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Residual Feed Intake as a Measure to Select Genetically Productive Beef Cattle: A Review

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Abstract: Measures such as residual feed intake (RFI) have been increasingly considered to select cattle with superior feed efficiency, as it is a characteristic of feed efficiency calculated as the difference between observed intake and estimated intake considering metabolic weight and the weight gain. Estimated feed intake is obtained through the multiple regression equation of observed consumption on metabolic mean live weight and weight gain. The standard was shared among animals into one herd selected for low RFI (high efficiency) and compared to the one selected for high RFI (low efficiency). There was no correlated response in weight per year and in weight gain, and the effectiveness of low RFI selection in reducing feed costs was proven without affecting production. However, selection of animals with negative RFI is not done by selecting animals directly according to the size of the viscera, rather it is done indirectly, that is, when selecting the most efficient animals and normally these animals already have the smallest viscera size. The RFI is a trait that presents genetic variability, selectable to improve and has moderate heritability, between 0.30 and 0.35. The RFI is important because it reduces the direct economic impacts of reduced feed intake, as well as the effects of environmental impact on reducing methane emissions from enteric fermentation of ruminants.

Key words: Feed conversion, feed efficiency, enteric fermentation.

1. Introduction

Beef cattle are increasingly competitive and several resources have been applied to reduce the slaughter age of beef cattle, aiming to produce more meat in less time, which would increase the profitability of the farm [1]. An alternative is the selection of the most efficient animals, which can be done in different ways, for example by assessing the feed conversion of the cattle (amount in kilogram of feed consumed by the animal divided by the amount of kilogram gain produced) [2, 3].

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In order to find cattle with superior feed efficiency, measures such as residual feed intake (RFI) have been increasingly considered, as it is a characteristic of feed efficiency calculated as the difference between observed intake and estimated intake considering metabolic weight and the weight gain [1, 4]. Estimated feed intake is obtained through the multiple regression equation of observed consumption on metabolic mean live weight and weight gain, where RFI is considered as residue of the equation. Genetic selection for RFI results in lower feed intake progenies without decreasing animal performance. In a study with a Nellore cattle herd for feed intake, two groups were tested, and the animals were divided into one herd selected for low RFI (high efficiency) compared to the one selected for high RFI (low efficiency). There was no correlated response in weight per year and in weight gain, and the effectiveness of low RFI selection in reducing feed costs was proven without affecting production. The RFI is important because it reduces the direct economic impacts of reduced feed intake, as well as the effects of environmental impact on reducing methane emissions from enteric fermentation of ruminants [5].

Farmers usually select cattle only for their size, and the biggest disadvantage would be the increased energy requirement for the cattle to perform its basic activities such as walking or grazing [6]. This term is technically called maintenance energy, which would necessarily cause the animal to consume more feed, increasing the cost of producing this meat on the farm. However, it is possible to select genetically superior cattle that respond positively to feed (have the potential to gain weight by eating less feed). Cattle of similar age and weight show different performances when consuming the same amount of feed. Even with a homogeneous herd of cattle, the intake and weight gain were different after weighing evaluations, which proves that there are superior animals in the same group and can be identified after the RFI evaluation [2]. Selecting beef cattle for feed efficiency is undoubtedly one of the alternatives to increase production efficiency, reduce production costs and mitigate the environmental impacts of livestock.

2. Importance and Relevance

This concept of selection of most efficient animals was initially developed in the 1960s “nineteen-sixties”, with not very promising return. However, in recent years there has been a strong emphasis on this type of selection in countries such as Australia, U.S., Canada and Brazil. The selection is made through the RFI assessment technique [7]. Unlike feed conversion, it is calculated as the difference between actual consumption and the amount of feed an animal should eat in relation to its average live weight over a given period as a proof of weight gain. Thus, more efficient animals have negative RFI, while less efficient animals have positive RFI [8]. Terms used for livestock growth characteristics and feed efficiency are shown in Table 1, adapted from Arthur and Herd [4]. The RFI is a trait that presents genetic variability, selectable to improve and has moderate heritability,

Table 1 Terms used for cattle growth traits and feed efficiency.

