de l'acide butyrique.

cimatérol / croissance / ingestion / qualité de carcasse / digestion

INTRODUCTION

The link between the human diet and consumer health has become increasingly evident during the last decade (Combs, 1988). Recently, a number of scientists have recommended a reduction in caloric intake from fat to ≈ 35% of total intake (Gormley *et al*, 1987; NRC, 1988). On the other hand, it has been known for many years that adrenaline and noradrenaline can alter carcass composition towards less fat and more protein in poultry (Cunningham, 1963) and pigs (Cunningham *et al*, 1963). More recently, it has been demonstrated that synthetic catecholamines can significantly change carcass composition in meat-producing animals (Asato *et al*, 1984). Therefore, these repartitioning agents offer the opportunity to meet the needs of the consumer.

Besides the repartitioning of energy, β-agonists also improved animal performances in Friesian steers (Quirke *et al*, 1988). Nevertheless, more research with these compounds is warranted to investigate if their effect is similar in bulls. This report deals with the effect of cimaterol on intake, liveweight gain, carcass characteristics and meat composition of finishing bulls and the influence on digestibility and rumen fermentation in sheep and bulls. A preliminary report on this work has already been given by Boucqué *et al* (1987).

MATERIALS AND METHODS

Forty-eight Belgian White-blue bulls with normal conformation were purchased in the market. After an adaptation period of ≈ 2 months they were randomly divided into 2 groups, in such a manner that mean live weight, pre-experimental liveweight gain and body conformation (visual score) of both groups were similar. Each group was loose-housed in 2 straw-bedded pens, with 12 animals per pen. A concentrate diet was offered *ad libitum*. Intake was recorded daily on a pen basis. Straw and drinking water were always available. Straw intake was not measured. Cimaterol was incorporated at 4 ppm in the concentrate of the treatment group. The composition of the concentrate is given in table I.

Wither height and trunk length were measured in animals from 1 pen from each treatment at the start and the end of the experiment as described by De Boer *et al* (1974). The animals were weighed at 4-wk intervals and on 3 consecutive days at the beginning and the end of the experiment and at the end of the withdrawal period. A 20-h fast was imposed before the last weighing prior to slaughtering. Cimaterol was withdrawn for 6 d. All carcasses were weighed immediately after slaughtering and then were transferred to a cooler at 3 °C. Cold carcass weight, weights of liver, lungs and heart, carcass length (De Boer *et al*, 1974) and EUROP classification (Anonymous, 1981) were registered at 24 h *post mortem*. Dressing percent was calculated as cold carcass weight over fasted live weight. Carcass composition from each animal was assessed by dissection of the 8th rib-cut (Verbeke and Van de Voorde, 1978). The cross-sectional area of the longissimus dorsi muscle at the 8th rib interface of carcasses from one pen of each treatment was also recorded.

Table I. Composition of the concentrate.

	Control	*Cimaterol*
Ingredients (g/kg)		
Sugarbeet pulp	600	600
Wheat	118	113
Maize gluten feed	100	100
Malt sprouts	50	50
Soybean meal	35	35
Beet molasses	60	60
Feed phosphate	14	14
Lime	2.5	2.5
Salt	5	5
Trace elements	10	10
Vitamin A, D3 and E	5.5	5.5
Cimaterol premix	–	5
Chemical analysis		
Dry matter (DM, g/kg)	884	884
Composition of DM (g/kg)		
Crude protein	144	144
Crude fibre	181	128
Ether extract	11	11
Ash	89	91
Gross energy (MJ)	17.2	17.1

The influence of cimaterol on digestibility was estimated with 5 mature wethers fed at maintenance level and with 5 young growing White-blue bulls, weighing 383.4 ± 47.1 kg, fed *ad libitum* on the concentrate as mentioned in table I. A 10-d collection period preceded by a 4-wk adaptation period was used in these experiments. During 2 consecutive periods they received the concentrate containing 0 and 4 ppm, respectively ($n = 3$), or in a reversed order ($n = 2$). At the end of the sheep digestion trial, rumen fluid samples were taken from 3 fistulated sheep during 4 consecutive days at 2.5 h after the morning feeding, to determine pH, ammonia (Voigt and Steger, 1967) and volatile fatty acids (Supelco, 1986).

Treatment effects in the beef production experiment and the digestibility trial were assessed by analysis of variance. Rumen fermentation characteristics were calculated by analysis of variance in a repeated measures experiment (Snedecor and Cochran, 1980).

RESULTS

Cimaterol significantly increased daily liveweight gain from 1.46 to 1.63 kg during the first 112 experimental d (see table II). Afterwards, growth rate was significantly lower in the cimaterol-treated animals than in the control group: 1.20 *vs* 1.31 kg. Consequently, daily liveweight gain of control and cimaterol-treated bulls for the entire study was similar and averaged to 1.39 and 1.41 kg, respectively. Height at withers and trunk length were not different at the end of the experiment.

