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Intake in relation to the animal

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Abstract

Feed intake variations between animals are reviewed according to liveweight, fatness, breed, sex, previous growth and production systems. In generally they appear to be great and are partly related to digestive tract development and fatness. If fatness seems to depress voluntary feed intake for a given animal, an inverse relationship appears between breeds having different earliness.

An attempt to quantify and predict the voluntary intake capacity of different kinds of cattle with the "fill units" system is proposed and discussed.

Résumé

Variations de l'ingestion liées à l'animal

Les facteurs de variations entre animaux des quantités ingérées sont passés en revue : le poids vif, l'état d'engraissement, la race, le sexe, la croissance antérieure et le système de production. Les variations sont généralement importantes et en partie reliées au développement du tube digestif et à l'état d'engraissement. Si pour un même animal l'augmentation de l'état d'engraissement semble diminuer la capacité d'ingestion, on observe l'inverse quand on compare des animaux de races ayant des « précocités » différentes. Le système des « unités d'encombrement » qui essaye de quantifier et de prédire la capacité d'ingestion des différentes catégories d'animaux est présenté et discuté.

Introduction

Knowlegde regarding voluntary intake of animals is of importance for appropriate feeding of cattle. It varies both with animals and with diet characteristics. The main characteristics of the animal are liveweight, fatness, genotype, sex and shape of the growth curve in relation to the production system. Other factors independent of feed, such as health and welfare, housing and general environment, can modify intake. This paper will not deal with such factors but will examine the variations directly related to the animal itself.

Although a large amount of data on feed intake is available, variations in intake related to the nature and composition of the diet are so great that those related to animals do not stand out clearly. Therefore intake of different kinds of animals must be studied only when they receive the same type of diet. Intake of different animals eating different diets can also be compared if feed intake is expressed by using units which are independent of the diet, for example, the French "fill units" system.

I. — Feed intake variations between animals

We shall try to analyse the effects of different factors on variation between animals, using data on different kinds of animals receiving the same diet. In fact, available data are rather scarce ; either they concern only a few animals or the composition of the diets is too variable for the data to be comparable.

A. — *Variations according to weight and fatness*

For a given animal, voluntary dry matter intake increases with liveweight, but not linearly. Therefore, intake expressed as a percentage of liveweight decreases

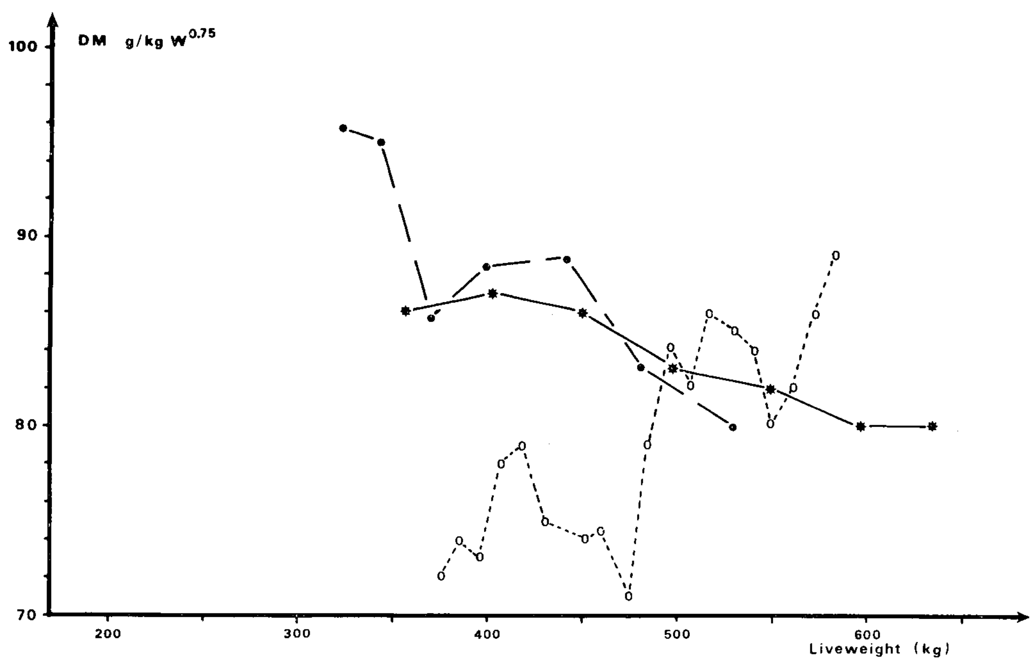

FIG. 1. — *Variations of DM intake curves from different sources of data with Charolais bulls.*

●— —● 75 per cent maize silage — 25 per cent concentrate (BONSEMBIANTE, in press).
———— 75 per cent maize silage — 25 per cent concentrate (GEAY, unpublished data).
○ - - - - - ○ 90 per cent concentrate — 10 per cent hay (GEAY, 1979).

with liveweight and varies less than total dry matter intake. Intake is generally related to metabolic weight ($W^{0.75}$) and decreases with liveweight. However, to our knowledge, nobody has given any mathematical expression of intake related to liveweight which can be constant throughout the life of the animal.

The shape of this variation of DM intake per $W^{0.75}$ according to bodyweight, differs in various sources of data (fig. 1). However, for a given type of animal and for a given diet, some general relationship between DM/$W^{0.75}$ and W, using a sufficient number of data, may be defined as shown in figure 2 for young dairy bulls between liveweights of 150 and 550 kg.

Since fatness increases simultaneously with liveweight (fig. 3) and since body fat content can regulate animal intake, a decrease in intake per $W^{0.75}$ according to liveweight can be related to an increase in fatness. It is impossible to separate the influence of these two factors on the same animal. However, in a large group of animals having the same characteristics and liveweights, the effects of individual variations of fatness on feed intake may be taken into consideration. We have not been able to establish such a significant relationship from our data at the present time. However, if we compare different populations, such as Friesian and Charolais × Friesian, the higher intake fits the higher body fat content (fig. 3). Therefore, some differences in intake appear between breeds, independent of weight and fatness.

