Beef cattle models for optimum feedlot harvest endpoint

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How long to feed cattle for maximum profit?

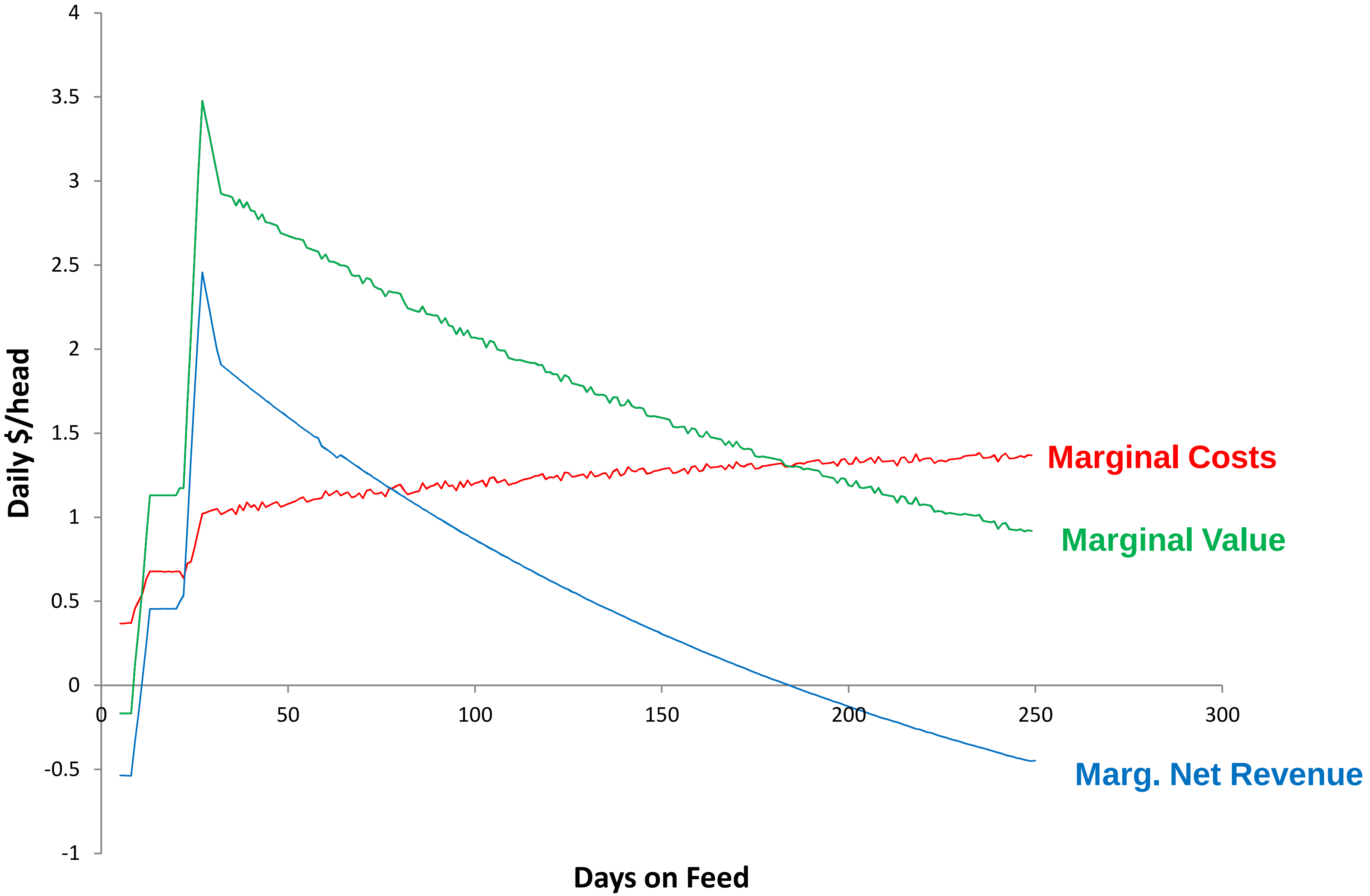
- *type of cattle*
- *market demand and price*
- *ownership of feedlot and/or cattle*
- *marketing and management tools*

Outline:

1. *economic principles*
2. *biology of the animals fed*
3. *bioeconomic modeling*

How long to feed cattle for maximum profit?

Economic Principle-Profit Maximization

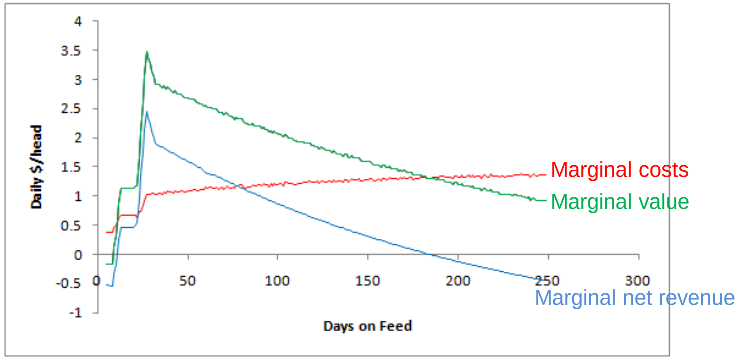


TAURUS Profit Projection
University of California Software

Economic Principle-Profit Maximization

- *Owner of the cattle*
- *Owner of the feedlot*
- *Pen replacement – annual or continuous*
- *Market expectations*

Profit Maximization
– Independent cattle owner



Feed while:

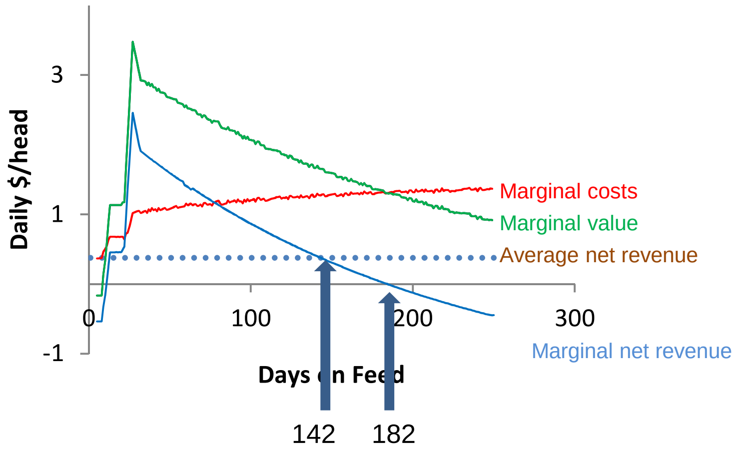
Σ *Daily costs < Daily gain* X *Value of gain*

Feed until daily cost exceeds daily gain in value
(*marginal net revenue becomes negative*)

Price discounts for increasing carcass weight or decreasing yields may be sudden.

Pens with more variable cattle have shorter optimum feeding periods (Smith et al., 1988).

Profit Maximization
– Feedlot owns cattle



Feed while:

Marginal net revenue > Average net revenue

Feed until marginal net revenue (daily profit) no longer exceeds the average daily profit for an average replacement animal in the feedlot

As long as the average net revenue is positive, cattle owned by the feedlot will be fed fewer days than those owned by others (as long as average net revenue is positive).

More variable cattle will be fed fewer days than more uniform ones, but shorter days on feed reduce the chance of discounts.

Two exceptions:

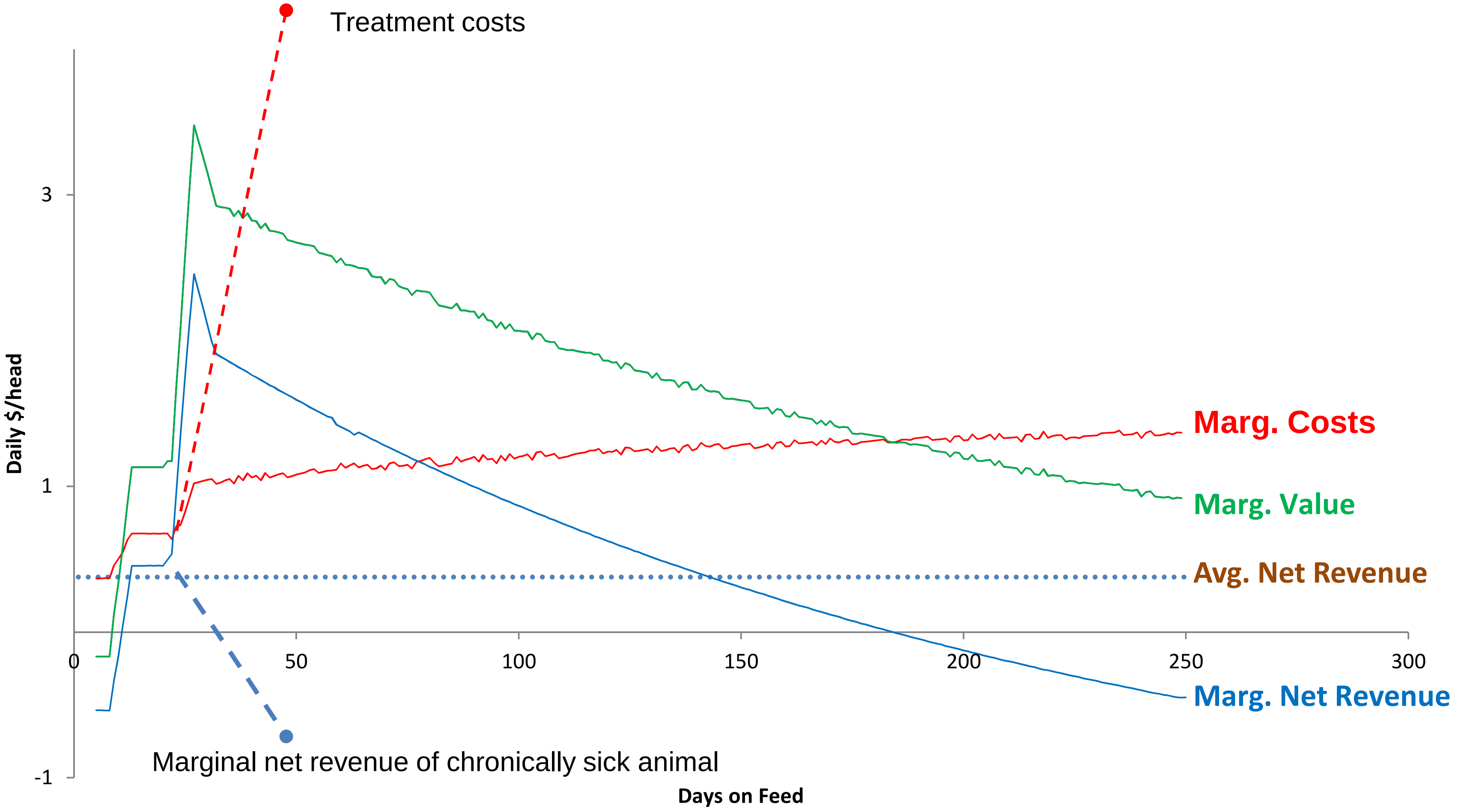
- ***Cattle owner capital limited by pen on feed***

