Ann. Zootech., 1980, **29**, n° h. s., 233-250.

Effect of energy density of diets for intensive bull beef production on intake, growth rate and feed conversion

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Abstract

The impact of the energy concentration (kg SU/kg DM) of *ad libitum* fed diets, on intake, growth rate and efficiency was investigated with 119 groups loose housed Belgian white-blue store bulls (I), 62 groups of individually tied up Belgian white-blue store bulls (II) and 42 groups of individually tied up Belgian white-red baby-beef bulls (III). We established a negative relationship between the energy density (x) and the dry matter intake (y = g DM/kg $W^{0.75}$).

Group I : $y = 136.1 - 68.7\ x$; $r = -0.72^{**}$; SD = 5.0
Group II : $y = 139.2 - 87.6\ x$; $r = -0.67^{**}$; SD = 7.0
Group III : $y = 120.6 - 51.1\ x$; $r = -0.49^{**}$; SD = 5.5

Within the studied range of energy density (0.53 to 0.89 kg SU/kg DM) the relationship with energy intake (y = g SU/kg $W^{0.75}$) was positive :

Group I : $y = 33.2 + 40.0\ x$; $r = 0.67^{**}$; SD = 3.3
Group II : $y = 41.6 + 17.9\ x$; $r = 0.28^{*}$; SD = 4.3
Group III : $y = 30.6 + 41.2\ x$; $r = 0.52^{**}$; SD = 4.1

The increasing energy intake with higher energy densities (x) resulted in an increasing growth rate (y = g/d) (except for group II) but the correlation was lower :

Group I : $y = 708.1 + 780.6\ x$; $r = 0.49^{**}$; SD = 105.8
Group II : $y = 1009.4 + 119.5\ x$; $r = 0.09$ NS ; SD = 93.8
Group III : $y = 823.5 + 464.6\ x$; $r = 0.36^{*}$; SD = 71.3

The feed conversion (y = kg SU/kg gain) in function of the energy concentration (x) did not indicate a significant relationship for two of the three groups :

Group I : $y = 4.31 + 0.61\ x$; $r = 0.12$ NS ; SD = 0.37
Group II : $y = 2.84 + 2.35\ x$; $r = 0.42^{**}$; SD = 0.37
Group III : $y = 3.79 + 0.22\ x$; $r = 0.06$ NS ; SD = 0.22

Communication No. 428 of the Institute.

Ad libitum feeding of higher energetic rations resulted in decreased dry matter and increased net energy intake. Daily liveweight gain was positively affected by a higher energy density, while the influence on the feed conversion was very small, except for the tied store bulls.

Résumé

Influence de la concentration énergétique des rations sur la consommation, la vitesse de croissance et l'efficacité alimentaire de jeunes bovins intensifs

Les auteurs ont étudié les effets de la concentration énergétique (Valeur Amidon/kg de MS) de rations offertes à volonté sur la consommation, la vitesse de croissance et l'efficacité alimentaire de 119 lots de taurillons Blanc-Bleu-Belges en stabulation libre (I), 62 lots de taurillons Blanc-Bleu-Belges en stabulation entravée (II) et de 42 groupes de taurillons Blanc-Rouge-Belges en stabulation entravée (III). Ils ont établi une liaison négative entre la concentration énergétique (x) et la quantité de matière sèche ingérée (y = MS/kg poids^{0,75}).

Lot I : $y = 136{,}1 - 68{,}7\,x$; $r = -0{,}72^{**}$; SD = 5,0
Lot II : $y = 139{,}2 - 87{,}6\,x$; $r = -0{,}67^{**}$; SD = 7,0
Lot III : $y = 120{,}6 - 51{,}1\,x$; $r = -0{,}49^{**}$; SD = 5,5

Dans l'intervalle de concentration énergétique considéré (0,53 à 0,89 UA/kg MS) la liaison avec la quantité d'énergie ingérée (y = UA/kg P^{0,75}) a été positive.

Lot I : $y = 33{,}2 + 40{,}0\,x$; $r = 0{,}67^{**}$; SD = 3,3
Lot II : $y = 41{,}6 + 17{,}9\,x$; $r = 0{,}28^{*}$; SD = 4,3
Lot III : $y = 30{,}6 + 41{,}2\,x$; $r = 0{,}52^{**}$; SD = 4,1

L'accroissement de la quantité d'énergie ingérée lié à celui de la concentration énergétique (x) a entraîné une augmentation de la vitesse de croissance (y = g/jour) (sauf pour le lot II), mais avec de plus faibles corrélations.

Lot I : $y = 708{,}1 + 780{,}6\,x$; $r = 0{,}49^{**}$; SD = 105,8
Lot II : $y = 1009{,}4 + 119{,}5\,x$; $r = 0{,}09$ NS ; SD = 93,8
Lot III : $y = 823{,}5 + 464{,}6\,x$; $r = 0{,}36^{*}$; SD = 71,3

La relation entre le coût énergétique du kg de gain (y = VA/kg gain) et la concentration énergétique (x) n'a pas été significative pour 2 des 3 lots.

Lot I : $y = 4{,}31 + 0{,}61\,x$; $r = 0{,}12$ NS ; SD = 0,37
Lot II : $y = 2{,}84 + 2{,}35\,x$; $r = 0{,}42^{**}$; SD = 0,37
Lot III : $y = 3{,}79 + 0{,}22\,x$; $r = 0{,}06$ NS ; SD = 0,22

La distribution à volonté de rations de plus en plus riches en énergie a entraîné une réduction de la quantité de matière sèche ingérée et une augmentation de la quantité d'énergie ingérée ; les gains de poids vif journaliers ont été améliorés par l'accroissement de la concentration énergétique tandis que l'efficacité alimentaire a été peu modifiée, sauf pour les taurillons II en stabulation entravée.

1. — Introduction

There is a great diversity of beef production in Europe, due in part to the large number of breeds with their own genotype. Bulls of Anglo-Saxon and dairy breeds have an early maturity which results in fatter carcases compared to the continental beef breeds. The variability in the performance of beef cattle can be further enhanced when animals receive different feeding levels (GEAY and ROBELIN, 1979). A higher energy level either increased the fat content in the carcase at equal carcase weights, or decreased carcase weight at an equal fat content (CALLOW, 1961 ; HENRICKSON *et al.*, 1965 ; GARRIGUS *et al.*, 1969 ; WALDMAN *et al.*, 1971 ; BOND *et al.*, 1972 ; ANDERSEN, 1975). When reared in the same conditions, bulls of different breeds with equal carcase weights gave a different fat content in the carcase or when the fat content was comparable, there was a difference in carcase weight (GEAY and MALTERRE, 1973).

Variability also exists concerning feed conversion data cited in the literature, even within the same category of animals fattened with comparable diets. The starch equivalent intake per kg of liveweight gain of Israeli-Friesian male cattle was 3.8 to 4.2 kg (LEVY *et al.*, 1968 and 1970) while similar bulls of the Belgian white-red breed had a better feed conversion : 2.9 to 3.4 (BUYSSE, 1969 ; BUYSSE and BOUCQUE, 1975).

However, there is no agreement concerning the effect of decreasing the level of energy intake on feed efficiency. Some feeding experiments reported a better efficiency on a restricted energy level (DE BOER *et al.*, 1971 ; BOND *et al.*, 1972 ; LEVY *et al.*, 1974 ; ANDERSEN, 1975), while other trials (GUENTHER *et al.*, 1965 ; MEYER *et al.*, 1965) gave a better efficiency with *ad libitum* feeding, or no difference (GEAY *et al.*, 1976 ; LEVY *et al.*, 1976 ; ROHR and DAENICKE, 1978).

This study will not investigate the influence of energy levels, but rather the impact of the ration energy concentration on feed intake, growth rate and feed conversion of fattening bulls.