During the withdrawal period, live weight of cimaterol-treated bulls decreased from 680.9 to 677.6 kg ($P > 0.05$), while it increased from 655.9 to 663.0 kg ($P < 0.001$) in the control group. This weight change was significantly different ($P < 0.001$) between control and cimaterol-treated animals.

During the first 112 d control animals ate 3.3% more concentrate per day (table III). Afterwards, intake was the same for both groups. Average daily intake was only slightly different during the whole period. However, due to the different liveweight evolution, DM intake per kg $W^{0.75}$ was always lower for cimaterol-treated bulls. There was a variable effect of cimaterol on feed efficiency. During the first 112 experimental d, cimaterol reduced feed conversion by 14% from 5.62 to 4.85 kg. Afterwards DM intake per kg gain in the cimaterol-treated groups was 10% higher than in the control group: 8.19 *vs* 7.46 kg. On average feed efficiency was 2.6% better for the cimaterol treatment.

Table IV gives the effect of cimaterol on carcass traits. While cimaterol-treatment decreased fasting weight loss by 10%, the difference between control and cimaterol-treated animals was not statistically significant.

Table II. Effect of cimaterol on liveweight gain and body measurements.

	Control	*Cimaterol* [a]
No of bulls	24	24
Initial weight (kg)	354.3 ± 27.5[b]	354.5 ± 26.7
Weight after 112 d (kg)	517.7 ± 33.6	537.6* ± 31.4
Final weight (kg)	655.9 ± 37.4	680.9* ± 44.2
Experimental d	217.6 ± 20.7	231.6 ± 35.0
Weight after withdrawal (kg)	663.0 − 36.7	677.6 ± 43.1
Daily liveweight gain (kg) :		
Start to 112 d	1.46 ± 0.15	1.63*** ± 0.17
113 d to end	1.31 ± 0.18	1.20* ± 0.23
Average	1.39 ± 0.12	1.41 ± 0.16
Body measurements (cm) :	(*n* = 12)	(*n* = 12)
Height at withers		
Start	116.2 ± 2.6	116.3 ± 1.6
End	129.8 ± 3.8	129.4 ± 3.6
Trunk length		
Start	133.1 ± 4.6	133.3 ± 4.1
End	158.8 ± 7.6	157.6 ± 6.0

[a] In this and subsequent tables: * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$. [b] Standard error.

Cold carcass weight was increased by cimaterol from 416.2 to 449.4 kg ($P < 0.001$). Neither carcass weight loss after 24 h cooling nor carcass length were affected by cimaterol. Cimaterol feeding significantly increased dressing percent by 3.5 units and longissimus dorsi area by 26.3 cm^2. EUROP conformation was improved and fat covering was reduced by the incorporation of the β-agonist in the diet. Carcasses from cimaterol-treated animals yielded 8.6% more lean meat and 30.9% less fat than carcasses from control animals, while the relative amount of bone was not affected. Weights of heart and lungs were decreased in the cimaterol-treated group, while liver weight did not differ between both treatment groups.

Table III. Effect of cimaterol on feed intake.

	Control	*Cimaterol*
Daily concentrate intake (kg) :		
Start to 112 d	9.3	9.0
113 d to end	11.1	11.1
Average	10.2	10.1
Daily DM intake/kg $W^{0.75}$ (g) :		
Start to 112 d	86.2	81.3
113 d to end	81.6	80.0
Average	83.5	80.8
DM intake/kg gain (kg) :		
Start to 112 d	5.62	4.85
113 d to end	7.46	8.19
Average	6.49	6.32

Table IV. Effect of cimaterol on carcass traits and organ weights.

	Control	*Cimaterol*
Fasting weight loss (%)	3.31 ± 0.81	2.96 ± 0.99
Cold carcass weight (kg)	416.2 ± 23.1	449.4 *** ± 28.1
Cooling loss after 24 h (%)	1.75 ± 0.27	1.74 ± 0.20
Carcass length (cm)	134.1 ± 3.6	132.6 ± 3.7
Dressing (%)	65.0 ± 1.5	68.5*** ± 1.3
Longissimus dorsi area (cm^2)	139.0 ± 15.4	165.3** ± 15.1
EUROP classification :		
Conformation [1]	12.8 ± 2.1	16.3*** ± 1.2
Fatness [2]	7.1 ± 1.5	5.0*** ± 1.0
Carcass composition (%) :		
Meat	67.5 ± 2.4	73.3*** ± 2.3
Fat	18.8 ± 2.5	13.0*** ± 2.5
Bone	13.7 ± 0.8	13.7 ± 0.9
Organ weight (kg) :	(n = 12)	(n = 12)
Heart	2.5 ± 0.2	2.2*** ± 0.1
Lungs	6.6 ± 0.5	6.0** ± 0.5
Liver	6.7 ± 0.6	6.9 ± 1.4

1 : EE = 18; E = 15, U = 12; R = 9; 0 = 6; P = 3 points. 2 : Class 1 = 3 points (low); ... class 5 = 15 points (very high).