  Feed cattle while marginal net revenue exceeds average net revenue (~feedlot owner)

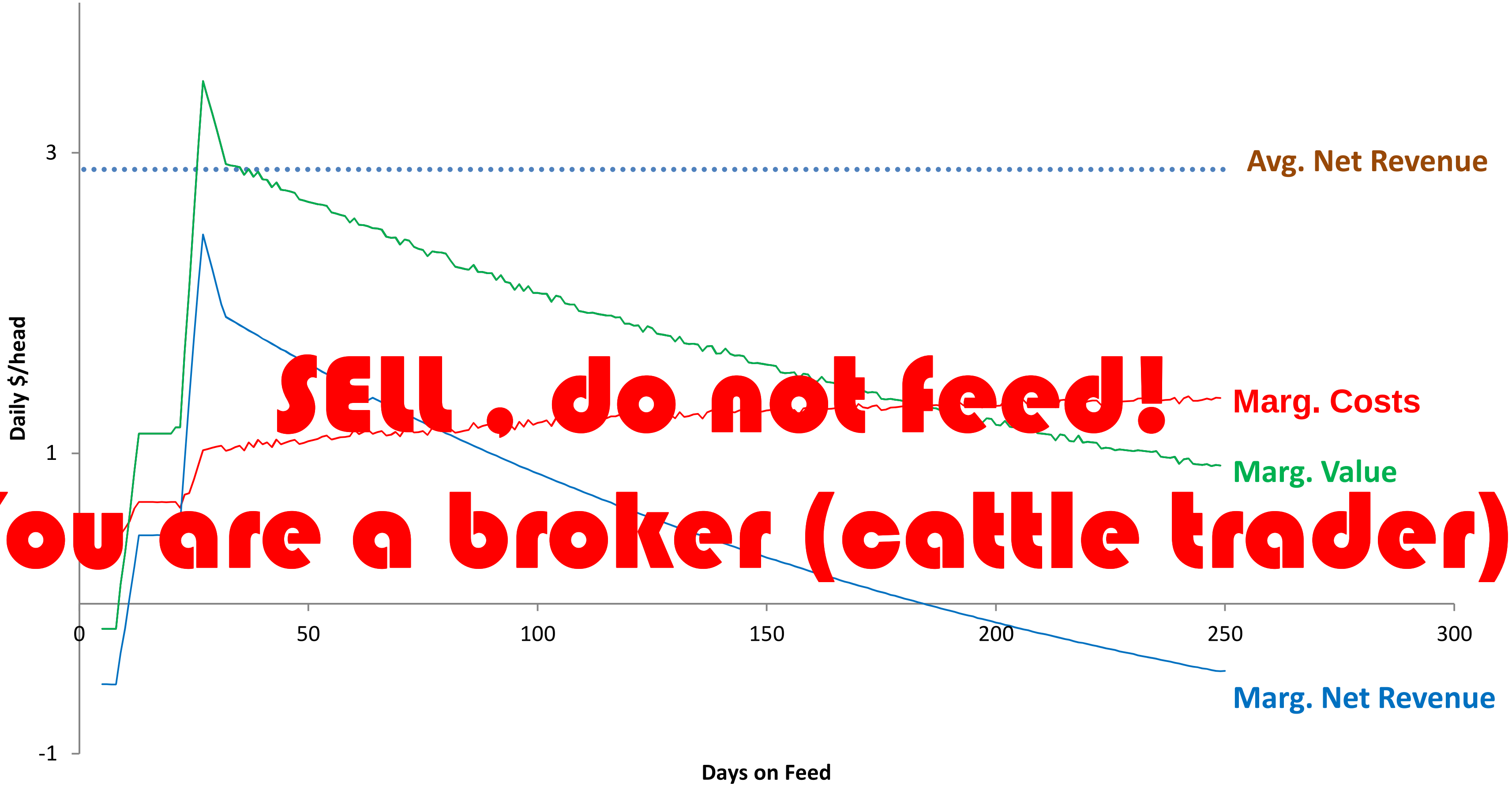
- ***Feedlot owns cattle but cannot reuse pen***

  Feed cattle while marginal net revenue is positive (~outside owner)

Marginal net revenue usually positive



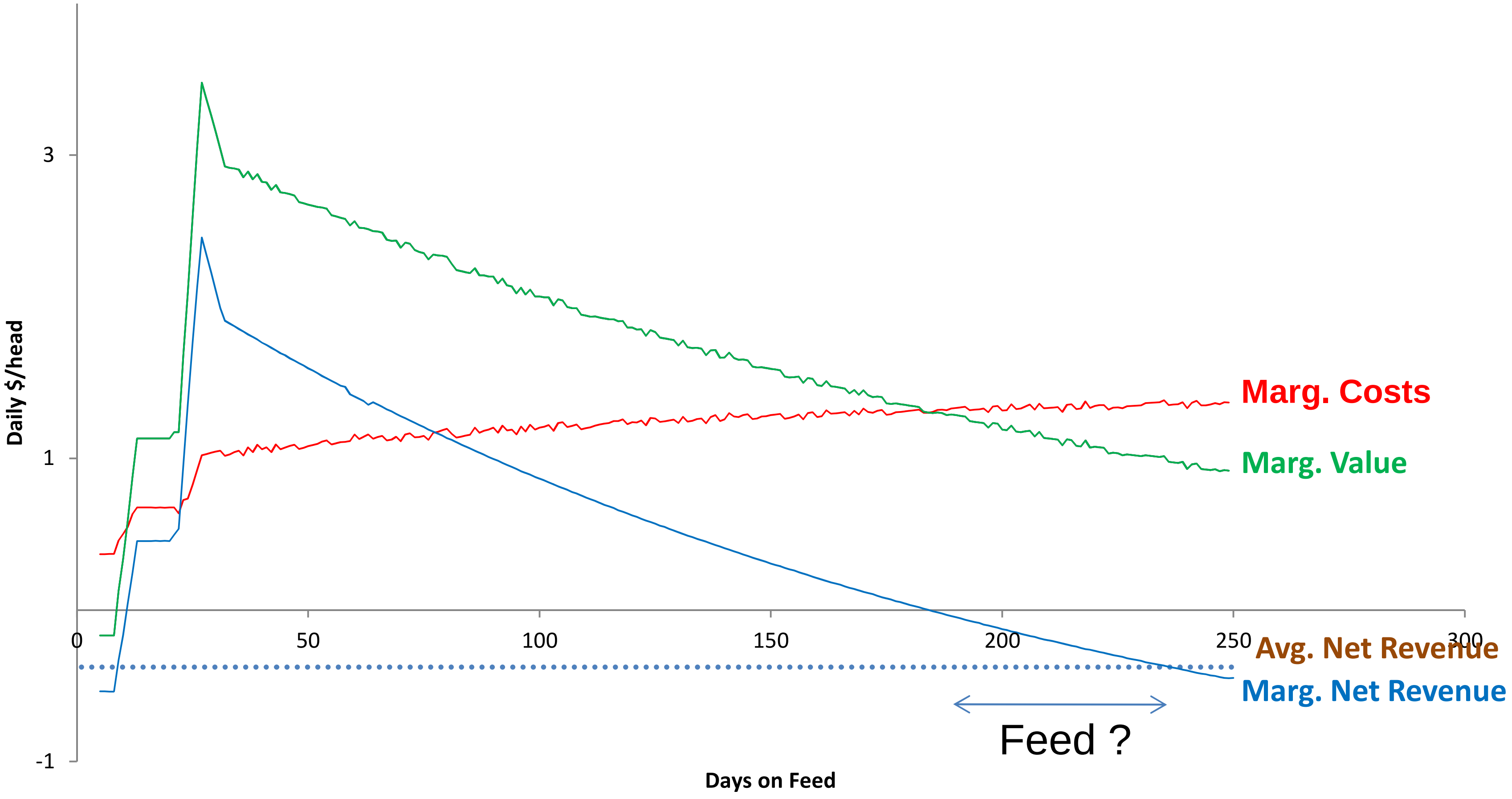
Buying Low, Selling High



SELL , do not feed!

You are a broker (cattle trader).

Anticipation of lower markets ?



Biological Constraints:

Variation in Growth Rate and Carcass Value
Returns - Efficiency of gain (Gain/Feed)

Animal Value - carcass weight, quality, possible defects and other market factors;

How does animal value change as slaughter endpoint approaches?

Carcass weight - Drives Value

Feeding to heavier weights – Increases Profit

Concerns:

- Excessive carcass size in slaughter plants
- Undesirably large muscle cuts
- Decreased retail cut yield with fatness
- Increasing cost of gain with size (maintenance)
- Decreased feed intake with fatness
- BUT increased marbling with time on feed

Age at feedlot entry

Calves

May have enhanced marbling, but backfat reaches a given level at a lighter weight, so to avoid carcass yield discounts may be slaughtered with less marbling and decreased value

Yearlings

May be more profitable if the cost of gain is high, and the trend to feed these older cattle increases with feed and grain prices

Frame Size (Mature size) interacts with optimal time on feed

Larger frame cattle benefit from earlier feedlot entry

Smaller frame cattle benefit from early growth on forage diets or pastures

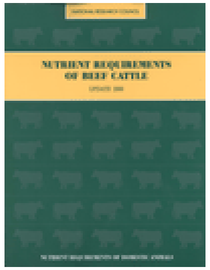
Backfat does not increase as it does on feedlot rations (Sainz et al., 1995)

How can we use models to account for all these factors in feeding systems for beef cattle?