2. — Experimental

The bulls involved with this investigation can be divided in three groups :

I: store bulls of the Belgian white-blue (BWB) breed, group-housed (119 rations with 929 animals, liveweight range of 292.4 ± 4.1 ($s_{\bar{x}}$) to 596.2 ± 3.1 kg);

II: store bulls of the BWB breed, but individually tied up (62 rations with 439 animals, liveweight range of 260.0 ± 3.5 to 543.9 ± 4.1 kg);

III: baby-beef bulls of the Belgian white-red (BWR) breed, individually tied up (42 rations with 265 animals, liveweight range of 159.2 ± 4.2 to 479.9 ± 2.5 kg).

In each group there was a diversity of diets varying from complete dry rations to mixed rations. For the mixed diets the basic feedstuff was always administered to appetite, while the daily allowance of concentrate was restricted to 1 or 0.75 kg per 100 kg liveweight. Therefore the animals were weighed monthly and the amount of concentrate was adapted accordingly. Initial and final weights were recorded on three and two consecutive days respectively. The main roughages were maize silage, dehydrated alfalfa pellets, dehydrated whole maize plant pellets, grass hay and also some industrial by-products (BOUCQUE *et al.*, 1978) (Table 1).

All rations were chemically analysed and digestibility of the complete diets or of the main feedstuffs was determined with wethers as described by COTTYN and BOUCQUE (1969).

TABLE 1

CLASSIFICATION OF THE RATIONS FOLLOWING THE BASIC FEEDSTUFFS AND THE ENERGY DENSITY

Group / Ration type	Number of rations		
	I (n = 119)	II (n = 62)	III (n = 42)
Hay + concentrate	-	14	-
Maize silage + concentrate	18	24	-
Dehydrated maize pellets + concentrate	6	4	8
Dehydrated alfalfa pellets + concentrate	20	-	-
Fodderbeet + concentrate	1	-	-
Ensiled pressed beet pulp + concentrate	7	-	-
Dried beet pulp (≥ 75%) rations	14	6	-
Complete dry rations*	49	12	28
Maize grain + concentrate	4	2	6
Energy density of the diet (kg SU/kg DM)			
< 0.600	12	12	-
0.600 - 0.649	10	5	3
0.650 - 0.699	30	21	3
0.700 - 0.749	33	19	23
0.750 - 0.799	20	3	7
0.800 - 0.849	11	-	3
≥ 0.850	3	2	3

* Mainly dried sugar beet pulp and other by-products

The impact of the energy concentration on dry matter and net energy intake, growth rate and feed conversion was studied by regression analysis (DRAPER and SMITH, 1966).

The net energy content was expressed in starch equivalents. The requirements for maintenance and daily liveweight gain (LWG) were calculated by the following regressions (BUYSSE, 1974) :

SE for maintenance (kg/d) = 0.8 + 0.0045 W

SE for production (kg/kg LWG) = 1.22 + 0.00273 W.

3. — Results and discussion

3.1. — *Feed intake*

According to the studies of MONTGOMMERY and BAUMGARDT (1965) ; BAUMGARDT (1970) and DINIUS and BAUMGARDT (1970), we can expect an increasing dry matter and energy intake by enhancing the energy concentration. Once a threshold density is exceeded, there would be no point in a higher energy concentration, because animals eat for calories !

Giving more concentrated rations results in a decreasing dry matter intake and a stable or slightly decreasing energy intake. CONRAD (1966) found that the digestible dry matter intake of dairy cows levelled off and approached a straight line between 66 and 80 per cent DM digestibility. The DM digestibility of the diets concerned in this study ranged between 66 and 87 per cent.

Our investigation always resulted in a decreasing DM intake ($y =$ g/kg $W^{0.75}$) (figure 1) with increasing energy concentration ($x =$ kg SU/kg DM).

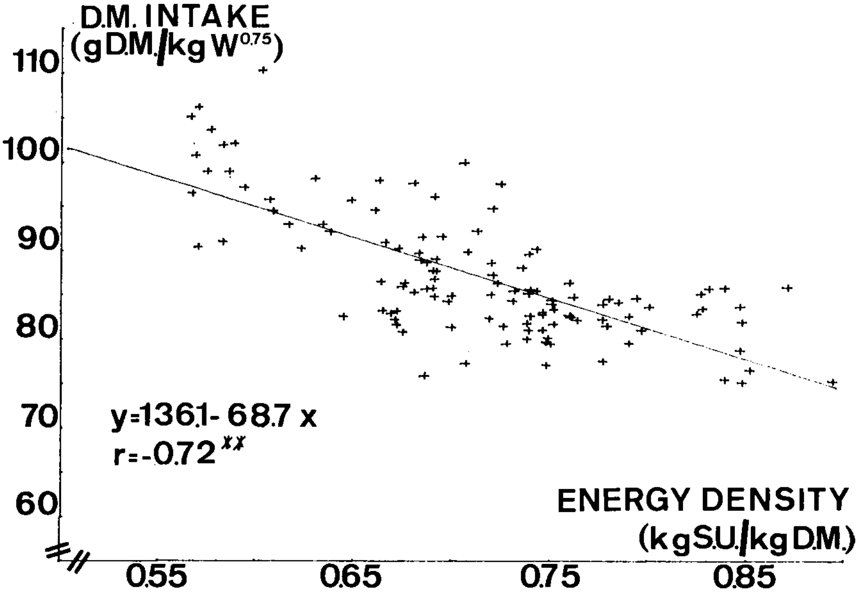

FIG 1. — *Relationship, energy density and DM intake by bulls (I).*

The relationship was respectively :

Group I : $y = 136.1 — 68.7\ x$; $r = — 0.72^{**}$; SD = 5.0

Group II : $y = 139.2 — 87.6\ x$; $r = — 0.67^{**}$; SD = 7.0

Group III : $y = 120.6 — 51.1\ x$; $r = — 0.49^{**}$; SD = 5.5

These findings are in accordance with most of the literature data shown in Table 2.

Table 2. Influence of the energy concentration on ad lib. intake, daily gain and energy utilization