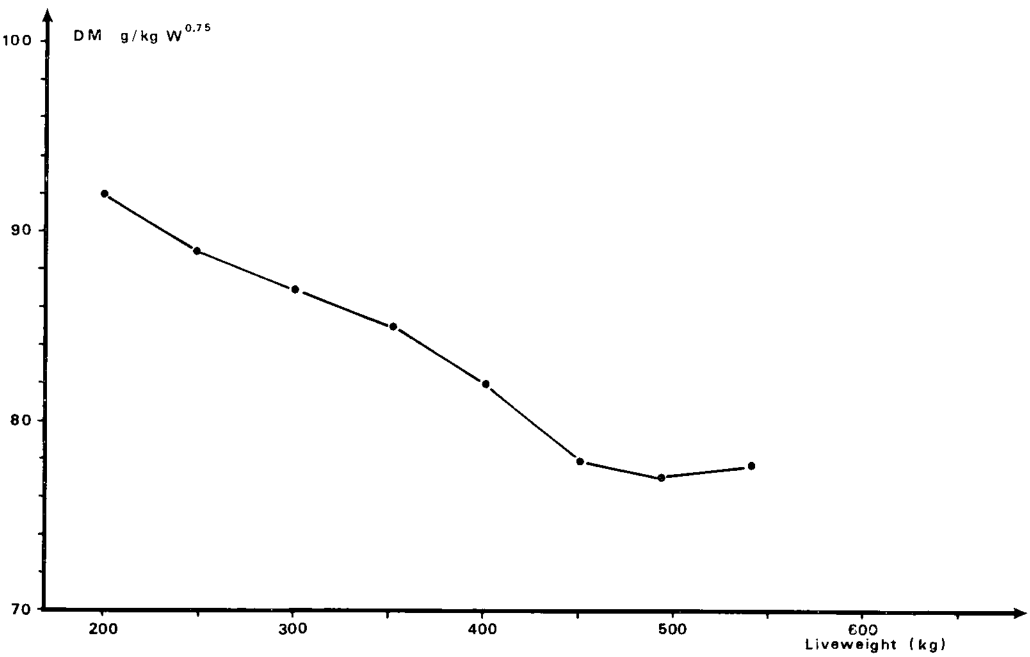

FIG. 2. — *Variations of DM intake/$W^{0.75}$, according to liveweight of young dairy bulls fed on maize silage (75 per cent) diet*
(average values from 54 groups of 5 to 20 bulls) (GEAY and MICOL, unpublished data).

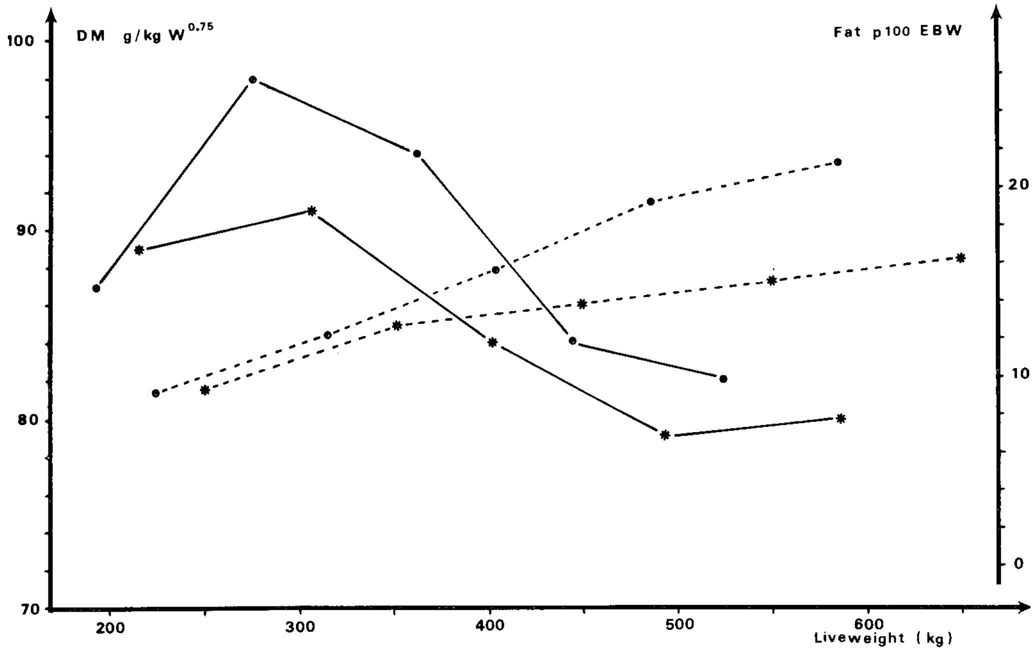

FIG. 3. — *Evolution of DM intake / $W^{0.75}$ (———) and of fat content of empty body weight (- - - -) according to liveweight from Friesian (●) and Charolais × Friesian (*) young bulls* (GEAY and ROBELIN, unpublished data).

B. — *Variations according to breed*

From trials which aimed at comparing different breeds and crosses or progeny, variations of intake according to genotype may be shown only if animals are kept on the same diet and under the same conditions.

COLLEAU and BONAITI (unpublished) compared several dairy and beef breeds and crosses, with young bulls fattened between 9 and 15 or 18 months of age, on a ground and pelleted diet (70 per cent lucerne, 30 per cent sugar beet pulp) fed *ad libitum* (Table 1). Cattle from dairy breeds eat more dry matter than dual purpose breeds or crosses, and much more than beef breeds. Within the group of dairy breeds and crosses, as within the group of beef breeds, intake can be related to body composition, i.e. fat content and development of digestive tract. Average intake increases with carcase fatness and also with the percentage of digestive tract in empty bodyweight. A large variation appears between extreme types such as, on the one hand, Holstein cattle with high milk production potential, high fat and low muscle proportions, and on the other hand, Limousin cattle (or double muscle Charolais) with poor milk production, low fat and very high muscle proportions.

These French results are confirmed by BONSEMBIANTE (1979) in Italy, using a large proportion of maize silage in the diet (Figure 4). Limousin bulls always have a lower intake but Charolais bulls are in an intermediate position and vary very much during the period.

TABLE 1

VARIATIONS IN VOLUNTARY DM INTAKE BETWEEN BREEDS (YOUNG BULLS FATTENED BETWEEN 9 AND 15 OR 18 MONTHS, WITH A GROUND AND PELLETED DIET FED *ad libitum*. 70% LUCERNE, 30% DRY SUGAR BEET PULP) BERANGER (1971); COLLEAU AND BONAITI (UNPUBLISHED DATA).

Breeds	Number of Animals	DM intake ($g/kg W^{0.75}$)			At slaughtering		
		At 350 kg LW	At 450 kg LW	At 550 kg LW	Carcase weight (kg)	Fat percentage on carcase	Empty digestive tract % Empty body weight
Fattening from 9 to 15 months:							*
Holstein Friesian	32	119	110	-	285	18.9	6.5
Holstein x Normand	30	114	104	-	307	18.9	5.9
Normand	59	104	97	-	290	16.3	5.8
Charolais x Normand	15	106	101	-	318	15.7	5.4
Fattening from 9 to 15 months and 18 months:							*
Hereford	39	111	88	-	262	15.4	8.2
Maine Anjou	30	119	116	102	358	12.8	7.5
Charolais	45	111	103	87	340	10.5	6.6
Limousin	32	102	92	82	323	9.7	5.9
Charolais fattened from 9 to 15 and 20 months:							
Normal	23	-	116	107	369	12.2	5.3
Double muscle	23	-	95	92	364	5.0	4.7

* Animals from the two groups of breed were slaughtered in two different places where empty body weight and empty digestive tract were not measured in similar conditions.