Trait name	Abbreviation	Definition	Formula
Feed intake	FI	Feed intake per day	
Live weight	LWT	Weight (wt) at a specified age	
Average daily gain	ADG	Wt gain per day	Regression coefficient from the regression of weight on time (day)
Relative growth rate	RGR	Growth relative to instantaneous size Expressed in this study as percentage of change in LWT per day	100 × (log end wt – log start wt) ÷ days on test
Kleiber ratio	KR	Wt gain per unit metabolic body wt	ADG ÷ average test period $LWT^{0.75}$
Feed conversion ratio	FCR	FI per unit wt gain	FI ÷ ADG
Partial efficiency of growth	PEG	Efficiency of wt gain net of maintenance feed (Fm) requirements	ADG ÷ (FI – Fm), where Fm was obtained by formulas from feeding standards
Residual feed intake (by feeding standards formula)	RFI_{fsf}	FI net of the expected feed requirements for maintenance and growth, with the expected feed requirements (expFI) obtained from feeding standards formula	FI – expFI, where expFI was obtained by formulas from feeding standards
Residual feed intake (by regression)	RFI_{reg}	FI net of the expected feed requirements for maintenance and growth, with expFI obtained by regression	FI – expFI, where expFI was obtained by the regression of FI on average test period $LWT^{0.75}$ and ADG

Adapted from Arthur and Herd [4].

Table 2 Heritability (h^2) estimation of RFI, definition of RFI, number of animals (N), sex, country, breed and age of animals during different collection years evaluated.

Year of collection	h^2	$RFI_{(1)}$	N	Sex	Country	Breed	Age (cattle)
1963	0.28	RFI	1.324	M and F	USA	Hereford Angus and Shorthorn	Less than 18 months
1992	0.077	RFI	650	M	USA	Holstein and Swiss brown	Less than 18 months
	0.27	RFI	650	M	USA		
2000	0.16	RFI	542	M	Australia	Hereford	Less than 18 months
2001	0.39	RFI	1.180	M and F	Australia	Angus	Less than 18 months
2001	0.39	RFI	510	M	France	Charolais	Less than 18 months
	0.43	RFI	792	M	France	Charolais	
2003	0.30	RFI	410	M	Canada	Charolais	Less than 18 months
	0.26	RFI	410	M	Canada	Charolais	Above 24 months
2007	0.21	RFI	464	M	Canada	Alberta hybrid, Angus and Charolais	Above 24 months
2009	0.24	RFI	1.007	M	Australia	Brahman	Above 24 months
	0.38	RFI	1.209	M	Australia	Tropical breed	Above 24 months
2009	0.41	RFI	468	F	USA	Angus	Post weaning
	0.42	RFI	468	F	USA	Angus	Post weaning
2009	0.49	RFI	22.099	M and F	Japan	Wagyu	Less than 18 months
2010	0.20	RFI	678	M	France	Blonde d'Aquitaine	Less than 18 months
	0.45	RFI	708	M	France	Limousine	Less than 18 months
2010	0.30	RFI	2.567	M and F	USA	70% Angus	Above 24 months
2010	0.45	RFI	2.102	M	Ireland	Aberdeen Angus, Charolais and Hereford Limousine and Simmental	Less than 18 months
2010	0.36	RFI	1.340	M	France	Charolais	Less than 18 months
	0.15	RFI	510	M	France	Charolais	Less than 18 months
	0.09	RFI	472	F	France	Charolais	Above 24 months
2010	0.42	RFI	1.433	M	USA	Angus, Simmental and crossbreed	18-24 months
	0.20	RFI	760	M	USA	Angus, Simmental and crossbreed	Less than 18 months
2011	0.22	RFI	863	M	Japan	Wagyu	Less than 18 months
2011	0.178	RFI	491	M and F	Brazil	Nellore	Less than 18 months

(1) RFI, residue of regression of dry matter intake on phenotypic values of metabolic body weight and average daily gain; M = male, F = Female.

Adapted from Del Claro *et al.* [5].

between 0.30 and 0.35 are the values most commonly found in technical articles. Heritability measures the level of correspondence between the phenotype and the genetic value of each cattle (phenotype = observable characteristics such as animal development or morphology).

In countries such as the USA, Australia, France, Canada, Japan, Ireland and Brazil, estimates of genetic parameters are classified by weight, sex, age group (cattle under 18 months, between 18 months and 24 months and over 24 months).

The studies evaluated were related in chronological order (Table 2), with estimation of the heritability (h^2) of the RFI characteristic, definition of RFI, number of animals, sex, country, breed and age in which animals were tested, the data were adapted from Del Claro *et al*. [5].

3. Effect of RFI on Carcass Composition

Many experimental results indicated that animals with negative RFI tend to have adequate subcutaneous fat thickness without the risk of having a carcass with poor back fat thickness, which could devalue the price of meat in the market. The cover fat prevents cold shortening of the carcass during the refrigeration process in the cold chamber in slaughterhouse [9, 10]. Negative RFI cattle tend to have leaner and less marbled carcasses (intramuscular fat). This fact can be explained by the fact that the fat deposit in the carcass is dependent on higher energy intake (higher feed intake or higher concentrate feed intake). Back fat thickness can be checked with live cattle using ultrasound. Fat deposition in carcass is less energy efficient than protein deposition [11]. However, there are no studies showing changes in beef tenderness or taste after the animal is classified as more or less efficient (negative or positive RFI).