Ref. N°	*	**	Liveweight interval (kg)	Energy concentration		Daily intake				Daily gain		Feed conversion			
				Units/kg DM	%	DM	%	Units	%	(g)	%	kg DM/ kg gain	%	Units/kg gain	%
5	B	BWB	209 - 520	765 g SU	100	6.58 kg	100	5.04 kg SU	100	1358	100	4.85	100	3.71 kg SU	100
			210 - 521	663 g SU	87	7.27 kg	110	4.83 kg SU	96	1281	94	5.68	117	3.77 kg SU	102
			209 - 509	646 g SU	84	7.67 kg	117	4.96 kg SU	98	1188	87	6.46	133	4.17 kg SU	112
			209 - 514	571 g SU	75	7.99 kg	121	4.56 kg SU	90	1165	86	6.86	141	3.92 kg SU	106
6	B	BWR	148 - 488	774 g SU	100	6.09 kg	100	4.71 kg SU	100	1286	100	4.73	100	3.66 kg SU	100
			149 - 475	668 g SU	86	6.85 kg	112	4.57 kg SU	97	1221	95	5.61	119	3.74 kg SU	102
			146 - 487	635 g SU	82	7.37 kg	121	4.68 kg SU	99	1286	100	5.73	121	3.64 kg SU	99
7	B	BWR	138 - 461	736 EF_r	100	5.09 kg	100	3743 EF_r	100	1172	100	3.46	100	2547 EF_r	100
			138 - 489	692 EF_r	94	6.25 kg	123	4328 EF_r	116	1259	107	3.92	113	2715 EF_r	107
			139 - 491	656 EF_r	89	6.55 kg	129	4297 EF_r	115	1250	107	4.11	119	2698 EF_r	106
			138 - 472	623 EF_r	85	6.39 kg	126	3983 EF_r	106	1125	96	4.34	125	2706 EF_r	106
10	B	BWB	326 - 642	733 g SU	100	87.3 $g/W^{0.75}$	100	64.0 g $SU/W^{0.75}$	100	1263	100	7.12	100	5.22 kg SU	100
			331 - 610	732 g SU	100	81.2 $g/W^{0.75}$	93	59.4 g $SU/W^{0.75}$	93	1112	88	7.37	104	5.40 kg SU	103
			329 - 628	696 g SU	95	85.9 $g/W^{0.75}$	98	59.8 g $SU/W^{0.75}$	93	1197	95	7.36	103	5.11 kg SU	98
			325 - 613	669 g SU	91	86.5 $g/W^{0.75}$	99	57.9 g $SU/W^{0.75}$	90	1159	92	7.52	106	5.04 kg SU	97
20	B	BWR	157 - 480	708 g SU	100	6.37 kg	100	4.51 kg SU	100	1188	100	5.36	100	3.79 kg SU	100
			157 - 490	691 g SU	98	6.59 kg	103	4.55 kg SU	101	1175	99	5.61	105	3.88 kg SU	102
			157 - 477	695 g SU	98	6.55 kg	103	4.55 kg SU	101	1050	88	6.24	116	4.34 kg SU	115
			150 - 477	649 g SU	92	5.76 kg	90	3.74 kg SU	83	1009	85	5.71	107	3.70 kg SU	98
		BWB	233 - 571	708 g SU	100	8.00 kg	100	5.66 kg SU	100	1409	100	5.68	100	4.02 kg SU	100
			222 - 575	691 g SU	98	8.58 kg	107	5.93 kg SU	105	1429	101	6.01	106	4.15 kg SU	103
			222 - 551	695 g SU	98	7.99 kg	100	5.55 kg SU	98	1241	88	6.44	113	4.47 kg SU	111
			222 - 539	649 g SU	92	8.24 kg	103	5.35 kg SU	95	1168	83	7.06	124	4.58 kg SU	114
33	B	S	339 - 562	2.005 Mcal ME	100	10.7 kg	100	21.465 Mcal ME	100	1183	100	8.97	100	18.145 Mcal ME	100
			338 - 561	2.627 Mcal ME	131	9.0 kg	84	23.965 Mcal ME	112	1186	100	7.52	84	20.207 Mcal ME	111
		CA x S	342 - 555	2.005 Mcal ME	100	9.3 kg	100	18.655 Mcal ME	100	1134	100	8.19	100	16.451 Mcal ME	100
			343 - 591	2.627 Mcal ME	131	9.1 kg	98	24.039 Mcal ME	129	1322	117	6.85	84	18.184 Mcal ME	118
		CA	343 - 533	2.005 Mcal ME	100	9.1 kg	100	18.628 Mcal ME	100	1035	100	8.79	100	17.998 Mcal ME	100
			339 - 564	2.627 Mcal ME	131	8.4 kg	92	22.198 Mcal ME	119	1244	120	6.94	80	17.844 Mcal ME	99
34	B	S	295 - 545	2.25 Mcal ME	100	-		18.42 Mcal ME	100	1276	100	-		18.42 Mcal ME	100
			301 - 549	2.55 Mcal ME	113	-		19.94 Mcal ME	108	1264	99	-		19.94 Mcal ME	108
26	B	F	167 - 485	650 EF_r	100	5.51 kg	100	3.43 kEF_r	100	1032	100	5.34	100	3.32 kEF_r	100
27			168 - 475	550 EF_r	85	6.54 kg	119	3.54 kEF_r	103	996	97	6.56	123	3.55 kEF_r	107
			167 - 491	475 EF_r	73	6.81 kg	124	3.24 kEF_r	94	1052	102	6.47	121	3.08 kEF_r	93
			168 - 418	395 EF_r	61	7.03 kg	128	2.78 kEF_r	81	813	79	8.65	162	3.42 kEF_r	103
28	B	75 % F 25 % J	167 - 484	655 EF_r	100	5.89 kg	100	3.86 kEF_r	100	1020	100	5.77	100	3.79 kEF_r	100
			166 - 496	556 EF_r	85	6.79 kg	115	3.78 kEF_r	98	990	97	6.86	119	3.78 kEF_r	100
			168 - 488	492 EF_r	75	7.50 kg	127	3.69 kEF_r	96	1017	100	7.37	128	3.63 kEF_r	96
			168 - 481	416 EF_r	64	7.72 kg	131	3.21 kEF_r	83	871	85	8.86	154	3.69 kEF_r	97
43	B	F	240 - 489	2.41 Mcal ME	100	-		25.71 Mcal ME	100	1016	100	-		22.45 Mcal ME	100
			239 - 477	2.13 Mcal ME	88	-		24.38 Mcal ME	95	748	74	-		28.58 Mcal ME	127

Table 2 : (continued)