Precision Livestock Systems

- Dynamic Prediction of Growth
- Tracking of Value Related to Carcass Quality
- Real-time prediction of costs-returns

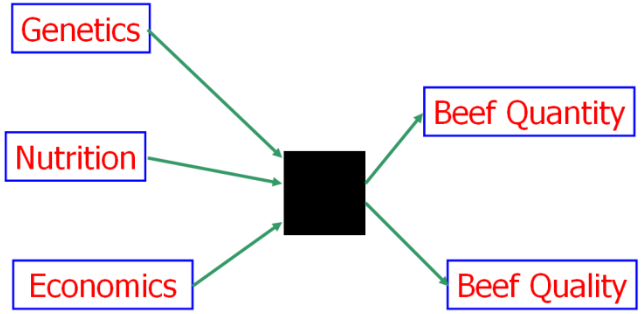
Current Feeding Systems



- Predict retained energy in order to estimate growth rate
- Use an empirical relationship between retained energy and body weight gain
- Composition inferred by assuming protein content of the fat-free mass (22.01%) and energy value of protein and fat gain (23.8 and 39.6 MJ/kg, respectively)

Current Feeding Systems, Limitations & Needs

- Response to Wider range of inputs required
- Better composition prediction for compensating cattle
- Precisely track changes in composition as cattle near slaughter endpoint



Genetics

Nutrition

Economics

Beef Quantity

Beef Quality

Dynamic Models allow inputs (and outputs) to vary within the time period of interest

- limit feeding
- sorting into uniform groups
- new growth adjuvants
- individual animal differences
- variable maintenance
- transition states

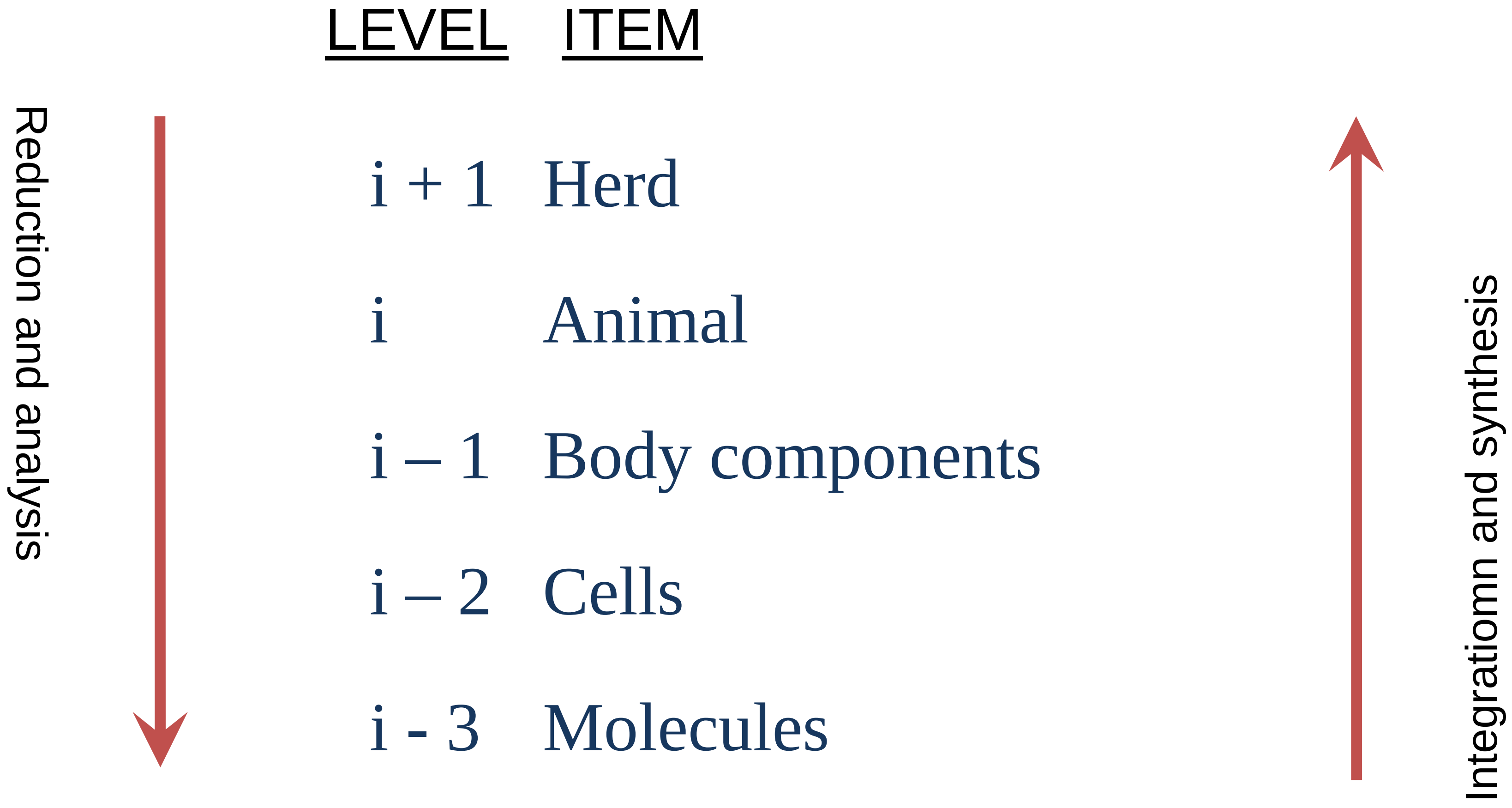
Definitions

Model: abstract representation of a system

System: combination of elements that interact with each other, with boundaries, inputs and outputs

Simulation: the process of solving a model to predict the responses (outputs) to a given set of inputs

Levels of aggregation



Reduction and analysis

LEVEL	ITEM
i + 1	Herd
i	Animal
i – 1	Body components
i – 2	Cells
i - 3	Molecules

Integratiomn and synthesis

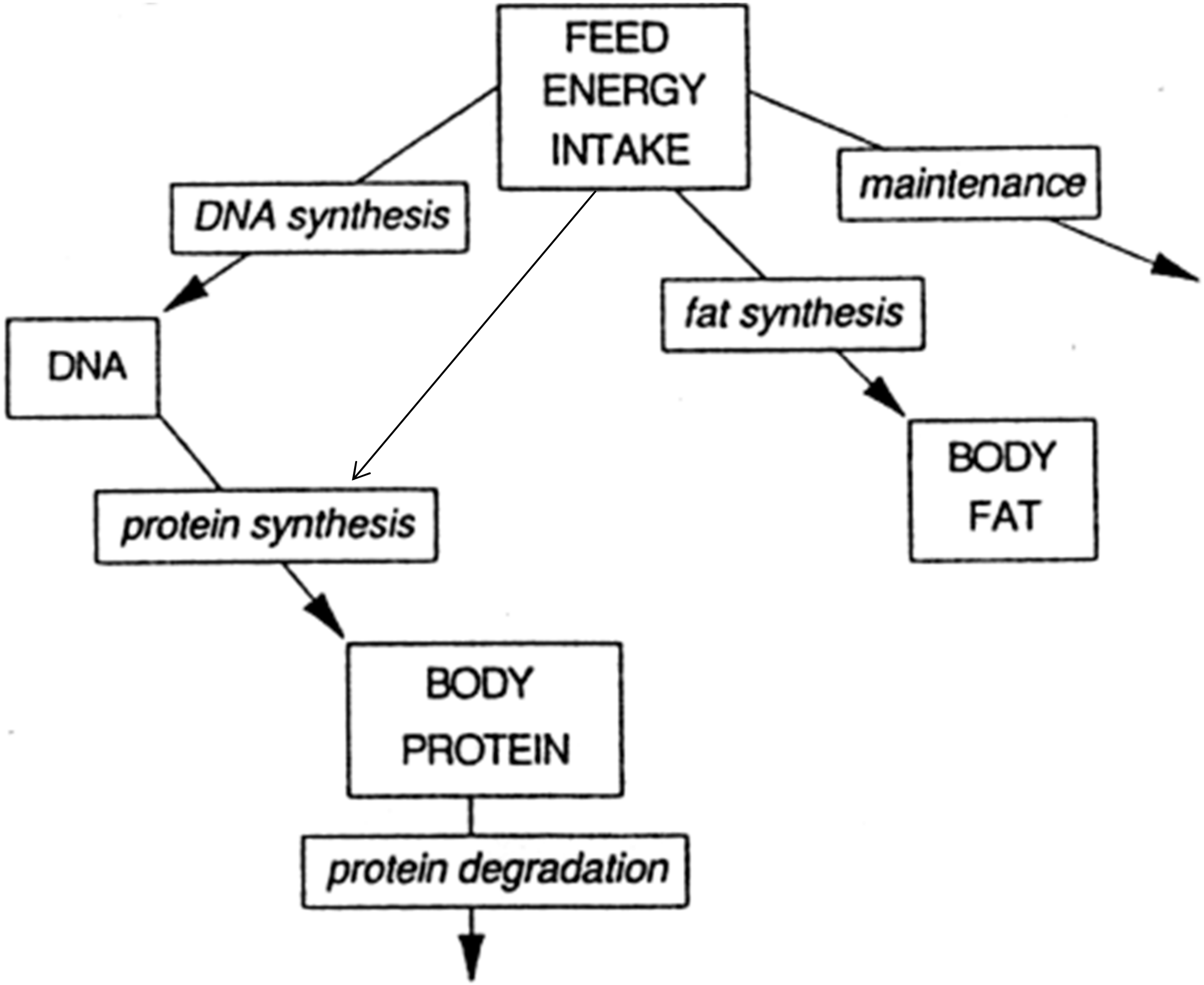
Growth Models based upon Baldwin & Black, 1979:

1) the primary genetic determinant of organ size is the final DNA content of the organ in mature, normally grown individuals of the species and nutritional status determines the rate of DNA accumulation and whether target DNA content is achieved

2) each unit of DNA specifies on a genetically defined basis for each tissue and each species, the ultimate formation of a specific amount of cell material, and nutritional and physiological status determines whether this target is achieved

3) the specific activities of enzymes responsible for tissue growth vary exponentially with organ size and the kinetic properties of these enzymes are relatively constant across species

Davis Growth Model – flow diagram



Davis Growth Model

$d\mathrm{DNA}/dt = \mathrm{K}_1 * [\mathrm{DNAMX} - \mathrm{DNA}(t)] * \mathrm{NUT}_1$