In a research to identify the most efficient cattle, with negative RFI, Nellore × Red Angus crossbred castrated cattle were bred on paddocks of rotated Mombasa grass pastures. The animals were divided into groups. Once a day, specific groups received concentrated feed (containing protein and energy) in an individual trough, where the daily actual consumption of concentrated feed (offered at 0.6% of the live weight of each animal per day) was calculated. At the end of the experimental period, all the animals were slaughtered for a detailed evaluation of carcass yield. It can be concluded that feeding could modify the ranking of animals regarding RFI performance [12].

4. Factors That Influence the RFI

Mammals naturally produce body heat, and in animals with negative RFI, body heat production is lower. In cattle with positive RFI, higher organ weights such as liver, lungs, abomasums and intestines were observed, which can consume 50% of energy costs for the maintenance of cattle alone, without considering weight gain. This explains the lower response in weight gain, because this energy that could be destined for weight gains is partly spent on the viscera organs themselves [13]. However, selection of animals with negative RFI is not done by selecting animals directly according to the size of the viscera organs, rather it is done indirectly, and for the most efficient animals already have the smallest viscera organs size [14].

The physiological regulation of RFI is probably under the control of many genes. The metabolic factors that may contribute to RFI variation are many and the main physiological mechanisms that influence RFI variation are related to stress and tissue metabolism (37%), activity (10%), digestibility (10%), increment (9%), body composition (5%) and eating patterns (2%). As RFI increases, there is higher proportion of metabolizable energy intake directed to heat production and lower proportion to energy retention [15].

5. More Efficient Animals and Methane Production

Ruminants produce methane gas (CH_4) through the ruminal fermentation of the feed intake, an atmospheric polluter and an aggravating greenhouse effect. Different methane amounts may be produced by *Bos indicus*, *B. taurus* and their crossbreeds. These variations can be associated to the different characteristics of cattle, ruminal volume capacity, feed selection, retention time of feed in rumen and associations of factors linked to lower or greater digestion capacity of fibers in feed [16]. This emission may range from 8% to 14% of the digestible energy lost by feed intake. This may represent an average emission of 28 L of methane (or 20.2 g) per kilogram of dry matter intake by the cattle [17]. Methane gas emissions may be reduced when using animals with negative RFI for the same weight gain. Specially manufactured yokes are used for the evaluation of methane gas emissions by beef cattle. Methane gas is collected directly from the animal's nostril and is stored in this yoke attached to the neck of the cattle (Fig. 1). Later these full yokes are taken to the laboratory and analyzed, and the more efficient animals (negative RFI) also make better use of the energy of feed by emitting less methane and polluting the environment less [12].

6. Economic and Environmental Return

By selecting more efficient animals, it is concluded that they would have the same weight gain, but with less feed intake, which economically can be very significant especially when considering the reduction of 400 g to 1 kg of dry matter per day if considered as a confined finishing animal. And by assessing the environmental aspect, there would be a reduction in nutrient use, as well as the production of pollutants (manure, slurry, methane gas and nitrous oxide) per unit of meat produced.

Animals that consume less feed also produce fewer feces, decreasing the amount of effluent, and also decreasing methane emitted during rumen fermentation as well as fecal fermentation. In cattle, the largest methane production occurs in the rumen (87%-90%) while in the gut it represents only about 10%-13% of all methane produced [18].

After assessing the economic and environmental impact of selection at different percentiles for the different estimators, this analysis was situated. To Boaitey *et al.* [19] the results show that selection for feed efficiency in cattle can increase financial returns and reduce methane emissions. A unit reduction in feed intake (kg as fed/day) was associated with an average increase of $13.23 in returns and 33.46 tonnes reduction in emission at the end of the feeding period. On a percent intake basis, this translates into a 2.3% increase in returns for each percent improvement in efficiency.

By selecting more efficient animals, it is possible to reduce the use of grazing areas to produce the same amount of meat. For all aspects presented, the future trend can be concluded to select more efficient production animals so that the producer can make more profit contributing to the preservation of the environment [15, 20, 21].

Fig. 1 Beef cattle with a yoke for methane gas study (CH_4).

7. Conclusions

Residual Feed Intake is a feature that allows producers to identify more efficient animals without the need for concomitant selection for greater weight gain and greater weight at adulthood. The RFI is important because it reduces the direct economic impacts of reduced feed intake, as well as the effects of environmental impact on reducing methane emissions from enteric fermentation of ruminants

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