44	B	F	200 - 400	2.54 Mcal ME	100	7.99 kg	100	20.36 Mcal ME	100	1031	100	7.75	100	19.75 Mcal ME	100
				2.39 Mcal ME	94	9.05 kg	113	21.67 Mcal ME	106	985	96	9.18	118	22.01 Mcal ME	111
			200 - 450	2.55 Mcal ME	100	8.37 kg	100	21.35 Mcal ME	100	1069	100	7.83	100	19.97 Mcal ME	100
				2.38 Mcal ME	93	9.20 kg	110	21.98 Mcal ME	103	1009	94	9.18	117	21.78 Mcal ME	109
			200 - 500	2.54 Mcal ME	100	8.79 kg	100	22.41 Mcal ME	100	1122	100	7.83	100	19.97 Mcal ME	100
				2.38 Mcal ME	94	9.73 kg	111	23.24 Mcal ME	104	1054	94	9.23	118	22.05 Mcal ME	110
36	S	HE	227 - 355	69.5 % TDN	100	3.67 kg	100	2.65 kg TDN	100	1100	100	-		2.41 kg TDN	100
			224 - 320	54.3 % TDN	78	4.14 kg	113	2.33 kg TDN	88	830	75	-		2.81 kg TDN	117
			222 - 425	69.5 % TDN	100	3.76 kg	100	2.71 kg TDN	100	930	100	-		2.91 kg TDN	100
			223 - 394	54.3 % TDN	78	4.18 kg	111	2.35 kg TDN	87	790	85	-		2.98 kg TDN	102
			229 - 440	54.3 % TDN	78	4.17 kg	111	2.35 kg TDN	87	820	88	-		2.87 kg TDN	99
37	S	HE	220 - 400	1592 kcal NE	100	7.72 kg	100	12.2 Mcal NE	100	852	100	-		14.35 Mcal NE	100
			223 - 405	1302 kcal NE	82	6.95 kg	90	8.9 Mcal NE	73	698	82	-		12.58 Mcal NE	88
38	S	F	150 - 350	2.95 Mcal ME	100	6.03 kg	100	17.79 Mcal ME	100	1200	100	5.03	100	14.83 Mcal ME	100
			150 - 350	2.55 Mcal ME	86	6.69 kg	111	17.06 Mcal ME	96	1040	87	6.43	128	16.40 Mcal ME	111
			150 - 350	2.30 Mcal ME	78	7.12 kg	118	16.38 Mcal ME	92	870	73	8.18	163	18.83 Mcal ME	127
39	S	F	150 - 350	2.96 Mcal ME	100	5.05 kg	100	14.95 Mcal ME	100	1180	100	4.28	100	12.67 Mcal ME	100
			150 - 350	2.87 Mcal ME	97	6.99 kg	138	20.06 Mcal ME	134	1060	90	6.59	154	18.92 Mcal ME	149
			150 - 350	2.82 Mcal ME	95	6.66 kg	132	18.78 Mcal ME	119	1060	90	6.28	147	17.72 Mcal ME	140
			150 - 350	2.68 Mcal ME	91	6.31 kg	125	16.91 Mcal ME	113	880	75	7.17	168	19.22 Mcal ME	152
48	S	F	122 - 501	3.26 Mcal DE	100	6.26 kg	100	20.43 Mcal DE	100	1040	100	6.07	100	19.64 Mcal DE	100
			115 - 512	2.99 Mcal DE	92	6.66 kg	106	19.93 Mcal DE	98	1190	114	5.65	93	16.75 Mcal DE	85
			127 - 498	3.23 Mcal DE	100	5.94 kg	100	19.21 Mcal DE	100	1130	100	5.32	100	17.00 Mcal DE	100
			121 - 486	3.00 Mcal DE	93	6.30 kg	106	18.92 Mcal DE	98	920	81	6.54	123	20.58 Mcal DE	121
			129 - 504	3.23 Mcal DE	100	6.01 kg	100	19.41 Mcal DE	100	1040	100	5.63	100	18.66 Mcal DE	100
			120 - 512	3.00 Mcal DE	93	6.47 kg	108	19.38 Mcal DE	100	1070	103	6.04	107	18.10 Mcal DE	97
49	S	F	300 - 420	12.5 MJ ME	100	7.88 kg	100	98.9 MJ ME	100	1260	100	6.25	100	78.49 MJ ME	100
				11.1 MJ ME	89	9.67 kg	123	107.2 MJ ME	108	1120	89	8.63	138	95.71 MJ ME	122
				10.4 MJ ME	83	9.23 kg	117	96.4 MJ ME	97	890	71	10.4	166	108.31 MJ ME	138
				10.1 MJ ME	81	8.60 kg	109	87.3 MJ ME	88	850	67	10.1	162	102.71 MJ ME	131
50	S	A x HE	255 - 495	2.9 Mcal ME	100	7.6 kg	100	22.6 Mcal ME	100	1050	100	7.3	100	21.52 Mcal ME	100
			259 - 520	3.1 Mcal ME	107	8.4 kg	111	25.8 Mcal ME	114	1170	111	7.2	99	22.05 Mcal ME	102
			258 - 540	3.2 Mcal ME	110	8.4 kg	111	26.5 Mcal ME	117	1250	119	6.7	92	21.20 Mcal ME	99
		CA+CI	274 - 639	2.9 Mcal ME	100	8.9 kg	100	24.5 Mcal ME	100	1200	100	7.4	100	20.42 Mcal ME	100
			275 - 661	3.1 Mcal ME	107	9.5 kg	107	26.9 Mcal ME	110	1280	107	7.4	100	21.02 Mcal ME	103
			275 - 676	3.2 Mcal ME	110	9.0 kg	101	26.2 Mcal ME	107	1330	111	6.7	91	19.70 Mcal ME	96
53	S	F	287 - 467	3.09 Mcal DE	100	9.5 kg	100	29.4 Mcal DE	100	1290	100	7.4	100	22.8 Mcal DE	100
			286 - 467	2.75 Mcal DE	89	9.7 kg	102	26.7 Mcal DE	91	1190	92	8.1	109	22.4 Mcal DE	98
			297 - 464	2.30 Mcal DE	74	9.9 kg	104	22.8 Mcal DE	78	1020	79	9.8	132	22.3 Mcal DE	98
56	S	HE x H	326 - 454	2.496 Mcal DE	100	-		22.6 Mcal DE	100	892	100	-		25.4 Mcal DE	100
			328 - 450	3.001 Mcal DE	120	-		22.1 Mcal DE	98	853	96	- -		26.4 Mcal DE	104
			328 - 484	3.515 Mcal DE	141	-		25.1 Mcal DE	111	1088	122	-		23.3 Mcal DE	92
47	H	H	(21 days)	4.41 Mcal BE	100	103 g/W$^{0.75}$	100	244.7 kcal DE/W$^{0.75}$	100	-		-		-	
				4.46 Mcal BE	101	90.7g/W$^{0.75}$	88	242.4 kcal DE/W$^{0.75}$	99	-		-		-	
				4.47 Mcal BE	101	76.4g/W$^{0.75}$	74	234.6 kcal DE/W$^{0.75}$	96	-		-		-	
				4.49 Mcal BE	102	81.2g/W$^{0.75}$	78	235.2 kcal DE/W$^{0.75}$	96	-		-		-	
51	H	HE	283 - 393	61.8 % TDN	100	-		-		892	100	-		-	
			283 - 398	69.0 % TDN	112	-		-		929	104	-		-	
			283 - 410	68.3 % TDN	111	-		-		1028	115	-		-	

* B : bulls, S : steers, H : heifers.

** A : Angus, BWB : Belgian white-blue, BWR : Belgian white-red, CA : Charolais, CI : Chianina, F : Friesian, H : Holstein, HE : Hereford, J : Jersey, S : Salers.

A possible explanation for the diminishing DM intake may be the fact that we had already exceeded the threshold concentration for maximum DM intake.

In that case, the relationship of MONTGOMMERY and BAUMGARDT (1965) suggests a constant energy intake. Nevertheless, in our trials (figure 2) we observed a significantly higher energy intake ($y =$ g SU/kg $W^{0.75}$) with increasing energy density (x):

Group I : $y = 33.2 + 40.0\ x$; $r = 0.67^{**}$; SD = 3.3
Group III : $y = 41.6 + 17.9\ x$; $r = 0.28^{*}$; SD = 4.3
Group III : $y = 30.6 + 41.2\ x$; $r = 0.52^{**}$; SD = 4.1

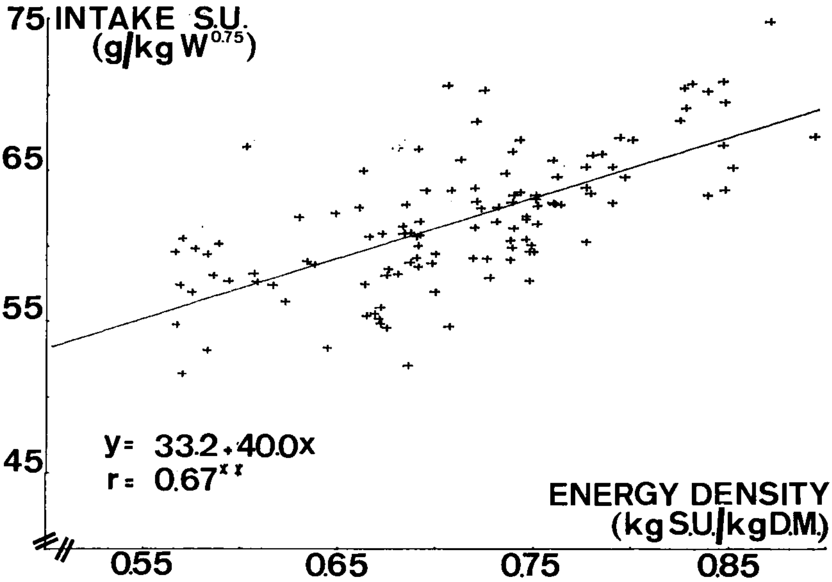

FIG. 2. — *Relationship, energy density and SU intake by bulls (BWB-group housed; n = 119) (I).*

This again is in agreement with most of the cited references in Table 2. However the uniformity among the 3 groups for the energy intake as a consequence of the caloric density is less pronounced than for the DM intake. Feed intake is also influenced by other parameters of the diet such as physical form (COTTYN *et al.*, 1971) and crude fibre content (DE BRABANDER *et al.*, 1978).

FREER and CAMPLING (1963) noted a lower energy intake on very high energy rations. At our institute COTTYN *et al.* (1978) established the same phenomenon with tieds bulls of the Belgian white-blue breed fed maize grain, while it was not confirmed with loose housed bulls (BOUCQUE *et al.*, 1978). This statement helps to explain the lower r value for group II.