$d\mathrm{PROT}/dt = \mathrm{PROTSYN}(t) - \mathrm{PROTDEG}(t)$

$\mathrm{PROTSYN} = \mathrm{K}_2 * \mathrm{DNA}(t)^{0.73} * \mathrm{NUT}_2$

$\mathrm{PROTDEG} = \mathrm{K}_3 * \mathrm{PROT}(t)^{0.73} * \mathrm{NUT}_3$

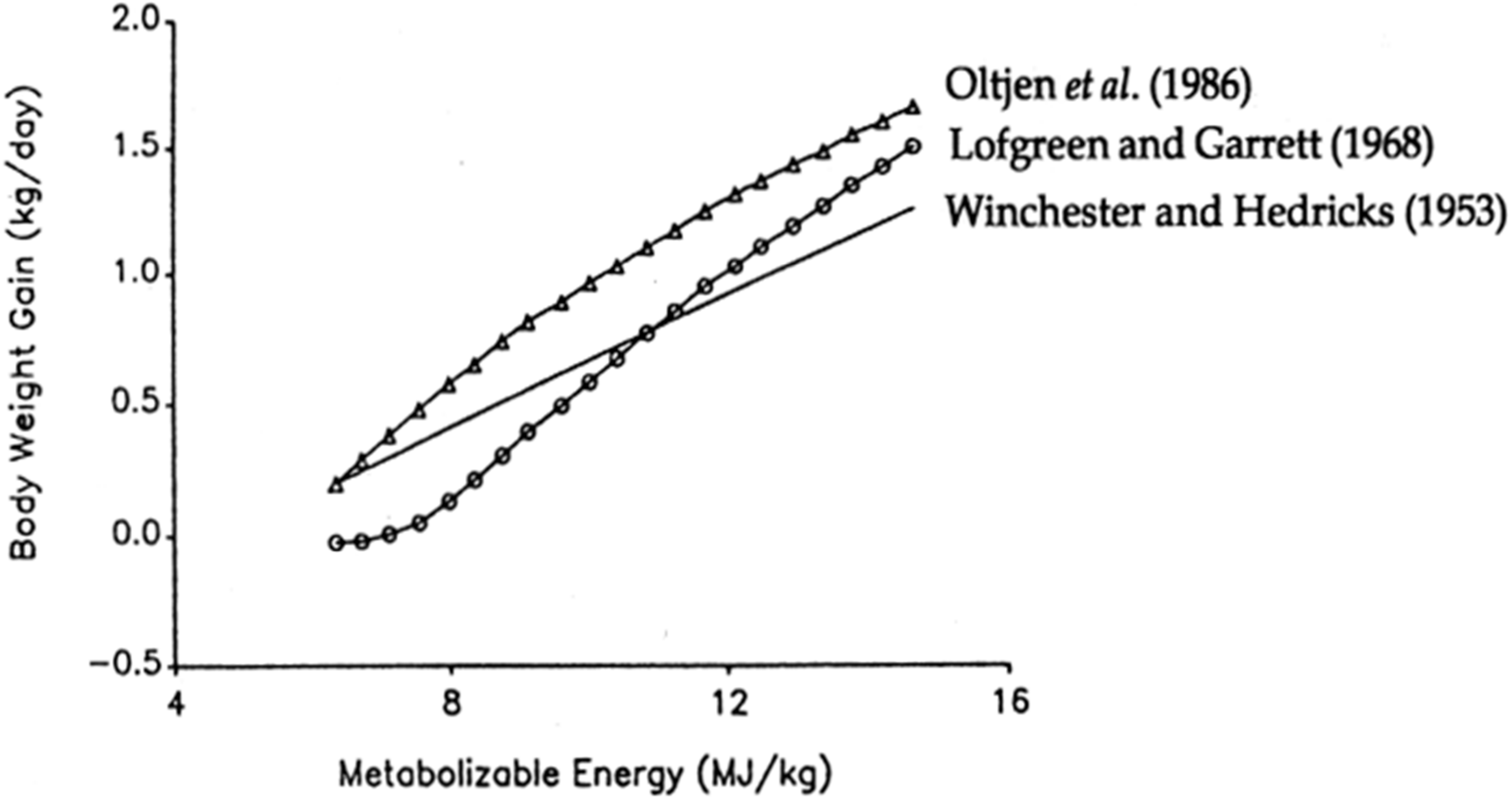
$$d\mathrm{FAT}\big/dt = \frac{\left(\mathrm{FI} - \dfrac{\mathrm{MAINT}}{\mathrm{NEm}}\right) * \mathrm{NEg} - \left(d\mathrm{PROT}\big/dt * 23.2\right)}{39.3}$$

Source: Oltjen et al., J. Anim. Sci. 62:86, 1986

Parameters were estimated using nonlinear least squares fit of a data set containing initial and final empty body weights and compositions, and metabolizable energy intakes for over 1,000 growing beef cattle

UC Davis Feedlot

Comparison among growth models



CORRELATION WITH RESIDUAL BODY WEIGHT

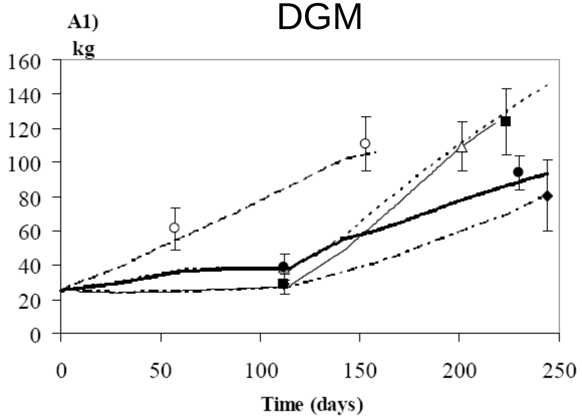
	Model	NRC (1984)	NRC (2000)	ARC
ME intake	-.13	-.14	-.32	.10
Initial Fat	-.00	-.02	.48	-.59
Frame Size	-.02	.54	-.08	-.70