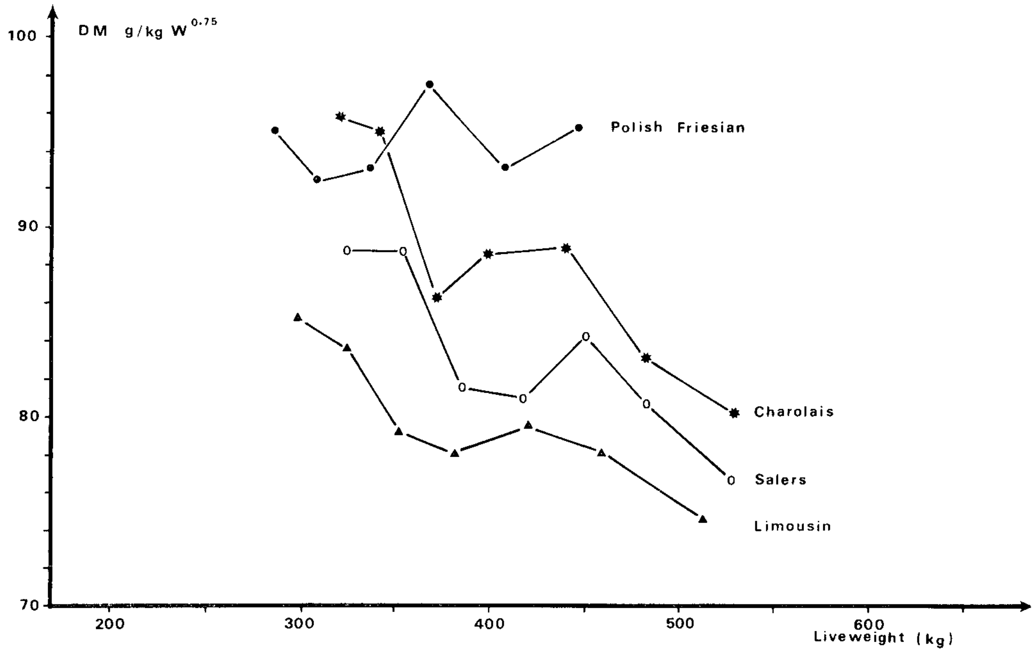

FIG. 4. — *Variations of DM intake/$W^{0.75}$ of young bulls from different breeds, fed on maize silage diet* (BONSEMBIANTE and BITTANTE, in press).

In current experiments at Clay Centre, Nebraska, with steers, a significant influence of the breed or crosses on voluntary energy intake has been indicated by SMITH *et al.*, (1976). Ranking of genotypes according to their muscularity is similar to the ranking done in French experiments, but with less variations.

When we compare the evolution of intake between early weaned dairy bulls and Charolais bulls from suckling herds, all fattened on a maize silage diet (70 - 80 per cent of total DM intake) we do not find the expected difference in intake (Figure 5). The previous system of feeding and rearing the animals may influence the subsequent intake. So it is rather difficult to draw comparisons between genotype with animals from dairy and beef herds.

C. — *Variations according to sex*

From many comparisons between bulls, steers and heifers of the same type, under the same conditions (see few data in Table 2), no clear differences in feed intake appear, regardless of the energy concentration of the diet and the breed of cattle (early or late maturing).

D. — *Variations according to previous growth and production systems*

In many experiments on compensatory growth, animals which have been underfed subsequently eat more dry matter per unit of bodyweight than comparable

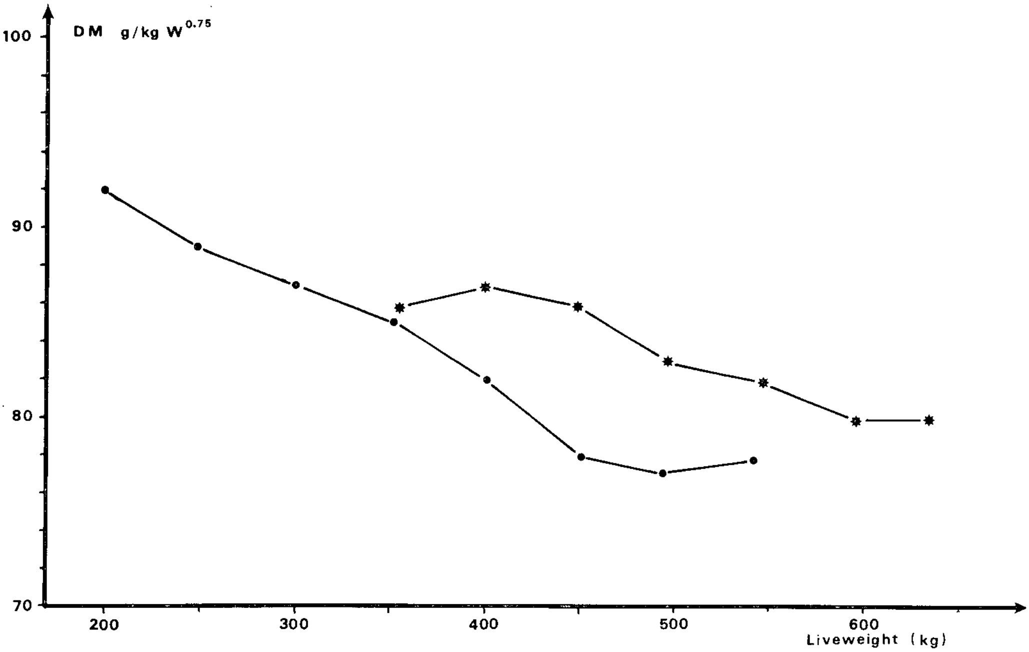

FIG. 5. — *Evolution of DM intake/$W^{0.75}$ during fattening period in dairy bulls, early weaned* (●) *and in Charolais bulls from beef herds* (*), *fed on maize silage* (*75 per cent*) *diet* (*mean values of 54 groups and 30 groups of cattle*) (GEAY and MICOL, unpublished data).