3.2. — *Daily liveweight gain*

Because of the positive correlation between the energy concentration and the energy intake, we expect a higher growth rate (y = g/day) with increasing energy concentration. This was confirmed by our investigation (Figure 3), but the correlation coefficients were lower (especially for group II) than those for intake and concentration. The relationship was respectively :

Group I : $y = 708.1 + 780.6\,x$; $r = 0.49^{**}$; SD = 105.8
Group II : $y = 1009.4 + 119.4\,x$; $r = 0.09$ NS ; SD = 93.8
Group III : $y = 823.5 + 464.6\,x$; $r = 0.36^{*}$; SD = 71.3

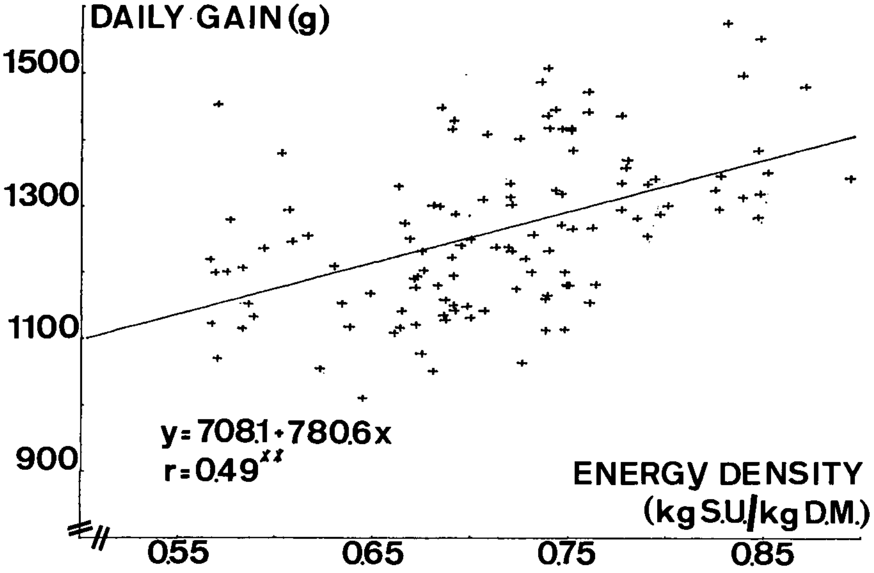

FIG. 3. — *Relationship, energy density and daily gain by bulls (I).*

This is also in accordance with the data in Table 2, although some investigations (FLACHOWSKY and LÖHNERT, 1977 and FLACHOWSKY, 1979), with high energetic rations but with a lack of fibrous material, resulted in a growth depression without a decreasing energy intake.

LANARI and SUSMEL (1979) found that maize rations with increasing energy concentration clearly improved daily gains of beef breed bulls ($r = 0.80$), while the increase in daily gain was less evident for dairy breed bulls ($r = 0.42$), light steers ($r = 0.26$) and heavy steers ($r = 0.67$).

In the case of store bulls only, there is a clearly better response on energy concentration with loose housed bulls (I) than with tied animals (II). This was already demonstrated with earlier results (BOUCQUE *et al.*, 1979).

The influence of the daily energy intake ($x =$ g SU/kg $W^{0.75}$) on the daily gain (y) (figure 4) gives a more significant relationship:

Group I : $y = 87.1 + 19.1\,x$; $r = 0.71^{**}$; SD = 85,8
Group II : $y = 452.4 + 11.9\,x$; $r = 0.57^{**}$; SD = 77.4
Group III : $y = 462.8 + 11.5\,x$; $r = 0.72^{**}$; SD = 53.3

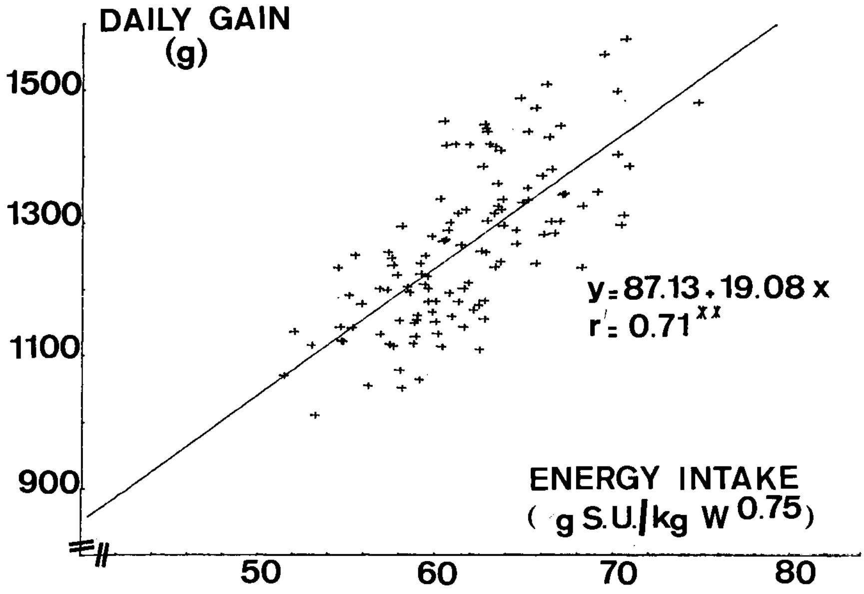

FIG. 4. — *Relationship, energy intake and daily gain by bulls (I).*

3.3 — *Feed Conversion*

3.3. 1. *Ad libitum energy intake*

Firstly the *total energy intake* (for maintenance and growth together) per kg liveweight gain (y = kg SU/kg gain) was expressed in function of the energy concentration (x = g SU/kg DM) (Figure 5). This relationship for the three groups was respectively :

Group I : $y = 4.31 + 0.61\,x$; $r = 0.12$ NS ; SD = 0.37
Group II : $y = 2.84 + 2.35\,x$; $r = 0.42^{**}$; SD = 0.37
Group III : $y = 3.79 + 0.22\,x$; $r = 0.06$ NS ; SD = 0.22

The higher correlation of group II seems a logical consequence of the low correlation between gain and energy density. Because of the positive correlation between energy concentration and energy intake (r = 0.67, 0.28 and 0.52), we could expect a luxury consumption at higher densities resulting in an unfavourable conversion due to a higher fat deposition. The regression equation for I and III do not sustain this hypothesis. Comparing these results with the data in Table 2, it becomes clear that there is no uniformity in the literature.

Rations with a decreasing energy density often result in a more unfavourable energy conversion (KAY *et al.*, 1970 and 1971 ; BOUCQUE *et al.*, 1971*a* and 1972 ; COTTYN *et al.*, 1973 ; LEVY *et al.*, 1974 and 1975 ; PIRIE and GREENHALGH, 1978) while there are trials with opposite results (HENRICKSON *et al.*, 1965 ; GEAY *et al.*, 1976*a*, *b* ; BOUCQUE, 1979) when the range of energy concentration was quite similar. Some authors established no clear effect (GUENTHER *et al.*, 1965 ; SWAN and LAMMING, 1970 ; BOUCQUE *et al.*, 1971*b* ; PRIOR *et al.*,