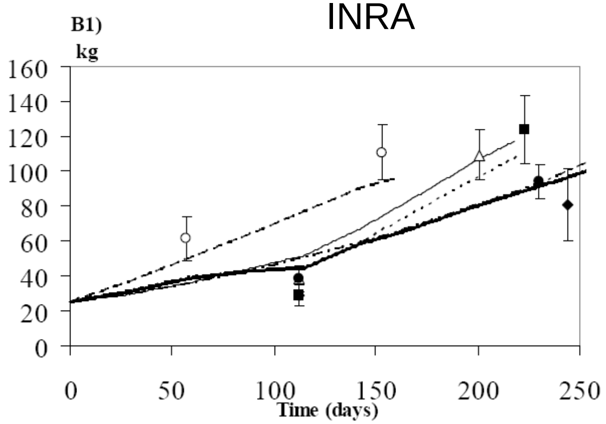
Body fat

DGM

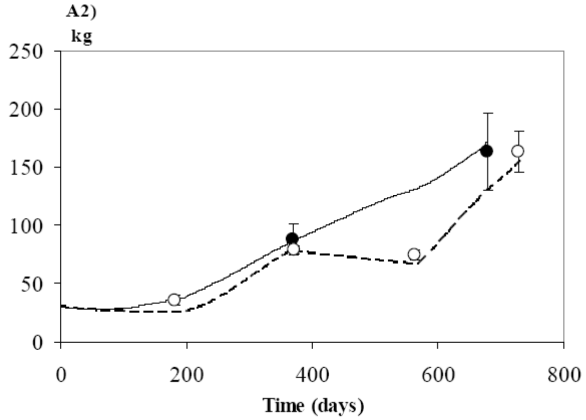
INRA

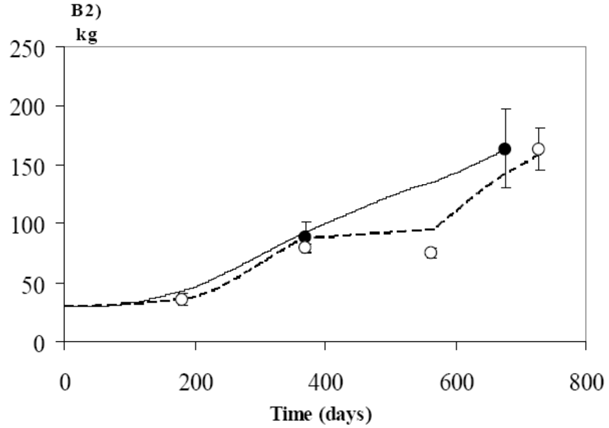
Angus-
Hereford
steers



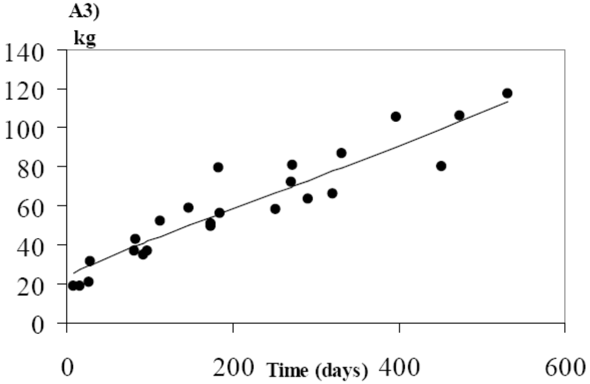


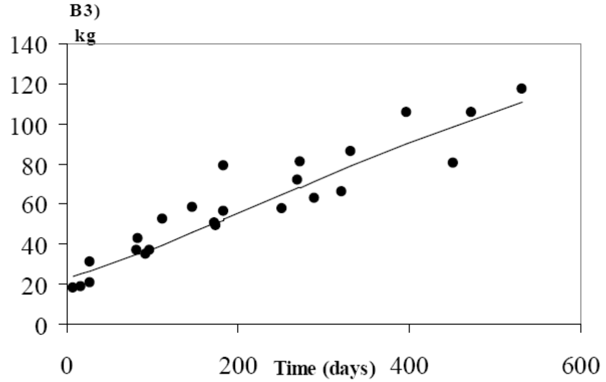
Salers
heifers





Charolais
bulls





From: Garcia et al., 2007

Comparison with Independent Data

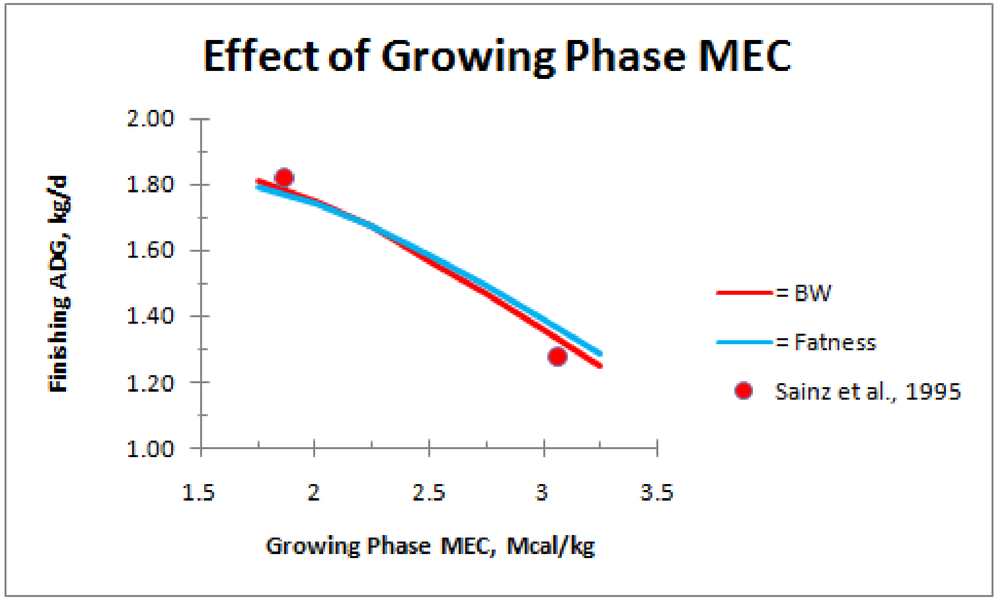
	SD
EB Weight	14 kg
EB Fat	10 kg

USDA Meat Animal Research Center (MARC) cycle one (Smith et al., 1976) and cycle two (Cundiff et al., 1981)

Senstivity Analysis

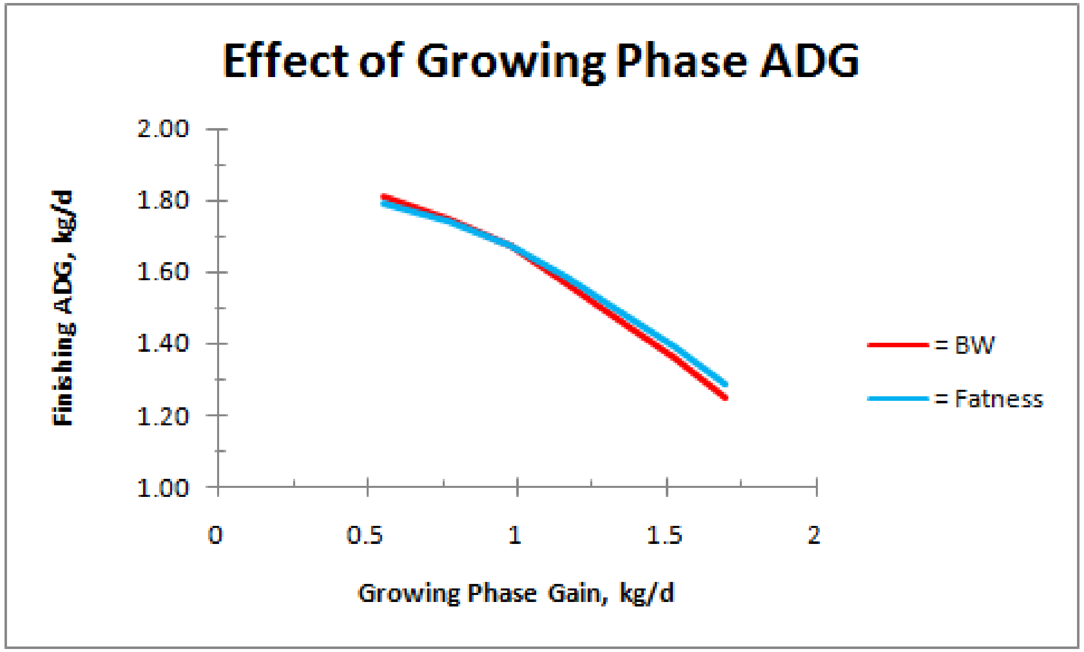
	Correlation Coefficient (r)	
	Residual	
	Protein	Fat
Intake	-.01	-.01
Initial Fatness	.03	-.13
Ration ME	.33	.45

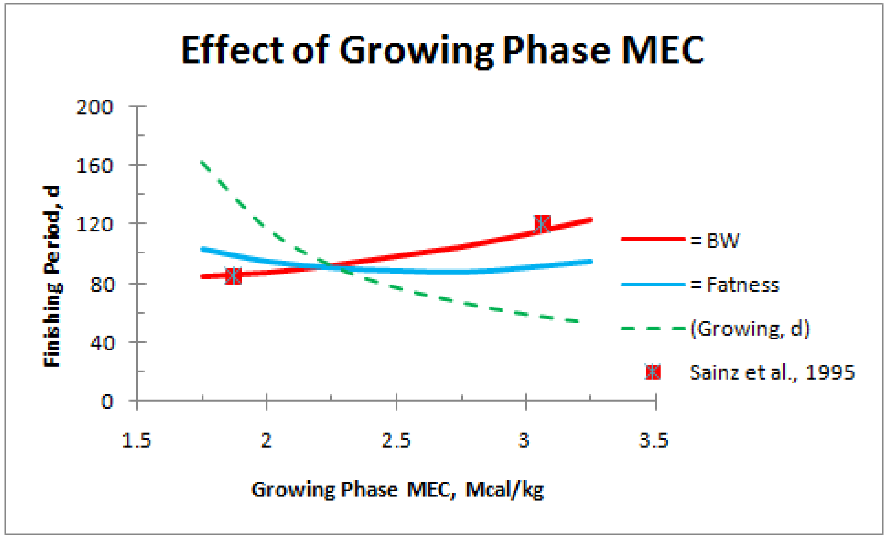
Fat gain was under-predicted ($P < 0.01$) at high feed energy concentrations



Finishing daily gain is inversely and nearly linearly related to previous growing phase performance.

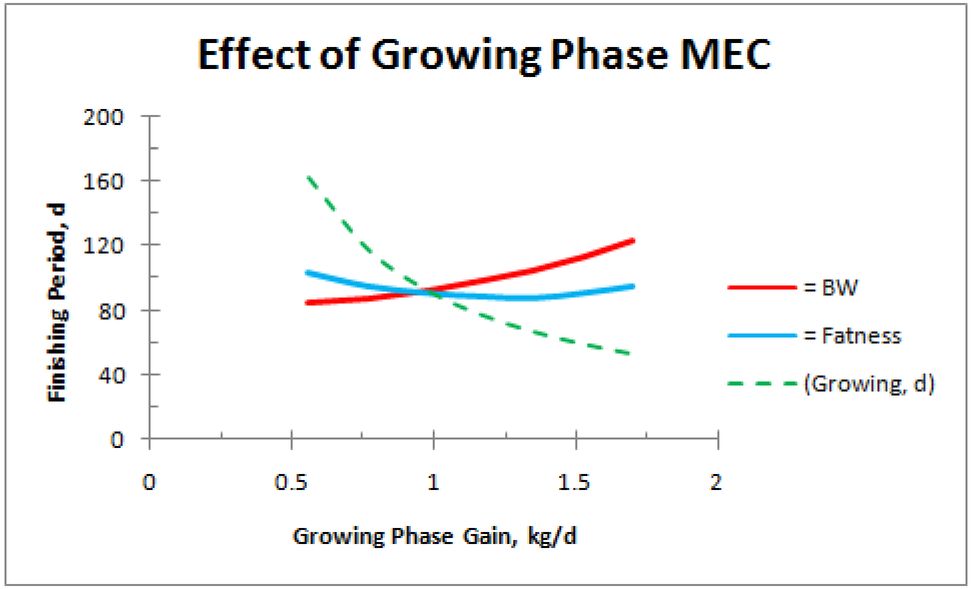
This hardly varied whether cattle were fed to equal body weight or fat content endpoints.





Steers fed to an equal body weight endpoint were more sensitive to previous growing phase ration energy compared to steers fed to a constant fat endpoint.

Those fed higher energy diets as calves reached acceptable carcass fatness at much lighter weights.



DGM

- Accounts for initial body composition and frame size

- Not always for fat gain.

- Not unexpected -- fat accretion is energy left after maintenance and protein gain

- Errors in maintenance or protein gain accumulate

- Also, efficiency of feed energy for fat accretion not equal to that for protein, a NE system assumption

Need more mechanistic accounting for maintenance energy use

***Maintenance energy closely related to changes in visceral protein mass** (Sainz and Bentley , 1997)*

Representation of Fat and Protein Gain at Low Levels of Growth and Improved Prediction of Variable Maintenance Requirement in a Ruminant Growth and Composition Model

Hutton Oddy

Jim Oltjen

Tanya Soboleva

Tony Pleasants

Objectives

- Improve prediction of growth at low or near maintenance levels
- Improve prediction of retained energy--requires more accurate estimation of maintenance or heat production (HP)
- To illustrate hypothesis tested, methods used, and subsequent equations and parameters accepted

Definition of Body Pools m, v, f

v = liver, heart, kidney, spleen and & gastro-gastrointestinal tract protein

m = remainder of empty body protein, mainly muscle

f = empty body fat

Model Equations

$$dm/dt = k_m\ (NEG + c_m\ f_a)\ (1 - m/m^*)$$

$$dv/dt = k_v\ (v^* - v)^{e3}$$

$$df/dt = NEG - dm/dt - dv/dt$$

where NEG is retained energy

Net Energy System (NRC, 2000)

$NEG = (DMI - NEm_{req}/[NEm])\ [NEg]$

Metabolizable Energy System (SCA, 1990)