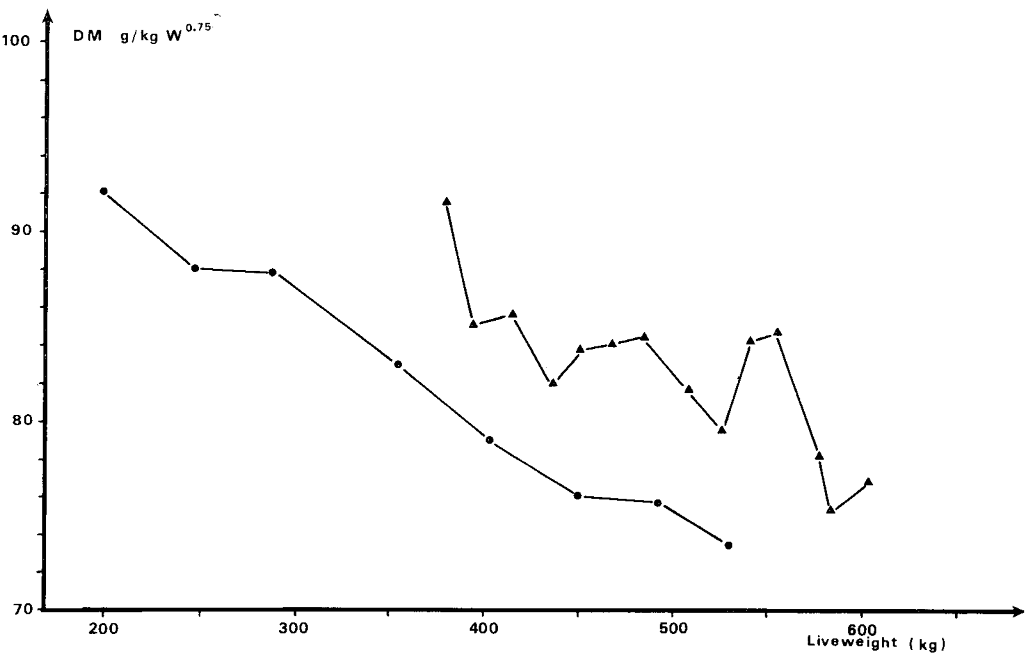

FIG. 6. — *Evolution of DM intake/$W^{0.75}$ during fattening period in Normand bulls weaned at 2-3 months* (●) *and in Normand bulls weaned at 8 months* (▲) (LE NEINDRE and MICOL, unpublished data).

TABLE 2

VARIATIONS IN VOLUNTARY DM INTAKE ACCORDING TO SEX

Authors	Experimental conditions		Relative value of intake ($DM/W^{0.75}$) according to sex (Number of animals)		
	Animals	Diets	Bulls	Steers	Heifers
Hedrick (1969)	Hereford 185 to 445 kg	76% ground ear corn 24% concentrate	100 (6)	79 (12)	83 (12)
	Hereford 310 to 530 kg	80% concentrate 20% hay	100 (12)	99 (12)	101 (12)
	Hereford 310 to 510 kg	80% concentrate 20% hay	100 (14)	113 (14)	103 (14)
Geay and Malterre (1971)	Salers 475 to 610 kg	65% lucerne hay 35% concentrate	100 (20)	99 (20)	- -
Beranger and Geay (1971)	Charolais 375 to 545 kg	65% pelleted lucerne 35% beet	100 (13)	102 (13)	- -
Price (1978)	Hereford 230 to 500 kg	20% hay 80% concentrate	100 (8)	100 (7)	- -
		50% hay 50% concentrate	100 (8)	104 (7)	- -
		80% hay 20% concentrate	100 (8)	101 (7)	- -

TABLE 2 (Continued)

Authors	Experimental conditions		Relative value of intake ($DM/W^{0.75}$) according to sex (Number of animals)		
	Animals	Diets	Bulls	Steers	Heifers
Geay (1979)	Charolais x Salers Bulls 310 to 540-580 kg	80% hay 20% concentrate	100 (10)	- -	105 (10)
	Heifers 285 to 440-480 kg	20% hay 80% concentrate	100 (5)	- -	103 (5)
Geay*	Charolais x Salers 300 to 550 kg	75% maize silage 25% concentrate	100 (14)	- -	99 (14)
	460 to 600 kg		- -	100 (14)	106 (14)
Micol*	Charolais 575 to 725 kg	85% maize silage 15% concentrate	100 (5)	102 (6)	- -
	Charolais x Normand 560 to 690 kg		100 (6)	96 (6)	-
	Normand 575 to 725 kg		100 (6)	94 (6)	- -
	Friesian 515 to 620 kg		100 (6)	100 (6)	- -
Micol*	Limousin 400 to 640 kg	80% maize silage 20% concentrate	100 (12)	94 (11)	97 (12)

* Unpublished data

TABLE 3

EFFECT OF DIFFERENCES IN LEVEL OF FEEDING DURING A PERIOD (I)(LOW VS HIGH) ON VOLUNTARY FEED INTAKE DURING THE SUBSEQUENT PERIOD (II)

Authors	Experimental Conditions				Gain during Period I (kg/d)			Intake during Period II ($g\ DM/W^{0.75}$)		
	Number of animals	Initial weight (kg)	Duration (d) Period I	Duration (d) Period II	Low	High	L/H	Previous low	Previous high	L/H
Meyer (1965)	2 x 12 steers	183	172	149	0.35	0.80	0.44	103	92	1.12
Béranger (1973)	2 x 18 twin steers	238	182	295	0.16	0.69	0.23	95	85	1.12
Boucqué (1975)	2 x 51 bulls	180	154	257	0.42	0.73	0.58	93	99	1.04
	2 x 50 bulls	166	154	252	0.47	0.76	0.61	92	89	1.03
Lopez Saubidet (1976)	2 x 24 steers	196	112	240	0.51	0.95	0.54	111	101	1.10
		189	112	224	0.27	0.95	0.28	116	101	1.15
		198	112	238	0.01	0.95	0.01	125	101	1.24
Béranger (1977)	2 x 26 bulls	461	192	92	0.73	1.06	0.69	92	84	1,10
	2 x 19 bulls	430	182	101	0.87	1.09	0.80	89	84	1.06

animals which have previously been well fed. (Review of WILSON and OSBOURN, 1960 ; of ALLDEN, 1970).

Several data presented in Table 3 show that these differences are important (more than 10 per cent) with one year old steers after a severe underfeeding period, but still appear (6 to 9 per cent) with two year old bulls after a rather good feeding period with only slight differences in feeding level between groups. These differences may partly be due to differences in the development of the digestive tract which is still growing during the underfeeding period. In our trials (BERANGER, 1973), at slaughter after compensatory growth, the digestive tract of previously underfed steers accounts for 6.5 per cent of empty weight versus 5.9 per cent for continuously well fed animals.

Similar differences in digestive tract and intake were found by LE NEINDRE *et al.* (unpublished) comparing calves receiving different amounts of milk and grass during their first eight months. During the suckling period a low level of milk induces higher intake of grass, greater digestive tract development and higher intake of forages during the subsequent fattening period (Table 4).