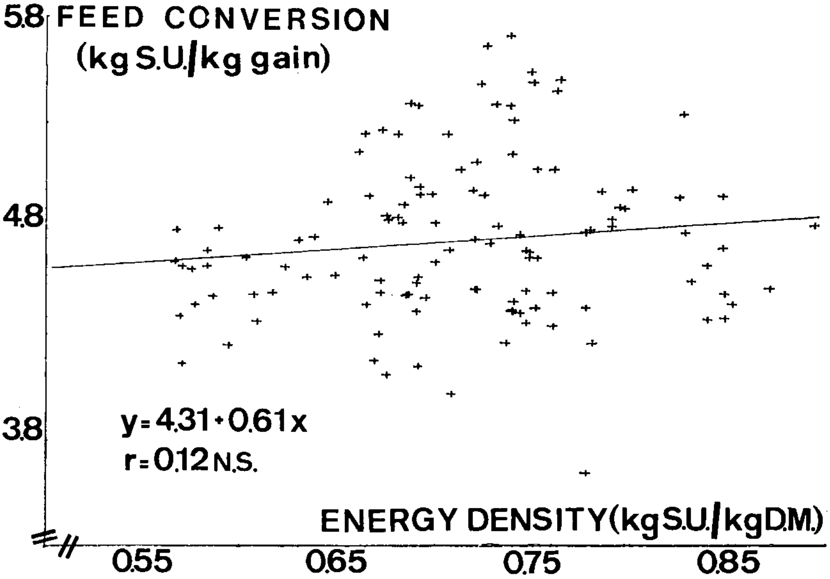

FIG. 5. — *Relationship energy density and energy utilzation (I),*

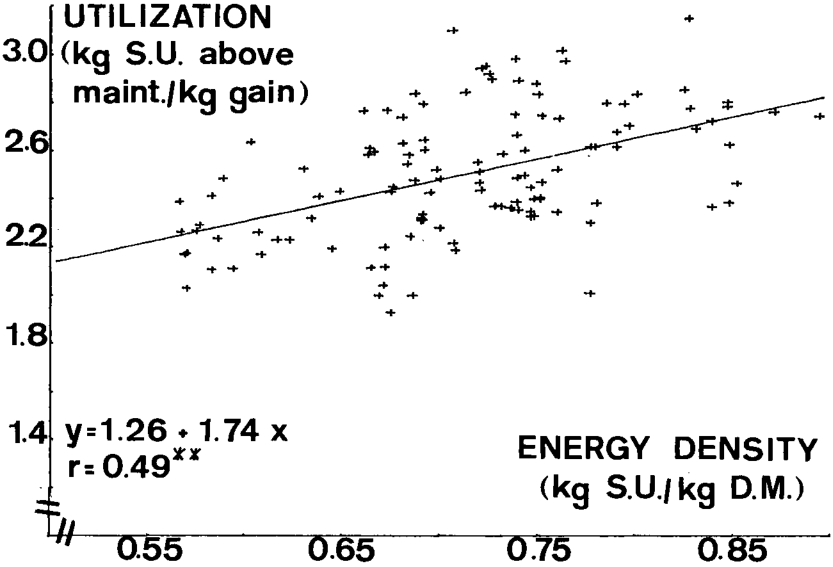

FIG. 6. — *Relationship energy density and energy utilization (I).*

1977). Certainly there exists a genotype-nutrition interaction (GEAY and ROBELIN, 1979). Rations with increasing energy density resulted in an unfavourable feed conversion of Salers bulls, while there was no influence on feed conversion of Charolais bulls (GEAY *et al.*, 1976*a*).

LANARI and SUSMEL (1979) concluded that there was no modification in efficiency due to energy concentration with beef breed bulls ($r = 0.10$), but the efficiency declined clearly with dairy breed bulls ($r = 0.44$), light steers ($r = 0.71$) and heavy steers ($r = 0.68$). When we took the liveweight (x_2 = kg LW) into account (beside the energy density x_1), we obtained the following multiple linear regression :

Group I : $y = 1.75 + 0.27\,x_1 + 0.0063\,x_2$; $R^2 = 0.31$; SD $= 0.31$.
Group II : $y = 1.06 + 1.41\,x_1 + 0.0060\,x_2$; $R^2 = 0.31$; SD $= 0.34$.
Group III: $y = 1.83 + 0.69\,x_1 + 0.0050\,x_2$; $R^2 = 0.19$; SD $= 0.20$.

The partial regression coefficients between liveweight (x_2) and energy conversion (y) are 0.56, 0.40 and 0.45 respectively.

Assuming that the maintenance requirements are constant, the energy intake *above maintenance* per kg liveweight gain (y = kg SU/kg gain) follows a more uniform pattern compared to the total energy consumption per kg gain (Figure 6 vs 5). In that case, there is a closer relationship with the energy concentration (x).

Group I : $y = 1.26 + 1.74\,x$; $r = 0.49^{**}$; SD $= 0.23$
Group II : $y = 0.73 + 1.90\,x$; $r = 0.44^{**}$; SD $= 0.28$
Group III : $y = 1.02 + 1.36\,x$; $r = 0.36^{*}$; SD $= 0.21$

Taking the average liveweight (x_2) into account, the following multiple linear regressions were calculated :

Group I : $y = 0.07 + 1.58\,x_1 + 0.00292\,x_2$; $R^2 = 0.37$; SD $= 0.23$.
Group II : $y = 0.71 + 1.89\,x_1 + 0.00006\,x_2$; $R^2 = 0.19$; SD $= 0.28$.
Group III: $y = -0.10 + 1.63\,x_1 + 0.00289\,x_2$; $R^2 = 0.19$; SD $= 0.21$.

The multiple regressions did not improve the relationship to any considerable extent. The relationship between the *total energy intake* (for maintenance and growth together) *per kg liveweight gain* (y) and the daily gain (x) demonstrates the beneficial effect of rapid growing animals :

Group I : $y = 6.55 - 0.00143\,x$; $r = -0.46^{**}$; SD $= 0.34$
Group II : $y = 6.81 - 0.00218\,x$; $r = -0.51^{**}$; SD $= 0.35$
Group III : $y = 4.14 - 0.00016\,x$; $r = -0.05$ NS ; SD $= 0.22$

The low r value for group III can be explained by the smaller range of liveweight gain (1 009 to 1 333 g) compared to group I (1 010 to 1 576 g) and II (899 to 1 397 g). Considering the *energy intake above maintenance* per kg liveweight gain (y) in function of the growth rate (x), the increase of energy consumed per unit of liveweight gain is generally rather low (except for group III) :

Group I : $y = 2.27 + 0.00018\,x$; $r = 0.08$ NS ; SD $= 0.27$
Group II : $y = 1.90 + 0.00012\,x$; $r = 0.03$ NS ; SD $= 0.31$
Group III : $y = 0.44 + 0.00136\,x$; $r = 0.46^{**}$; SD $= 0.20$

3.3. 2. *Different energy levels*

When a particular ration is fed at different levels one could expect the same result as when giving rations with different energy concentration to appetite. However, energy utilisation is more dependent on levels than on concentrations. The data in Table 3 mostly indicate a more favourable feed conversion at 80

TABLE 3

INFLUENCE OF ENERGY LEVEL ON FEED CONVERSION BY BULLS

Ref.	Breed	Liveweight interval (kg)	Energy level (%)	Unit	Feed conversion	
					Units	%
1	Red Danish	95 - 200	ad lib. = 100	Sc.f.u.	2.97	100
			85		2.98	100
			70		3.15	106
			55		3.38	114
		95 - 250	100		3.20	100
			85		3.17	99
			70		3.30	103
			55		3.54	111
		95 - 300	100		3.52	100
			85		3.39	96
			70		3.48	99
			55		3.79	108
		95 - 350	100		3.85	100
			85		3.65	95
			70		3.73	97
			55		4.07	106
		95 - 400	100		4.15	100
			85		3.95	95
			70		4.02	97
			55		4.43	107
		95 - 450	100		4.48	100
			85		4.27	95
			70		4.35	97
			55		4.83	108
		95 - 500	100		4.84	100
			85		4.61	95
			70		4.70	97
			55		5.28	109

TABLE 3 (Continued)

Ref.	Breed	Liveweight interval (kg)	Energy level (%)	Unit	Feed conversion	
					Units	%
21	MRY	249 - 427	100 (standard)	g S.U.	4200	100
		251 - 414	80		3670	87
		251 - 443	120		4360	104
		251 - 454	130		4420	105
31	Limousin	306 - 653	ad lib. = 100	Mcal ME	15.2	100
		304 - 654	81	Mcal ME	13.3	88
	Salers x Charolais	9-17 months	ad lib. = 100	Mcal ME	17.43	100
			97	Mcal ME	17.74	102
34	Salers	301 - 549	high = 100	Mcal ME	15.78	100
		299 - 560	moderate : 93		14.65	93
		299 - 555	high = 100		14.90	100
		289 - 539	moderate : 93		14.28	96
43	Friesian	240 - 489	ad lib. = 100	Mcal ME	22.45	100
		238 - 482	85		19.79	88
		231 - 496	70		23.51	105
		239 - 477	ad lib. = 100		28.58	100
		240 - 472	85		27.19	95
		237 - 476	70		26.59	93
45	Friesian	223 - 448	ad lib. = 100	Mcal ME	19.20	100
		216 - 460	80		19.66	102
		219 - 439	100		20.02	100
		217 - 439	80		20.04	100
52	Friesian	150 - 550	3700	g S.U.	4325	100
			4400		4312	100
			3700		4487	100
			4400		4232	94
57		96 - 555	LW x 10 + 800	g S.U.	3771	100
		96 - 514	LW x 10 + 200		3372	89

to 85 per cent of the *ad libitum* intake. Some investigations assume an interaction between energy level and energy concentration in the ration (LEVY *et al.*, 1974 ; ROHR and DAENICKE, 1978). Severe restriction (ANDERSEN, 1975) resulted in a pronounced unfavorable feed conversion. These statements can be explained by a less efficient energy utilisation at high energy levels due to a higher fat deposition (BERGEN, 1974) and higher energy requirements (VAN ES, 1976) on the one side, and to a relatively higher maintenance requirement at low densities on the other hand. ELSLEY (1976) also established this phenomenon for pigs. The genotype-nutrition-interaction was demonstrated by GEAY and ROBELIN (1979).