$NEG = (MEI - NEm_{req}/k_{maint})\ k_{gain}$

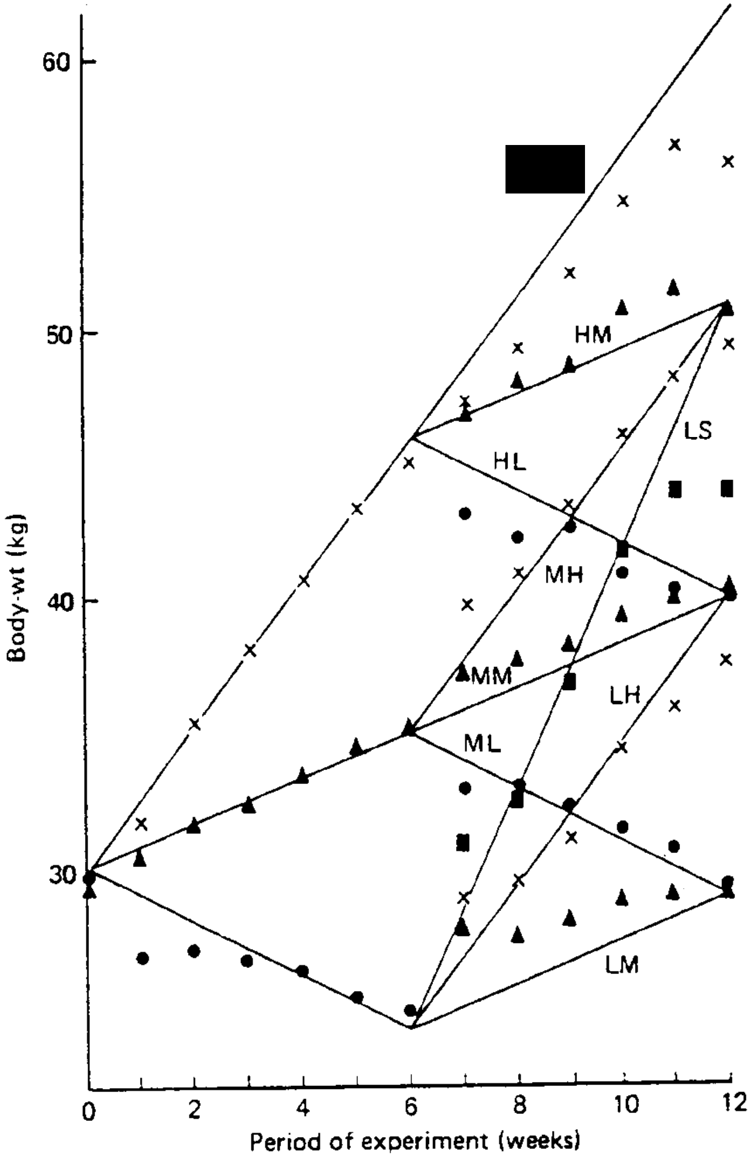
where $NEm_{req} = \alpha\ EBW^{0.75}$

Heat Production Estimation (Regression)

$NEG = MEI - HP$

where $HP = b_1m + b_2v + b_3dv/dt + b_4dv/dt$

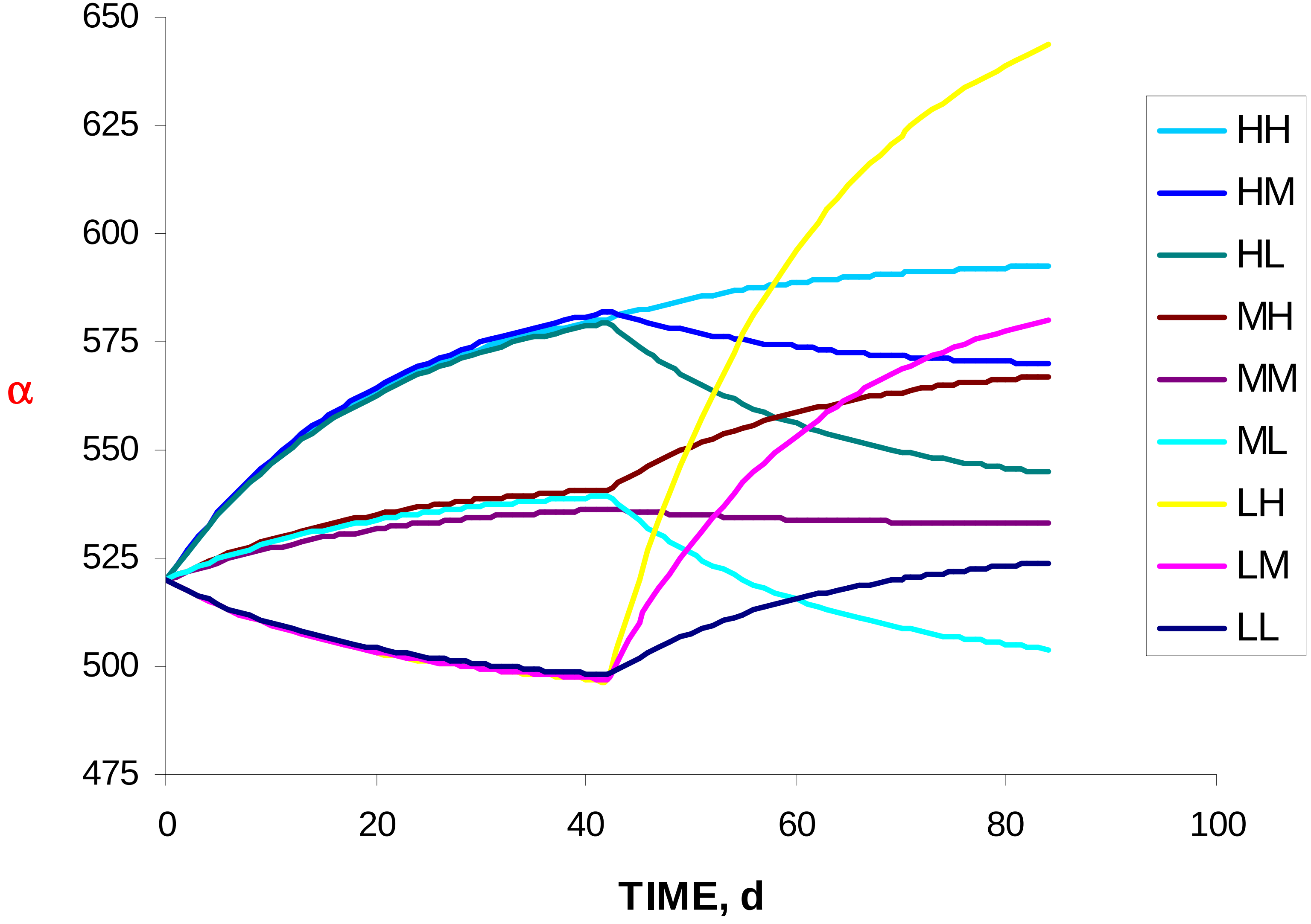
Ferrell et al., 1986



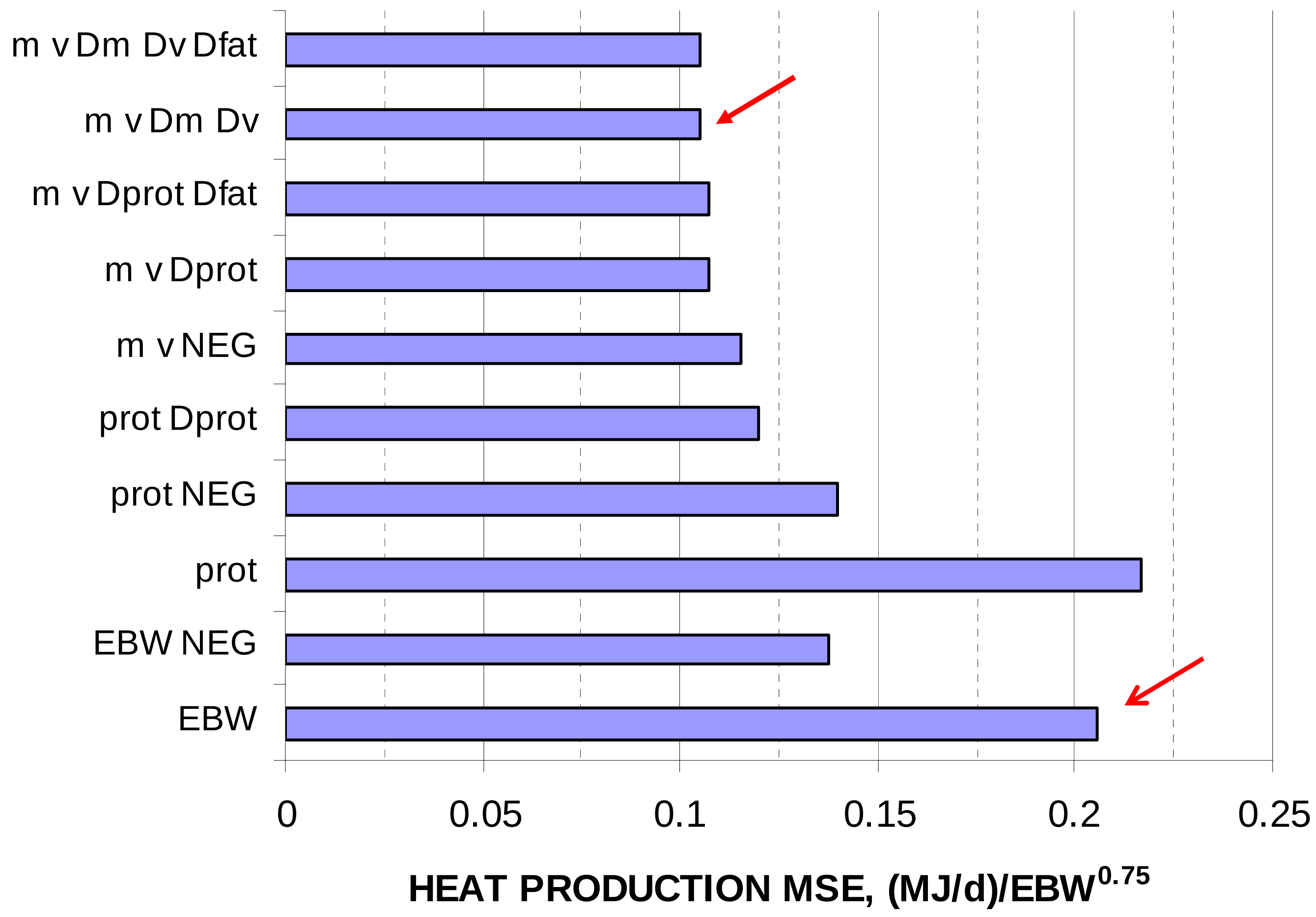
[redacted]

Fig. 1. Live body-weight of lambs assigned to various treatment groups with respect to period on test. Lambs assigned to gain 16 (H), 5 (M) or −6 (L) kg during period 1 (0 to 42 d) are indicated by ×, ▲ and ● respectively. Similarly, lambs fed to gain 16 (HH, MH, LH), 5 (HM, MM, LM) and −6 (HL, ML) kg during period 2 (43–84 d) are also indicated by ×, ▲ and ● respectively. Those fed to gain 27 (LS) kg are indicated by ■. Solid lines indicate target weights with respect to period on test.