Table V presents the effect of cimaterol on digestibility and rumen fermentation. Crude fibre was significantly less digestible when cimaterol was incorporated into the diet of sheep, but other feed components were not affected. With bulls fed *ad libitum*, digestibility of dry matter, organic matter, crude fibre and gross energy were lower in cimaterol-treated animals ($P < 0.05$), while there was also a tendency for a decreased digestibility of the N-free extract ($P < 0.10$). Daily concentrate intake of control and treated bulls amounted to 8.1 and 8.2 kg, respectively. The rumen fermentation study with sheep fed near maintenance revealed a higher pH, an increased concentration of acetic and propionic acid, and less butyric acid in cimaterol-treated animals.

DISCUSSION

Although the average liveweight gain was similar in control and cimaterol-treated animals, the weight evolution was completely different (see table II). The positive effect of the β-agonist, observed during the first 112 d, was not maintained throughout the experiment. Furthermore, the lower growth rate in treated animals during the last half of the experiment suggests that the growth-promoting effect of cimaterol depends on the duration of application.

Variable effects of β-agonists on growth rate have been reported. No effect of clenbuterol was found in Hereford steers (Ricks *et al*, 1984) in Friesian veal calves (Williams *et al*, 1987) or in crossbred

Table V. Effect of cimaterol on digestibility and rumen fermentation.

Feeding level cimaterol	*Sheep maintenance*		*Bulls ad libitum*	
	−	+	−	+
Digestibility (%)				
Dry matter	82.1 ± 1.1	81.5 ± 1.1	73.2 ± 1.9	69.9* ± 2.3
Organic matter	86.6 ± 1.1	86.2 ± 0.9	76.9 ± 2.1	73.8* ± 1.8
Crude protein	74.1 ± 2.4	73.1 ± 2.0	59.4 ± 2.5	58.0 ± 3.6
Ether extract	58.8 ± 2.4	52.5 ± 11.0	52.9 ± 3.5	51.1 ± 5.6
Crude fibre	82.6 ± 1.2	80.7* ± 1.5	66.2 ± 3.5	60.2* ± 2.7
N-free extract	90.9 ± 0.9	90.6 ± 0.7	83.6 ± 2.0	80.7 ± 1.5
Gross energy	83.8 ± 1.3	83.5 ± 1.3	73.4 ± 2.1	70.2* ± 1.9
Rumen fermentation:				
pH	5.9 ± 0.2	6.2** ± 0.2		
Total VFA (mM/100 ml)	10.2 ± 1.7	9.6 ± 1.0		
Volatile fatty acids (molar %)				
Acetic acid	59.7 ± 1.4	61.6* ± 1.9		
Propionic acid	24.2 ± 2.1	27.0* ± 2.4		
Butyric acid	13.8 ± 1.0	10.2** ± 1.0		
Isovaleric acid	0.2 ± 0.2	0.1 ± 0.1		
Valeric acid	2.0 ± 0.2	1.1 ± 0.2		
Caproic acid	0.1 ± 0.1	0.1 ± 0.1		
C2/C3 ratio	2.5 ± 0.3	2.3 ± 0.3		
NH_3 (mg/100 ml)	20.0 ± 5.1	19.2 ± 7.0		

heifers (Miller *et al*, 1988). A quadratic increase has been reported for cimaterol in Friesian steers fed between 0 and 66 mg cimaterol daily during a 91-d test period (Quirke *et al*, 1988). Reeds *et al* (1986) reported that the effect of clenbuterol on growth rate in rats became less with time. Kim *et al* (1989) found that the growth-promoting effect of cimaterol in lambs disappeared at about the 6th wk of a 13-wk experimental period. However, these results do not fully agree with our experiment, where a negative impact on the rate of gain towards the end of the experiment rather than a phenomenon of adaptation was observed. An initial increase of growth rate followed by a gradual decline with duration of β-agonist application was reported by Moloney *et al* (1990). Therefore, it appears that this response pattern is not specific for cimaterol, but may be characteristic of β-agonists in general. An adaptation to β-agonists may be explained by the downregulation of β-receptors (Stiles *et al*, 1984). However, it remains difficult to explain the reduced growth rate in cimaterol-treated bulls towards the end of our experiment.