4. — Conclusion

Diets with increasing *energy densities,* fed *ad libtum* to intensively fattened bulls of Belgian dual purpose breeds generally resulted in a decreased daily dry matter and an increased energy intake. The positive effect on growth rate was only significant for the loose housed store bulls and the tied baby-beef bulls. For these two groups the energy density of the diet did not modify the feed conversion to any considerable extent. For the tied store bulls however, higher energy diets resulted in a less favourable feed conversion due to a negligible growth response to increased energy intake.

When different *energy levels* are applied, generally lower growth rates were obtained which in many cases resulted in a better feed efficiency. Following many literature data, the most favourable feed conversion was obtained when bulls were fed at 80 to 85 per cent of *ad libitum* intake.

Besides the study of parameters related to energy content of the diet, our investigation emphasized the beneficial effect of high growth rates on feed conversion.

Acknowledgment

The technical assistance of the personnel of the Biometric Unit of the Center for Agricultural Research at Merelbeke is gratefully acknowledged. The authors are grateful to Mr. A. OPSTAL and Mrs. C DE PRAETER for skilled technical assistance.

References

ANDERSEN H.R., 1975. The influence of slaughter weight and level of feeding on growth rate, feed conversion and carcass composition of bulls. *Livest. Prod. Sci.,* **2**, 341-356.

BAUMGARDT B.R., 1970. Control of feed intake in the regulation of energy balance In : *Physiology of digestion and metabolism in the ruminant. E*d. A.T. PHILLIPSON. Oriel Press, Newcastle upon Tyne. 235-253.

BERGEN W.G., 1974. Protein synthesis in animal models. *J. Anim. Sci.,* **38**, 1079-1091.

BOND J., HOOVEN Jr, N.W., WARICK E.J., HINER R.L., RICHARDSON G.V., 1972. Influence of breed and plane of nutrition on performance of dairy, dual-purpose and beef steers. II. From 180 days of age to slaughter. *J. Anim. Sci.,* **34**, 1046-1053.

BOUCQUE Ch.V., COTTYN B.G., BUYSSE F.X., 1971*a*. *Effects of varying haypellets barley rations on performance of beef cattle.* Atti del VI Simposio Internazionale di Zootecnia, Milano 15-17 Aprile, p. 361-376.

BOUCQUE Ch.V., COTTYN B.G., BUYSSE F.X., 1971*b*. Maïs déshydraté et orge aplatie dans les rations complètes pour taurillons à l'engrais. *Revue Agric.*, Brux. **24**, 1295-1305.

BOUCQUE Ch.V., COTTYN B.G., BUYSSE F.X., 1972. Valeur comparée d'agglomérés de maïs pâteux déshydraté et de farine de maïs dans des rations sèches complètes pour taurillons à l'engrais. *Revue Agric., Brux.* **25**, 1273-1292.

BOUCQUE Ch.V., COTTYN B.G., BUYSSE F.X., 1978. Bull fattening with dehydrated whole-corn-plant pellets compared with corn silage and high-moisture corn grain. Proc. 2nd Intern. *Green Crop Drying Congr.* University of Saskatchewan, Saskatoon, Canada. 20 - 25 August, p. 327-33.

BOUCQUE Ch.V., FIEMS L.O., COTTYN B.G., BUYSSE F.X., 1978. Utilisation of some industrial by-products in beef production. Proc. *European Congress for Improved Beef Productivity* Paris, 28-29 September 1978, Eli Lilly, Saint Cloud, France.

BOUCQUE Ch.V., 1979. Unpublished data.

BOUCQUE Ch.V., FIEMS L.O., COTTYN B.G., BUYSSE F.X., 1979. The effect of straw bedded loose houses or tie stalls on the performance of finishing bulls. *Livest. Prod. Sci.*, **4**, 369-378.

BUYSSE F.X., 1969. Intensive beef production. *Proc. 8th Intern. Congr. Nutrition.* Prague, August 28th - September 5th, 1969. Ed. by Excerpta Medica, Amsterdam, 1970, p. 747-749.

BUYSSE F.X., 1974. *Nieuwe inzichten omtrent de energetische voederevaluatie en daarmede aansluitende voerdernormen.* Communication of the Institute nr. 304.

BUYSSE F.X., BOUCQUE Ch.V., 1975. Present and future beef production systems in Belgium. In : *Improving the Nutritional Efficiency of Beef Production.* Com, Eur. Com. 5488^{e} Theix 14 - 17 October, 1975. Ed. by J.C. TAYLER and J.M. WILKINSON, UK, p. 15-35.

CALLOW E.H., 1961. Comparative studies of meat. VII. A comparison between Hereford, Dairy Shorthorn and Friesian steers on four levels of nutrition. *J. Agric. Sci.*, **56**, 265-282.

CONRAD H.R., 1966. Symposium on factors influencing the voluntary intake of herbage by ruminants : physiological and physical factors limiting feed intake. *J. Anim. Sci.*, **25**, 227-234.

COTTYN B.G., BOUCQUE Ch.V., 1969. Digestibilité et valeur alimentaire de pulpes séchées de betteraves sucrières. *Revue Agric., Brux.* **22**, 1101-1109.

COTTYN B.G., BOUCQUE Ch.V., AERTS J.V., BUYSSE F.X., 1978. L'utilisation de maïs-grain humide ou sec dans des rations destinées à la production intensive de viande bovine. *Revue Agric., Brux.* **31**, 295-306.

COTTYN B.G., BOUCQUE Ch.V., BUYSSE F.X., 1971. Influence de la mouture, de la finesse de mouture et de la mise en agglomérés de foin de prairie sur la production de viande bovine. *Revue Agric., Brux.* **24**, 975-991.

COTTYN B.G., BOUCQUE Ch.V., BUYSSE F.X., 1973. Possibilités d'utilisation de fanes et cosses de pois déshydratées et agglomérées pour la production de viande bovine. *Revue Agric., Brux.* **26**, 813-827.

DE BOER F., SMITS B., DIJKSTRA K.T.J., 1971. Voederhoeveelheid, groei en slachtkwaliteit bij jonge vleesstieren. *Landbouwk. Tijdschr.* **83**, 354-359.

DE BRABANDER D.L., AERTS J.V., BOUCQUE Ch.V., BUYSSE F.X., 1978. Intake of preserved grassland products by dairy cattle. *Proc. 7th General Meeting Europ. Grassld Fed. Constraints to Grass Growth and Grassland Output.* Ed. by Government Agric. Res. Centre Gent, Merelbeke, Belgium, p. 6.87-6.94.

DINIUS D.A., BAUMGARDT B.R., 1970. Regulation of food intake in Ruminants. 6. Influence of caloric density of pelleted rations. *J. Dairy Sci.*, **53**, 311-316.

DRAPER N.R., SMITH H., 1966. *Applied regression analysis.* Ed. J. WILEY, New York. 407 pp.

ELSLEY F.W.H., 1976. Limitations to the manipulation of growth. Proc. *Nutr. Soc.* **35**, 325-337.