Therefore, not only the level but also the types of feeding and management system can result in differences in subsequent intake. For example, if we compare bulls of the same breed (Normand) receiving the same maize silage diets during the fattening period, animals from suckling systems (weaned at 8 months) have a higher intake at the same weight than animals weaned early (2 - 3 months) (Figure 6). In this comparison we found the same type of curves as in a compa-

TABLE 4

INFLUENCE OF THE LEVEL OF MILK CONSUMPTION DURING SUCKLING PERIOD ON FEED INTAKE AND ON RUMEN DEVELOPMENT (44 NORMAND CALVES PER GROUP)
LE NEINDRE, unpublished data

	Low level of milk	High level of milk
Suckling period from 3 to 8 months		
Average weight (kg)	211	239
Daily gain (kg)	1.05	1.36
Intake (kg): Milk	4.39	8.24
Grass dry matter	3.65	3.18
Weight of empty rumen % of empty body weight	1.98	1.67
Fattening period from 8 to 15 months		
Average weight (kg)	439	477
Daily gain (kg)	1.20	1.12
Total dry matter intake: kg/d	8.07	8.42
$g/W^{0.75}$	84.2	82.5

rison between bulls from dairy herds and Charolais from beef herds (Figure 5). Therefore, some interaction between breeds and systems of feeding or management does occur with variations in voluntary intake.

***

As ruminant voluntary intake is controlled both by physical and metabolic regulation, variations between animals depend on rumen development which limits the gut fill, and also on the physiological state, especially in relation to body fat content. If fatness seems to depress appetite for a given animal, it does not appear to be the main factor of metabolic regulation. Indeed, bulls, steers and heifers which vary widely in fatness have a similar intake. Furthermore, when different breeds are considered, intake increases with body fat content.

Intake differences between animals depend on the composition of the diet according to the predominant type of regulation. With a forage diet, variations are probably related essentially to the differences in digestive tract development and cannot be expected to be very great. Morever, they are influenced by feeding and management at the different stages of growth, which can modify rumen development. With concentrated or pelleted diets, variations in intake between animals, which are linked to metabolic regulation, seem to be wider and not related to fatness. In fact, complex interactions between many factors can cause such variations. For example, breeding and selection for milk production indirectly increased feed intake capacity, while selection in beef cattle had the reverse effect, if any.

There is a lack of accurate comparisons between different kinds of growing and fattening animals and an analysis of the factors which might explain these variations is needed.

II. — Feeding standard and prediction of intake capacity

A. — *Evaluation of feed intake capacity in "fill unit" system regardless of type of feedstuff*

Recently, in France, the INRA group has built up a system (see Appendix 1) which ascribes one single value to the appetite of each category of animal, regardless of the food given, and one single value to the ingestibility of each forage, regardless of the category of animal it is fed to. This system of predicting the voluntary dry matter intake is expressed in "fill unit" (unité d'encombrement, UE). For a given animal, the "fill value" of a forage is determined by dividing the voluntary DM intake of a reference feedstuff, which is young pasture grass, by the voluntary DM intake of the forage. For the sake of simplicity, two fill values have been retained, one for sheep and one for cattle. Moreover, the fill unit value of concentrates is variable depending on the associated forage fill value and on the rate of substitution occuring between concentrate and forage. Having applied the calculated fill values of the diet to the observed DM intakes of animals in many trials, we have calculated the feed intake capacity of different kinds of cattle in terms of fill units.

TABLE 5

CHARACTERISTICS OF TRIALS USED TO DETERMINE THE FEED INTAKE CAPACITY OF GROWING AND FATTENING CATTLE

Types of cattle	Number of groups*	Nature of diet
Early maturing young bulls from dairy breeds	54 40	75% maize silage and 25% concentrate 90-50% grass silage and 10-50% concentrate
Late maturing young bulls from beef breeds	30	75% maize silage and 25% concentrate
Steers slaughtered between 15 and 20 months	6	100-75% grass and 0-25% concentrate 65% lucerne hay and 35% concentrate
Steers slaughtered between 24 and 30 months	22	80% maize silage and 20% concentrate
Steers slaughtered between 36 and 40 months	6	70% grass silage and 30% concentrate Lucerne hay, maize silage and concentrate
Growing animals	13	Hay or grass silage
Growing females from dairy breeds	15	Hay or grass silage

* 5 - 20 animals per group

TABLE 6

FEED INTAKE CAPACITY EXPRESSED IN 'FILL UNITS' OF GROWING AND FATTENING CATTLE

	Types of cattle \ Liveweight (kg)	150	200	250	300	350	400	450	500	550	600	650	700
FATTENING CATTLE	Early maturing young bulls from dairy breeds	3.6	4.7	5.6	6.5	7.2	7.8	8.2	8.6	9.1	-	-	-
	Medium maturing young bulls	3.6	4.7	5.6	6.5	7.2	7.8	8.2	8.6	9.1	9.6	-	-
	Late maturing young bulls from beef breeds	-	-	5.1	6.0	6.9	7.8	8.5	9.1	9.5	9.7	9.9	-
	Steers slaughtered between 15 and 20 months*	-	-	-	7.1	8.0	8.8	9.3	9.4	-	-	-	-
		-	-	-	-	8.0	8.8	9.6	10.0	10.1	-	-	-
	Steers and heifers slaughtered between 24 and 30 months*	-	-	-	-	-	8.4	9.2	9.9	10.0	-	-	-
		-	-	-	-	-	-	9.2	10.0	10.7	10.7	-	-
		-	-	-	-	-	-	-	10.0	10.7	11.4	11.4	-
	Steers slaughtered between 36 and 40 months*	-	-	-	-	-	-	-	10.0	10.8	11.5	11.4	-
		-	-	-	-	-	-	-	-	10.8	11.5	12.2	12.1
	Young heifers intensively fed and slaughtered between 14 and 15 months	-	-	5.3	6.4	7.2	8.0	8.7	9.2	9.5	-	-	-
GROWING CATTLE	Growing males	-	4.6	5.5	6.3	7.0	7.8	8.5	9.2	9.9	10.5	-	-
	Growing females from beef calves	-	4.6	5.5	6.3	7.0	7.8	8.5	9.2	9.9	-	-	-
	Growing females from dairy breeds	-	4.9	6.0	7.0	8.0	8.9	9.7	10.4	11.1	-	-	-

* Feed intake capacity of these three categories of cattle is related to the initial liveweight at the beginning of the fattening period (first value of the line)

B. — *Intake capacity of various kinds of animals*

To determine the feed intake capacity of growing and fattening animals we considered the different categories of cattle separately, taking into account the sources of variation described previously: young bulls according to earliness of breed, steers or heifers fattened at different ages, growing steers and heifers (tables 5 and 6). We pooled voluntary feed intake data obtained with low concentrate diets, principally with maize silage and grass silage (table 5). We calculated the average intake in UE/$W^{0.75}$ and the shape or the variation curve of this intake with liveweight during the feeding period. Results obtained in this manner (table 6 and fig. 7) indicate a higher feed intake capacity for early maturing bulls from dairy herds than for late maturing bulls from beef herds, up to 400 kg, at the same weight. Likewise, intakes of 2 year and 3 year old steers, which had a discontinuous growth, appear to be higher than the intake noted for young bulls.