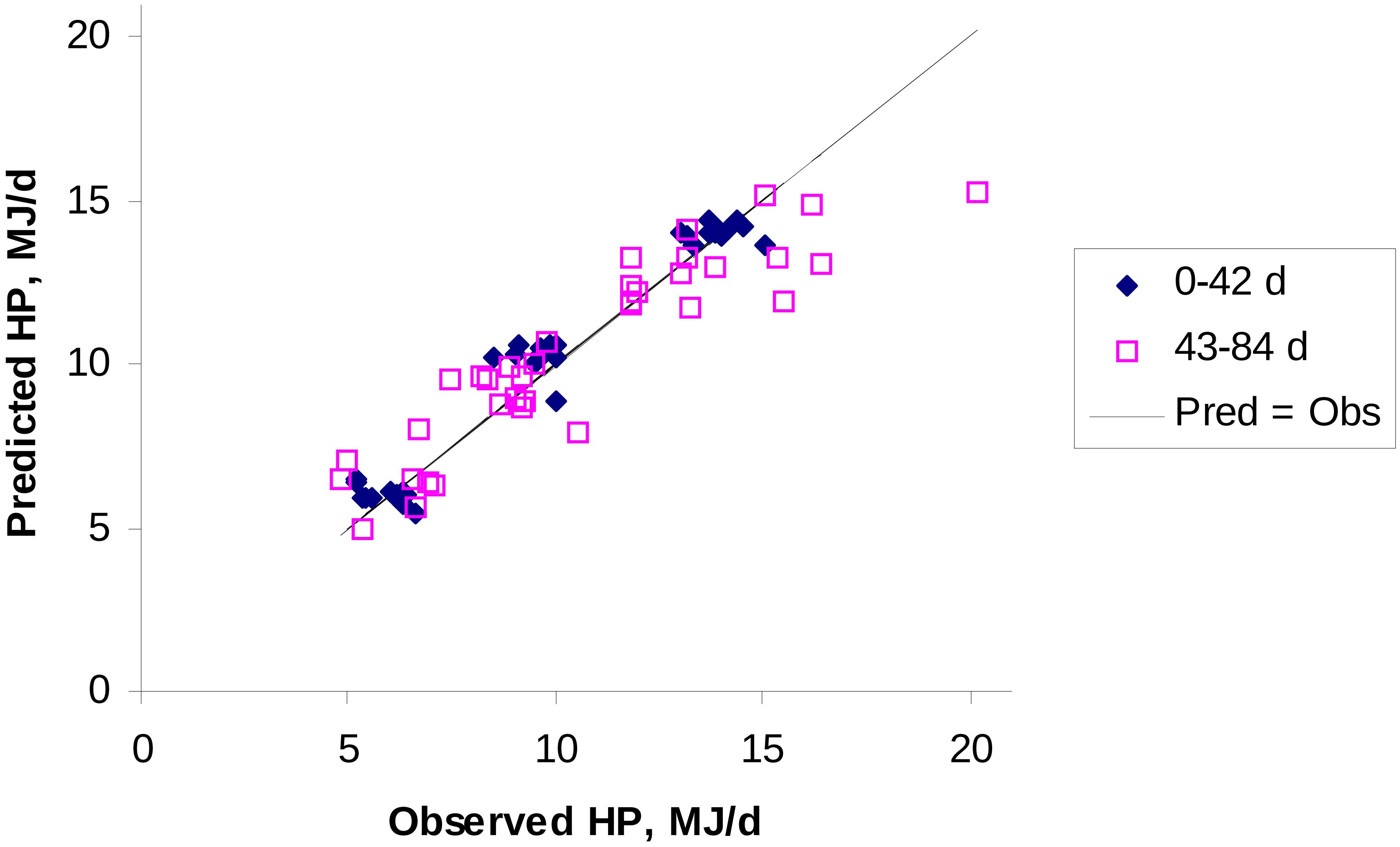
Trajectory of α



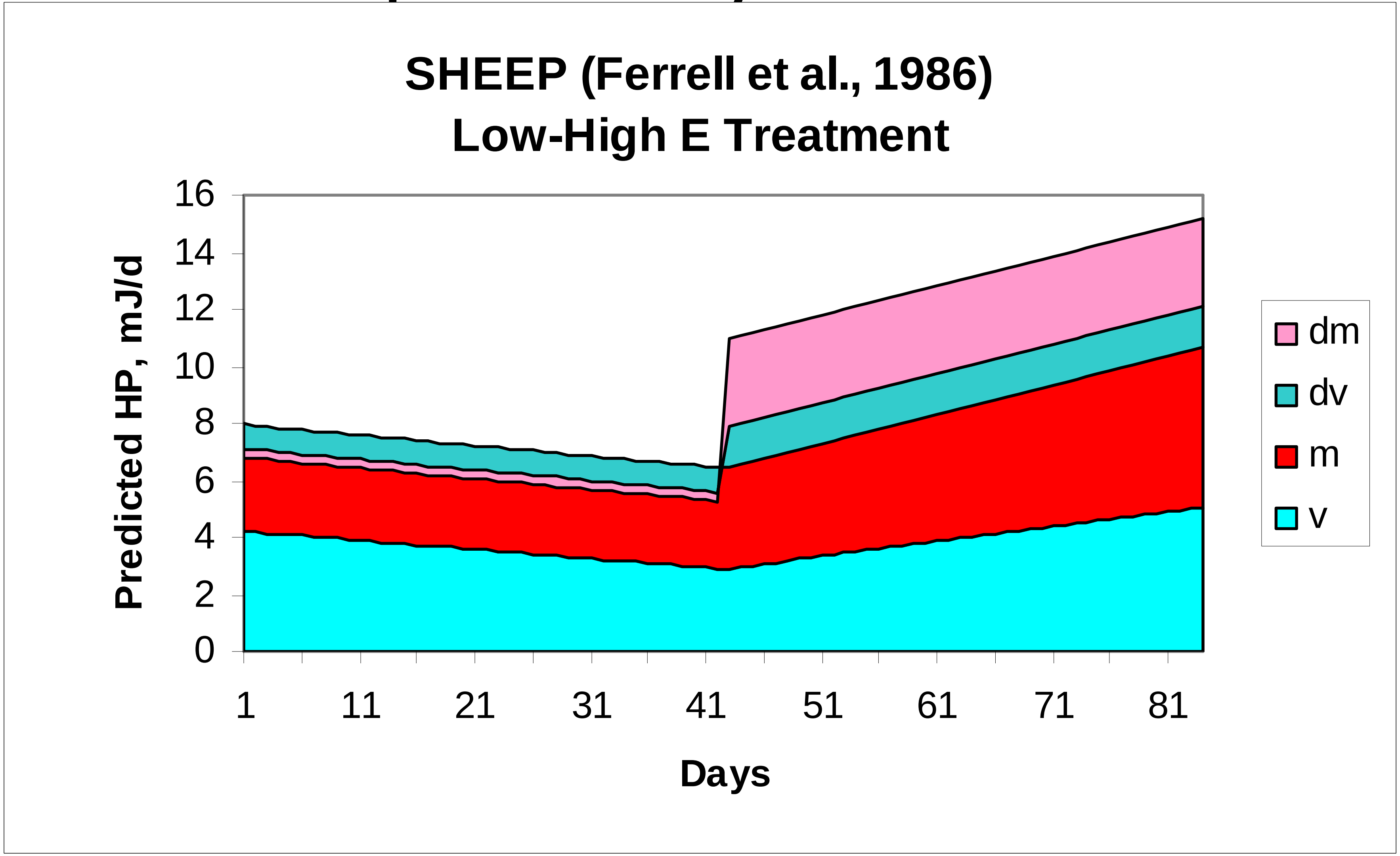
HP


m v Dm Dv Dfat
m v Dm Dv
m v Dprot Dfat
m v Dprot
m v NEG
prot Dprot
prot NEG
prot
EBW NEG
EBW
0
0.05
0.1
0.15
0.2
0.25
HEAT PRODUCTION MSE, (MJ/d)/EBW0.75

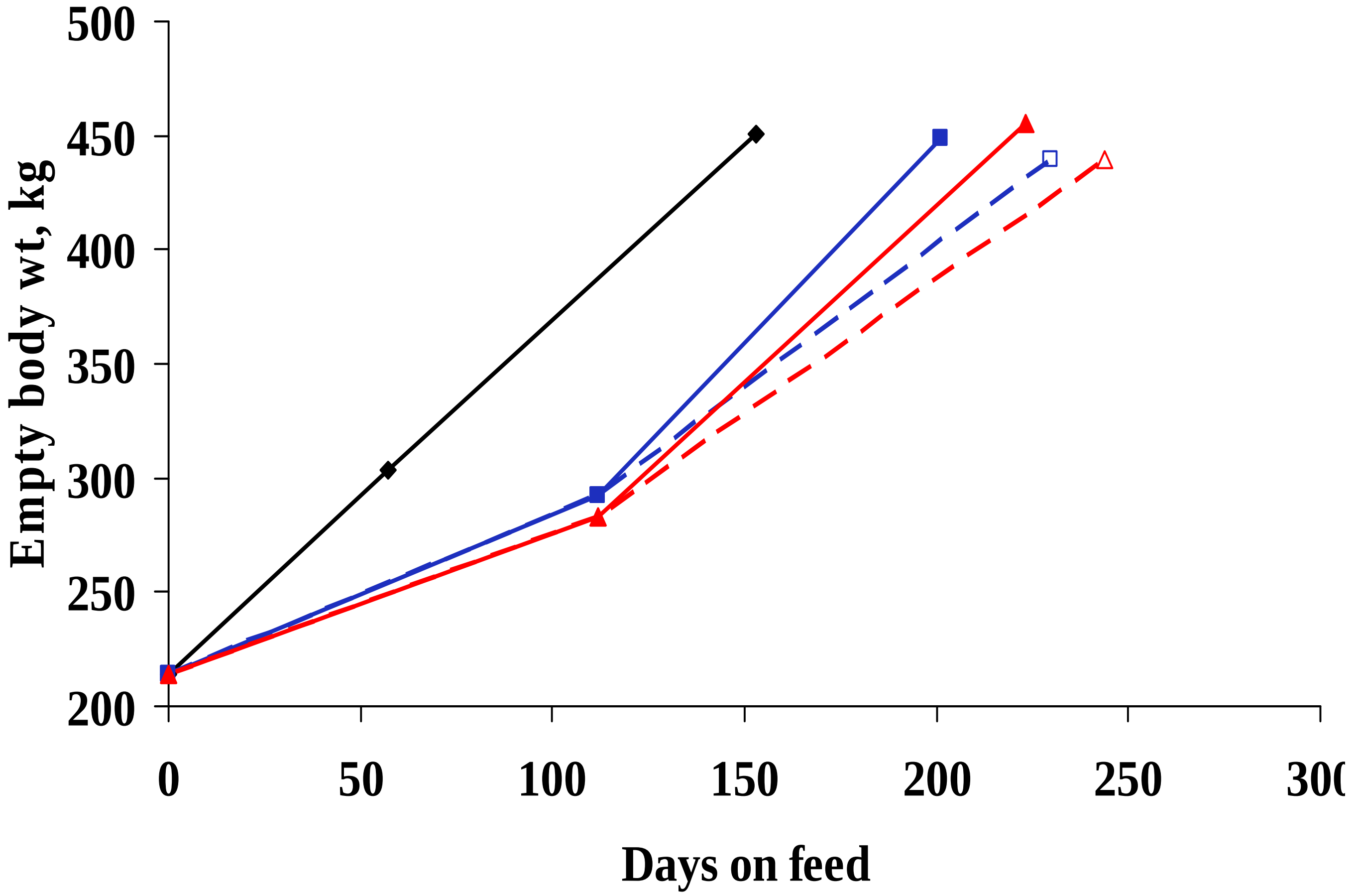
$HP = 1.02\,m + 10.5\,v + 60.9\,dm/dt + 283\,dv/dt$