FLACHOWSKY G., LÖHNERT, H.J., 1977. Pelletierte Fertigfuttermittel mit unterschiedlichen Strohanteilen in der Rindermast. 2. Futteraufname und Lebendmasseentwicklung. Tierernährung und Futterung - *Erfährungen, Ergebnisse, Entwicklungen.* **10**, 81-87.

FLACHOWSKY G., LÖHNERT H.J., HENNIG A., 1977. Pelletierte Fertigfuttermittel mit unterschiedlichen Strohanteilen in der Rindermast. 1. Versuchsanstellung und Pansenphysiologische Kennwerte. Tierernährung und Futterung - *Erfährungen, Ergebnisse, Entwicklungen* **10**, 73-80.

FLACHOWSKY G., 1979. Untersuchungen zum Einfluss einer unterschiedlichen Energiekonzentration in Rationen von Mastrindern verschiendener Genotypen auf Slachtkörperzusammensetzung und Ansatzkriterien. 1. Protein-, Fett- und Energiegehalt in Slachtkörper. *Arch. Tierernähr.* **29**, 17-26.

FREER M., CAMPLING R.C., 1963. Factors affecting the voluntary intake of food by cows. 5. The relationship between the voluntary intake of food, the amount of digesta in the reticulo-rumen and the rate of disappearance of digesta from the alimentary tract with diets of hay, dried grass and concentrates. *Br. J. Nutr.* **17**, 79-88.

GARRIGUS R.R., JOHNSON H.R., THOMAS N.W., FIRTH N.L., HARRINGTON R.B., JUDGE M.D., 1969. Dietary effects on beef composition. I. Quantitative and qualitative carcass traits. *J. Agric. Sci.*, Camb, **72**, 289-295.

GEAY Y., MALTERRE C., 1973. Croissance, rendement et composition des carcasses de jeunes bovins de différentes races. *Bull. Techn. du CRZV Theix* No. 14, 17-20.

GEAY Y., 1975. Fitting the diet to the potential of the animal. In : *Improving the Nutritional Efficiency of Beef Production.* Com. Eur. Com. 5488^e, Theix, 14-17 October 1975. Ed. by J.C. TAYLER and J.M. WILKINSON, UK, p. 333-347.

GEAY Y., ROBELIN J., BERANGER C., 1976*a*. Influence du niveau alimentaire sur le gain de poids vif et la composition de la carcasse de taurillons de différentes races. *Ann. Zootech.* **25**, 287-298.

GEAY Y., ROBELIN J., JARRIGE R., 1976*b*. *The influence of the metabolisable energy content of the diet on the efficiency of energy utilisation for young fattening bulls,* Proc. 7th Energy symposium - EAAP Publ. No. 19. Ed. M. VERMOREL and G-DE BUSSAC, Clermont-Ferrand, 1976, p. 225-228.

GEAY Y., ROBELIN J., 1979. Variation of meat production capacity in cattle due to genotype and level of feeding : genotype - nutrition interaction. *Livest. Prod. Sci.* **6**, 263-276.

GUENTHER J.J., BUSCHMANN D.H., POPE L.S., MORRISON R.D., 1965. Growth and development of the major carcase tissues in beef calves from weaning to slaughter weight, with reference to the effect of plane of nutrition. *J. Anim. Sci.* **24**, 1184-1191.

HENRICKSON R.L., POPE L.S., HENDRICKSON R.F., 1965. Effect of rate of gain of fattening beef calves on carcass composition. *J. Anim. Sci.* **24**, 507-513.

KAY M., MACDEARMID A., MASSIE R., 1970. Intensive beef production. 11. Replacement of cereals with ground straw. *Anim. Prod.* **12**, 419-424.

KAY M., MASSIE R., MACDEARMID A., 1971. Intensive beef production. 12. Replacement of concentrates with chopped dried grass. *Anim. Prod.* **13**, 101-106.

LANARI D., SUSMEL P., 1979. Feed-lot beef production from maize silage. *Euromais, European Maize Congress,* Cambridge, 3 - 7 September.

LEVY D., HOLZER Z., VOLCANI R., 1968. The effect of age and liveweight on feed conversion and yield of saleable meat of intact Israeli-Friesian male calves. *Anim. Prod.* **10**, 325-330.

LEVY D., HOLZER Z., VOLCANI R., 1970. Concrete slatted floors vs bedding for fattening Israeli-Friesian bull calves. *J. Anim. Sci.* **31**, 815-820.

LEVY D., HOLZER Z., NEUMARK H., AMIR S., 1974. The effects of dietary energy content and level of feeding on the growth of Israeli-Friesian intact male cattle. *Anim. Prod.* **18**, 67-73

LEVY D., HOLZER Z., FOLMAN Y., 1975. Effect of concentrate roughage ratio on the production of beef from Israeli-Friesian bulls slaughtered at different liveweights. *Anim. Prod.* **20**, 199-205.

LEVY D., HOLZER, Z., FOLMAN Y., 1976. Effect of plane of nutrition, diethylstilboesterol implantation and slaughter weight on the performance of Israeli-Friesian intact male-cattle. *Anim. Prod.* **22**, 55-59.

MEYER J.H., HULL J.L., WEITKAMP W.H., BONILLA S., 1965. Compensatory growth responses of fattening steers following various low energy intake regimes on hay or irrigated pasture. *J. Anim. Sci.* **24**, 29-37.

MONTGOMMERY M.J., BAUMGARDT B.R., 1965. Regulation of food intake in ruminants. 1. Pelleted rations varying in energy concentration. *J. Dairy Sci.* **48**, 569-579.

PICKARD D.W., SWAN H., LAMMING G.E., 1969. Studies on the nutrition of ruminants. 4. The use of ground straw of different sizes for cattle from twelve weeks of age. *Anim. Prod.* **11**, 543-550.

PIRIE R., GREENHALGH J.F.D., 1978. Alkali treatment of straw for ruminants. I. Utilization of complete diets containing straw by beef cattle. *Anim. Feed Sci. Technol.* **3**, 143-154.

PRIOR R.L., KOHLMEIER R.H., CUNDIFF L.V., DIKEMAN M.E., CROUSE J.D., 1977. Influence of dietary energy and protein on growth and carcass composition in different biological types of cattle. *J. Anim. Sci.,* **45**, 132-146.

RICHARDSON D., SMITH E.F., BAKER F.H., COX R.F., 1961. Effects of roughage-concentrate ratio in cattle fattening rations on gains, feed efficiency, digestion and carcass. *J. Anim. Sci.* **20**, 316-318.

ROHR K., DAENICKE R., 1978. Untersuchungen über den Einfluss des Fütterrungsniveaus und der Energieconcentration der Ration auf Pansenfermentation, Gewichtszuwachs und Slachtkörperzusammensetzung schwarzbunter Mastbullen. *Züchtungskunde,* **50**, 67-77.

SWAN H., LAMMING G.E., 1970. Studies on the nutrition of ruminants. 5. The effect of diets containing up to 70 per cent ground barley straw on the liveweight gain and carcass composition of yearling Friesian cattle. *Anim. Prod.* **12**, 63-70.

VAN ES A.J.H., 1976. Meat production from ruminants. *Proc. Symp. on Growth and Productivity of Meat Animals.* Eds. D. LISTER, D.N. RHODES, V.R. FOWLER, H.F. FULLER, Plenum Press, Prestbury, p. 391-401.

WALDMAN R.C., TYLER W.J., BRUNGARDT V.H., 1971. Changes in carcass composition of Holstein steers associated with ration energy level and growth. *J. Anim. Sci.* **32**, 611-619.

WEISS R.L., BAUMGARDT B.R., BARR G.R., BRUNGARDT V.H., 1967. Some influences on rumen volatile fatty acids upon carcass composition and performance in growing and fattening steers. *J. Anim. Sci.* **26**, 389-393.

WITT M., ANDREAE U., KALLWEIT E., 1971. Einfluss unterschiedlicher Fütterungsintensität auf Wachstum und Fettansatz beim Rind, untersucht an eineiigen Zwillingsbullen. *Züchtungskunde* **43**, 173-186.