As the group of animals used for these calculations might have a somewhat different energy intake from standard animals, data have been corrected to make a good adjustment between the DM intake and the previous energy feeding standards of each kind of animal.

For some categories of cattle such as one year and two year old heifers we did not find enough data from animals fed *ad libitum* on high forage diets to calculate the feed intake capacity with sufficient accuracy. Therefore, since there was no apparent difference according to sex, for the time being we have proposed standards from medium maturing young bulls or from 2 year old steers for these two categories of animals.

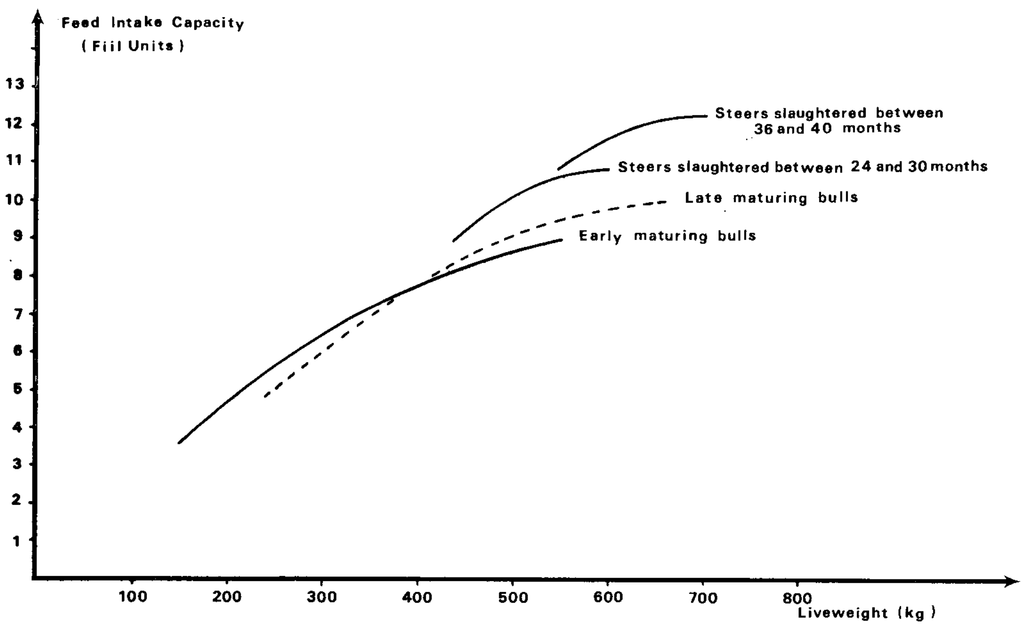

FIG. 7. — *Evolution of feed intake capacity expressed in "fill units" for different kinds of cattle.*

C. — *Discussion*

This system is a first attempt to propose voluntary feed intake standards. At present it is quite imperfect : firstly, it is based only on the physical regulation of the intake. Furthermore, each food should have several fill unit values according to the type of animal it is fed to, whereas, for the sake of simplicity, only two values have been retained. Lastly, the standards assume that no high interaction exists between diet type and animal type, which is not at all certain. Both additional and more accurate data are needed to obtain better fill unit values of feeds and to determine the forage concentrate substitution relationship accurately.

Nonetheless, with the present system it is possible to pool together large amounts of data on the voluntary intake of animals fed on different types of diet. The values of feed intake capacity obtained in this way remain very variable, due firstly to the inaccuracy of the system and also, certainly, to the large variations between animals in true feed intake capacity. In spite of these variations it appears possible to propose values for feed intake capacity for each category of cattle which are acceptable for predicting voluntary intake when formulating rations. However, more accuracy is required in evaluating feeds and diet fill values, and also a lot of additional data about different kinds of animals, in order to be able to study the variations in feed intake capacity between animals in this way.

Conclusion

Intake variations related to the animal appear to be great. They are linked to wide individual variations and also to differences between the type of animal, especially between breeds, as has been pointed out in this paper. The variations are rather difficult to explain, quantify and predict. To succeed involves the use of concepts, systems and units which enable very large amounts of voluntary intake data to be assembled, as we have attempted to do. At the same time, it is of importance to improve the basic knowledge of the physiological factors involved in voluntary intake regulation of the animal itself.

The field of investigation is vast and needs to be developed, bearing in mind that cattle will have to consume more and more forage in the future.

Acknowledgment

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Appendix 1

*Principles of "fill unit" system**
(Unités d'encombrement)

Voluntary intake depends both on feed ingestibility (maximum forage voluntary DM intake for a given animal) and on animal feed intake capacity (maximum voluntary DM intake of the animal for a given forage). Furthermore, concentrates influence the voluntary forage DM intake according to the substitution rate between forage and concentrates.

By using the "fill unit" it may be possible to ascribe one single value to the feed intake capacity of each category of animal regardless of the food given, and one single value to the ingestibility of each forage regardless of the category of the animal it is fed to.

1. The reference feedstuff which has a fill unit value of 1 (1 UE) is young pasture grass (DOM = 0.77, crude fibre = 25 per cent, crude protein = 15 per cent). Its voluntary intake varies with animals according to their physiological status; it amounts to 75 DM/kg $W^{.75}$ per dayfor the standard mature sheep, and 122.6 g DM/kg $W^{0.75}$ per day for the standard dairy cow.

*) Système des Unités d'Encombrement pour les Bovins. Bull. Techn. CRZV Theix - INRA, Décembre 1979 (38), 57-59.

2. For a given animal the fill value of a forage is calculated by dividing voluntary DM intake of reference grass by voluntary DM intake of forage. For the sake of simplicity two fill values have been retained for each forage:

$$\text{for adult sheep UEM} = \frac{75}{\text{Forage DM intake}/W^{0.75} \text{ by standard sheep}}$$

$$\text{for cattle UEB} = \frac{122.6}{\text{Forage DM intake}/W^{0.75} \text{ by standard dairy cow}}$$

The range of variation is from 0.85 UEM for very young grass to 2.3 UEM for straw in sheep, and from 0.9 UEB to 1.8 UEB for the same feeds in cattle.

3. In a mixed diet the fill unit system is additive, and the feed intake capacity of the animal is assumed to be constant whatever the diet:

Feed intake capacity = forage DM intake × forage fill value + concentrate DM intake × concentrate fill value.