Another fact is the weight loss of treated bulls, during the withdrawal period although the effect was not significant. In finishing pigs, cimaterol withdrawal did not change the rate of gain (Jones *et al*, 1985; Cromwell *et al*, 1988). However, the experiments of MacRae *et al* (1988) showed rapid alterations of the metabolism after

clenbuterol withdrawal in treated lambs towards that of control lambs. The effect of length of withdrawal period has been studied in detail by Hanrahan *et al* (1988) in lambs. The growth rate during the cimaterol-withdrawal period was significantly depressed. The growth-depressing effect was most pronounced during the first weeks of the withdrawal period.

The improved feed conversion in cimaterol-treated bulls during the first 112 d corresponds with the experiments of Quirke *et al* (1988) and Moloney *et al* (1990). Feed conversion was only improved by 2.6% for the entire study as a consequence of the higher DM intake per kg gain during the second part of the experiment. This unfavourable feed conversion towards the end of the experiment is in contradiction with the altered carcass composition. The higher protein deposition in cimaterol-treated bulls and the accompanying deposition of water (van Es, 1977; Robelin and Geay, 1978) suggest a lower energy requirement per unit of tissue. Furthermore, the decreased protein turnover in cimaterol-treated animals (Williams *et al,* 1987; MacRae *et al*, 1988; Fiems *et al,* 1990) is another argument for an improved feed conversion. Obviously, other mechanisms adversely affect feed conversion. A higher energy requirement for maintenance due to an increased heat production has been reported for β-agonist-treated rats (Sainz and Wolff, 1988), lambs (MacRae *et al,* 1988) and calves (Williams *et al,* 1987). If this mechanism affects the efficiency of energy utilization, then there is no reason to suppose that it is more important towards the end of the experiment, on the contrary. Herbert *et al* (1985) reported that the immediate increase of temperature after clenbuterol administration was not maintained. Parkins *et al* (1989) reported that nitrogen balance showed a diminished response to adrenergic stimulation with time. Furthermore, the altered endocrine status observed after cimaterol administration was only temporal (Beermann *et al,* 1987; Fiems *et al,* 1989).

The improvement of the carcass characteristics and the reduction of the weight of organs are in agreement with the findings previously observed in cattle (Ricks *et al,* 1984; Williams *et al,* 1987; Miller *et al,* 1988; Quirke *et al,* 1988) and sheep (Thornton *et al,* 1985; Kim *et al,* 1989). Reductions of the viscera were reported by Williams *et al* (1987) and Quirke *et al* (1988). From this point of view it appears that hypertrophied animals due to β-agonist treatment are comparable with hypertrophied animals of genetic origin, where viscera are also reduced (Ansay and Hanset, 1979).

We have no explanation for the different effect of cimaterol on the digestibility coefficients in sheep and bulls (table V). *Ad libitum* intake in bulls may have increased the rate of passage of the digesta, resulting in a lower digestibility in comparison with sheep. The reduced digestibility in cimaterol-treated bulls can not be explained by a feed intake level which differed from that in control animals. Our results obtained with sheep correspond with those of Rikhardsson *et al* (1988), Kim *et al* (1989) and Parkins *et al* (1989), where digestibility of dry matter, energy and nitrogen were not affected by β-agonists in animals with restricted feeding. Similar effects of β-agonists on crude fibre digestibility to those reported here have not been found in the literature.

Rumen fermentation in sheep was also altered by cimaterol. Feeding 10 mg clenbuterol per day did not affect rumen fermentation in steers, and total volatile fatty acids were only reduced when 500 mg per day was given (Ricks *et al,* 1984). Referring to the investigations of Graham *et al* (1982) with adrenaline and noradrenaline,

and Brikas *et al* (1990) with the β_2-agonist ritodrine, it is possible that the altered rumen fermentation is associated with an inhibition of the rumen motility. It is not clear whether the higher rumen concentrations of acetic and propionic acid are the result of a higher fermentation or a lower absorption. Eisemann *et al* (1988) reported lower whole blood arteriovenous concentration differences in the hindquarters for acetate and propionate in clenbuterol-fed steers. They also reported an increased blood flow, with a greater increase in blood flow to the hindquarters than to the portal drained visceral tissues. These results may explain a lower uptake of acetate and propionate.

CONCLUSIONS

The improved liveweight gain and feed conversion during the initial period followed by a reduced rate of gain and feed efficiency indicate a transient effect of cimaterol on these variables. Investigations to determine the optimum administration time are needed. The improvement in carcass quality, which was still perceptible after a 6-d withdrawal period, confirms previously reported results. The different effect of cimaterol on digestibility in sheep and bulls may depend on animal species or on feeding level. More research is required to elucidate this discrepancy.

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