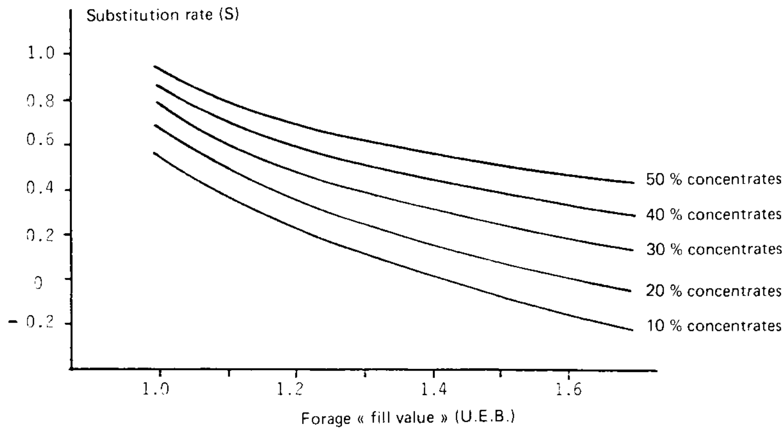

FIG. 1. — *Substitution relationship between forage and concentrates for growing and fattening cattle.*

Therefore the fill value of concentrates varies according to the substitution rate between forage and concentrates (S). As the addition of Q kg of DM of concentrates to the forage fed alone induces a decrease of (Q × S) kg of forage, the fill value of concentrate is S × forage fill value, to reach the constant feed intake capacity.

The variations S with the forage quality and with the percentage of concentrates were analysed through a great many trials carried out with sheep and cattle. Subsequently, relationships have been established for sheep, dairy cows and growing and fattening cattle (figure 1).

In formulating rations this system is very useful, both to predict voluntary DM intake of a forage fed alone

$$\text{DM intake (kg)} = \frac{\text{Feed intake capacity (UE)}}{\text{Forage fill value (UE)}}$$

and to determine the maximum forage DM intake and the associated concentrate level to reach the energy demand of the animal. For this purpose tables have been computed giving the forage intake in relation to forage quality and of the required energy density of the diet.

Discussion

Chair : Sir Kenneth BLAXTER (*UK*)

J.M. FORBES (*UK*). — There is one thing which seems, at first sight, to be puzzling. The lean breed of animal eats less food than you would expect, if fat was only having a negative effect on feeding. I would suggest, however, that the difference between these various breeds is that those which have a high propensity to fatten, those whose adipose tissue is more active at taking up acetate and other metabolites — whether it is more active because of its own activity or because it is more stimulated, for example by insulin — such animals will withdraw energy from the blood more rapidly, thereby leading to a return to feeding more quickly. We should not only think of fat as having a negative effect on feeding, but also a positive effect, at least in young animals, until the negative feedbacks become stronger. The negative factors can be both physical and, as I now believe, chemical or metabolic as well.

H. BICKEL (*Switzerland*). — I think that in this respect we should take the pig breeders into account. They say that selection for higher protein deposition results in choosing pigs with less intake, and that there is a genetic factor in it. I do not think we should continue to think that it is more fat deposition that depresses. It seems to me to be a kind of genetic factor that is bred into animals chosen for a high protein deposition.

J.M. FORBES. — We should still be able to explain it eventually in physiological terms though.

Sir Kenneth BLAXTER. — The breed differences that I know a little bit about are virtually in direct proportion to metabolic rate. If you say that an animal has a characteristic appetite, and this is measured as it comes down to this equilibrium value, that must eventually be equal to its maintenance requirement (as they grow). This is more or less what you would expect ; the range, if you work it out, is just what you would expect. A long while ago I did find that there was a correlation in individual animals between voluntary food intake and metabolic rate.

C. BERANGER (*France*). — Certainly high protein deposition and slow development of the digestive tract have been selected simultaneously. So we have two factors both depressing the appetite.

Ch. V. BOUCQUE (*Belgium*). — Concerning the effect of the fat mass : in Belgium, a selection station for white-blue bulls has compared the intake of the same diet — complete dry ration based on cereals — of double muscled and normal conformation animals of the same breed. If my memory is correct, intake was about 8 per cent lower from the double muscled animals, and with much less fat in the carcase than with the others.

Sir Kenneth BLAXTER. — That is what you got from the normal Charolais and the double muscled Charolais ; the appetite coming down from 105 to 94 ?

Ch. V. BOUCQUE. — It is the same with the pigs ; the Pietrain pig back fat is less than 2 cm, compared with the Landrace which has more than 3 cm. Intake is also lower with the Pietrain compared with the others.

Sir Kenneth BLAXTER. — I should mention that the ruminant working party of the Agricultural Research Council has undertaken a major study of appetite regulation in both cattle and sheep. The one thing which I think is striking in that comparison is the enormous variation from centre to centre. I believe Greenhalgh has published some of this work in Animal Production. There is a large difference between apparently similar feeds from centre to centre. One laboratory will have very high digestibility values, another laboratory very low ones. We have no idea why this should be. Dr. Forbes' values of the order of 100 g/kg $W^{\frac{3}{4}}$ comes in the middle, but there are quite a number of values for similar sorts of animals which are very much lower than that. Have you any ideas on why this should be ? Could it be stress factors, or housing ?

J.M. FORBES. — I suppose that between centres there is a range of body fatness levels at the start of the period of observation ; a range of qualities of silage, or whatever, feeds which though chemically similar may vary in terms of palatability ; a range of trough space per animal. If you put all these ranges together they may account for quite a wide range in end results. I would not say that it was a case of any one factor.

Sir Kenneth BLAXTER. — This does become a problem when we are trying to use something predictively. We can predict some sort of average which may be correct for INRA, for example, but not correct for another laboratory elsewhere. What is the real value of the standards if there is this large component variation ? What do we do in terms of saying, "This is the standard of intake" if there are these large differences between centres ?

A.J.H. VAN ES (*The Netherlands*). — With regard to explaining the influence of fat, is there any difference between the early maturing breeds and the late maturing breeds, as far as cell number or mature fat cell size are concerned ?

J. ROBELIN (*France*). — We have some results on the fat cell number and fat cell size between Friesian and Charolais. Roughly, it appears that for a given weight of lipid, the number and size of cells is the same between breeds. However, if you compare Friesian and Charolais at the same weight, or even at the same percentage of mature weight, the Friesian is fatter and has more cells which are larger. However, if you plot graphically the weight of lipid in the body and the fat cell size, you get a straight line. It is virtually impossible to distinguish the two breeds.

G. ALDERMAN (*UK*). — Dr. Béranger, could you expand on the substitution effect ? In your presentation you talked at some length on voluntary intakes of forages. However, your system does deal with substitution rates and I wonder whether you could indicate a few pieces of information and perhaps link in with Dr. McCullough's paper.

C. BERANGER. — We can give you the average relationship which we have obtained by pooling many data. We have started our work with many data with sheep in relation to different forages and concentrates. However, substitution in sheep is not the same as with beef cattle and growing cattle. So, with less data we have tried to establish a general relationship between substitution rates according to fill value of forage, which itself is related to feed energy content. We can go from grass, which is 1, to silage and hay which have approximately 1.2, 1.4 or 1.5 fill units, to straw which has something like 1.6 fill units. The substitution rate decreases and we have a different relationship according to the percentage of concentrate in the diet. Therefore, we have a three dimensional relationship. We have made these calculations from the data at our disposal but, as I have said, the problem is to get sufficient data to establish an accurate relationship between the two factors. So we can produce a table in which we can predict the percentage of intake capacity, eaten in the form of forage, in fill units, in terms of the fill unit value of the forage, the energy content of the forage, the energy content of the concentrate, and for different concentrations in the diet.

In this way we can calculate the maximum level of forage and the minimum level of concentrate which are necessary for a given weight, a given liveweight, and a given energy requirement. It is still very rough, but it is a first attempt at a model for predicting voluntary intake.

Sir Kenneth BLAXTER. — Is the fact that this is mildly curvilinear the result of your expressing the ration with voluntary intake of grass as your standard, divided by the voluntary intake of the roughage, which gives you a reciprocal relation ?

C. BERANGER. — No, because we have the same shape if we do the same thing with true dry matter value.

Sir Kenneth BLAXTER. — It is still curvilinear ?

C. BERANGER. — Yes, so we are a little surprised at McCullough's results being very linear with still a high level of concentrate in grass silage.

Sir Kenneth BLAXTER. — This scheme is three dimensional but it is still in accord with the idea that you have mutual substitution in proportion to maximal intake ; the only difference being that it is a curve rather than a straight line. Is there a significant difference between the curve and the straight line ?

J. ROBELIN. — Unfortunately we have no real data but, obviously, it is not linear. It could be easily demonstrated that this shape is necessary to have the evolution of total feed intake, as we have seen in Dr. McCullough's paper. When you increase the dried grass, or concentrate, you have an increase of total feed intake followed by a slight decrease. In order to have this decrease, it could be easily demonstrated that it is necessary that this relationship is not linear.

J.M. FORBES. — That is related to what I was going to say. If you extrapolate that towards zero percent concentrates — if it is all straight lines — then you feed the animal no supplement and it eats less. Clearly, that cannot be so.

C. BERANGER. — This system is satisfactory up to 50 per cent concentrates in the ration, but after that there is not a good relationship because there is more metabolic regulation. We have no relation with fill unit values of forage, and we cannot predict the intake of the animals.

G. ALDERMAN. — I would like to turn the tables. Yesterday I was asked how the UK energy system is being used in practice. Our French colleagues published this system two years ago and, though we are agreed it is a first attempt, what has been the reaction of your advisers to the system ? Are they using it, are they happy with it, or have they ignored it ?

C. BERANGER. — When we originally published the system we had considerable adverse reaction because in many cases it did not do well in practice. It gave a higher level of concentrates than is found in normal practice, especially in fattening cattle. The problem was that in our initial work we took most of our data from sheep and did not make sufficient allowance for the big difference between sheep and cattle. Our present work is with cattle data only and we have drawn a relationship between the fill value measure of sheep and that of cattle.

In the next issue of our technical bulletin we will be publishing the new system which we hope will have a satisfactory application in practical terms.

The principle of the new system is that it is not necessary to decide on a set amount of concentrate. The farmer can quickly determine the level of forage he can use and whether that forage can meet the requirements ; if not, he can establish the level of intake of forage and the level of concentrates required. It helps to formulate the ration more quickly.

R. JARRIGE (*France*). — As Dr. Beranger has said, the starting point was our data on sheep. We measured digestibility of the forage at near *ad libitum* which gave us a value of what we call the "ingestibility". It was necessary to have a new term because "voluntary dry matter intake" is a measure used simultaneously to measure the appetite of the animal and the characteristics of the forage. So, in our digestibility trials with sheep we measured the indigestibility of the forage. We had a mountain of data — more than 2,000 sets. We had a large amount of data on the dry matter intake of growing, fattening animals, dairy cows, and so on. We tried to find a system which integrated all the data we had. Initially, we established the principle of integration but we used mainly sheep data. For the sheep data, the reference herbage, which is theoretical, had an ingestibility of 75 g/kg metabolic weight. The range of the fill values of the roughages varied from 0.8 to 2.3 — it was very wide. Therefore the fill unit for sheep was not applicable to cattle. In the new system the ingestibility of the reference herbage is 123 g/kg metabolic weight for the standard dairy cow of 600 kg, 17 kg milk. We used the average of the data available with fresh herbage.

We have now transferred the fill value data on sheep to the dairy cow. The range of variation was less, something from 0.8 to 1.8. It worked for dairy cows and has now been applied to growing fattening animals. In fact, it is exactly the same system as the Scandinavian feed unit system of 100 years ago.

My second point is that the fill unit values are additive and we can predict the dry matter intake of the forage in the two situations. The first situation is forage only. If you have a 400 kg animal with, for example, an intake capacity of 8 units, it can eat 8 kg dry matter of the reference grass, or only 5 kg of straw. If some concentrates are fed, tables have been drawn up which give the percentage of the fill unit covered by the forage. So you have the quantity of forage from the fill unit value of the forage and its feed unit content.

A.J.H. VAN ES. — With regard to the substitution rate, does the composition of the concentrates influence the lines ; for example, one with a lot of sugar as opposed to one with a lot of cellulose ?

R. Jarrige. — Some of the substitution rates were measured on sheep, some on cattle, and some were obtained from the literature. In every case, concentrates where true concentrates made up of two thirds of cereal and one third of oil cakes and so on. You are perfectly right, more and more concentrates include by-products, the fill value of which is probably higher. Therefore, some corrections will be necessary.

J.M. Forbes. — Is there a simpler way of getting this fill value, other than seeing how much the animal will actually eat ? I am thinking of work where a simple mechanical measurement was made of how much space was occupied by different feeds. There have been some spectacularly high correlation coefficients reported in the literature between voluntary intake and fairly simple mechanical methods of measuring bulk of food.

Sir Kenneth Blaxter. — If you have to do the hard work of actually feeding the animal you will know that a sheep will eat one bag of feed a day, irrespective of what that feed is.

G. Alderman. — There was an earlier comment, by Dr Jarrige, about the digestibility of cell walls. I wondered whether our colleagues have some thoughts in this area that might relate to what Dr. Forbes was saying. Do we have to measure voluntary intake with the animal, or can we predict it from chemical or enzymatic measurements ?

R. Jarrige. — Some predictions can be made from enzymatic measurements, either from "in vitro", like Tilley and Terry, or cellulase systems. You have to measure the rate of digestion ; for example, the rate of digestion of the cell wall components in lucerne and legumes is quicker than in grasses. The fill effect that we measure through the animal is something like the product between the cell wall content and the cell wall retention time in the rumen. The system for the roughages reflects this fill effect in the rumen. The physiological factors are taken into account in the value of the intake capacity of the animal. I don't know if it is good English to say "intake capacity" but it is different from "appetite".