Components of HP for Compensatory Growth



Compensatory growth in beef cattle



From: Sainz et al., 1995

Compensatory Growth and Carcass Quality in Growth-Restricted and Refed Beef Steers[1]

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ABSTRACT: Beef steers were fed in two phases 1) to determine the relative importance of changes in DMI, gastrointestinal tract fill, energy expenditures, and composition of gain in the compensatory growth phenomenon, 2) to compare the effects of growth restriction due to ad libitum consumption of a low-energy (low-concentrate) diet to those of limited intake of a high-energy (high-concentrate) feed, and 3) to examine changes in carcass composition and quality resulting from different types of growth restriction. During the growing phase (237 to 327 kg), steers were fed either a high- (C) or low- (F) concentrate diet. Diet F was available for ad libitum consumption (FA) and diet C was available either for ad libitum consumption (CA) or on a limited basis (CL) to match the live weight gains by the FA group. During the finishing phase (327 to 481 kg), all steers received diet C, either for ad libitum consumption (CA) or restricted (CL) to 70% of the intake by the corresponding CA steers. Backfat thickness was markedly reduced ($P < .001$) by final feed restriction (7.4 and 6.9 mm for CL-CL and FA-CL respectively), compared with CA-CA (12.6 mm). Backfat also was lower in CL-CA (11.6 mm, $P < .10$) and FA-CA (9.9 mm, $P < .05$) than in CA-CA steers. Conversely, marbling scores were similar among groups, except for the FA-CL steers, which had lower marbling scores than FA-CA and CL-CA steers ($P < .05$). Higher DMI following growth restriction were accompanied by increased rates of live weight (+54 and +27%) and empty body weight (EBW; +57 and +43%) gain for CL-CA and FA-CA steers, respectively, compared with CA-CA steers. Gain:feed (EBW basis) were improved in some restricted/refed groups (+30, +13, and +10%, for CL-CA, CL-CL, and FA-CA, respectively) relative to CA-CA. Increased DMI played a major role in the compensatory gain response in both CL-CA and FA-CA groups. Maintenance requirement was reduced (−17%) in CL-CA and increased in the FA-CA group (+21%); both changes affected the magnitude of compensatory gain in those animals. In contrast, composition of gain had little or no effect on the compensatory gain response. Programmed feeding can be used to manipulate carcass quality, but low-concentrate feeding during the growing phase may impair overall feedlot performance.

Key Words: Restricted Feeding, Growth, Carcass Traits, Beef Cattle

J. Anim. Sci. 1995. 73:2971–2979

Introduction

A growing phase for cattle is usually imposed for a period between weaning and finishing in a feedlot. The growing phase allows body development before fattening, which in turn permits cattle to attain slaughter finish at desirable carcass weights. Marbling and quality grade are thus improved by allowing the animals to reach greater maturity (Thompson and O'Mary, 1983). Cattle are often under some nutritional stress during the growing phase and exhibit compensatory gain when placed on full feed. Compensatory gain, the more rapid and efficient growth of animals following a period of feed restriction, plays an important role in beef production. Animals entering the finishing phase attract unit price premiums if buyers perceive that they have undergone a period of nutritional stress, because their subsequent performance is expected to be superior to that of well-fed animals. Although intensive research has shed some light on the mechanisms of compensatory gain and its consequences for body and carcass composition, several aspects of these phenomena remain poorly understood. In particular, the roles of increased feed intake, altered composition of gain, and possibly altered patterns of energy utilization have not been fully elucidated.

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[1] The authors thank J. Gwerder, D. Kominek, R. Scadden, D. Sehnert, and all the students and staff of the Nutrition and Meats groups for their assistance with animal care and sampling.

[2] To whom correspondence should be addressed.

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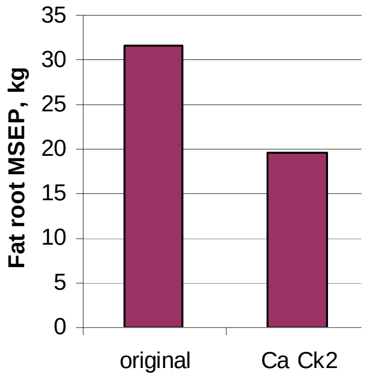
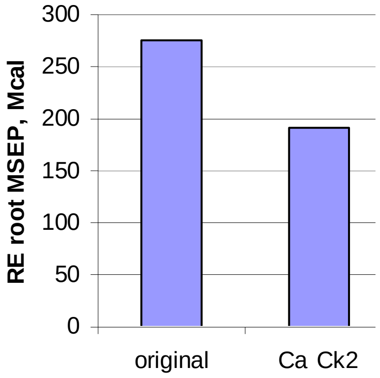
Barioni et al. (2006) using restricted – refed steers of Sainz et al. (1995)

a)



b)

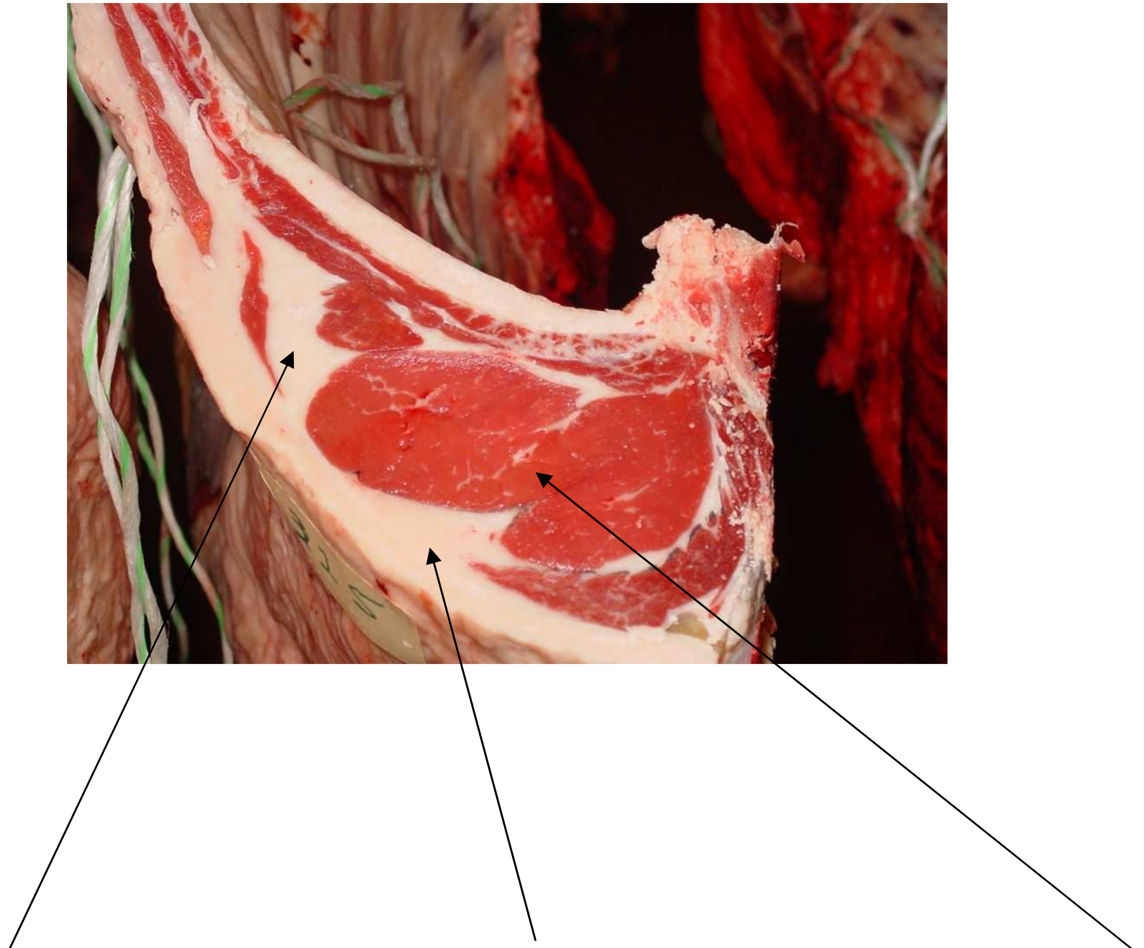


Residual Feed Intake (Castro Bulle et al., 2007)

- More efficient steers with negative RFI ate less (12%).
- RFI was related to maintenance energy requirements (r=0.42).
- No ‘significant’ association with carcass traits.
- Myofibrillar protein degradation rates were positively related to maintenance energy requirements (r=0.76), but were not related to RFI (r=-0.14).

A genetic trait related to RFI should be used in prediction models to account for differences in maintenance.

Eventually adjust for protein synthesis/degration rate differences which are explicitly represented in the Davis Growth Model.

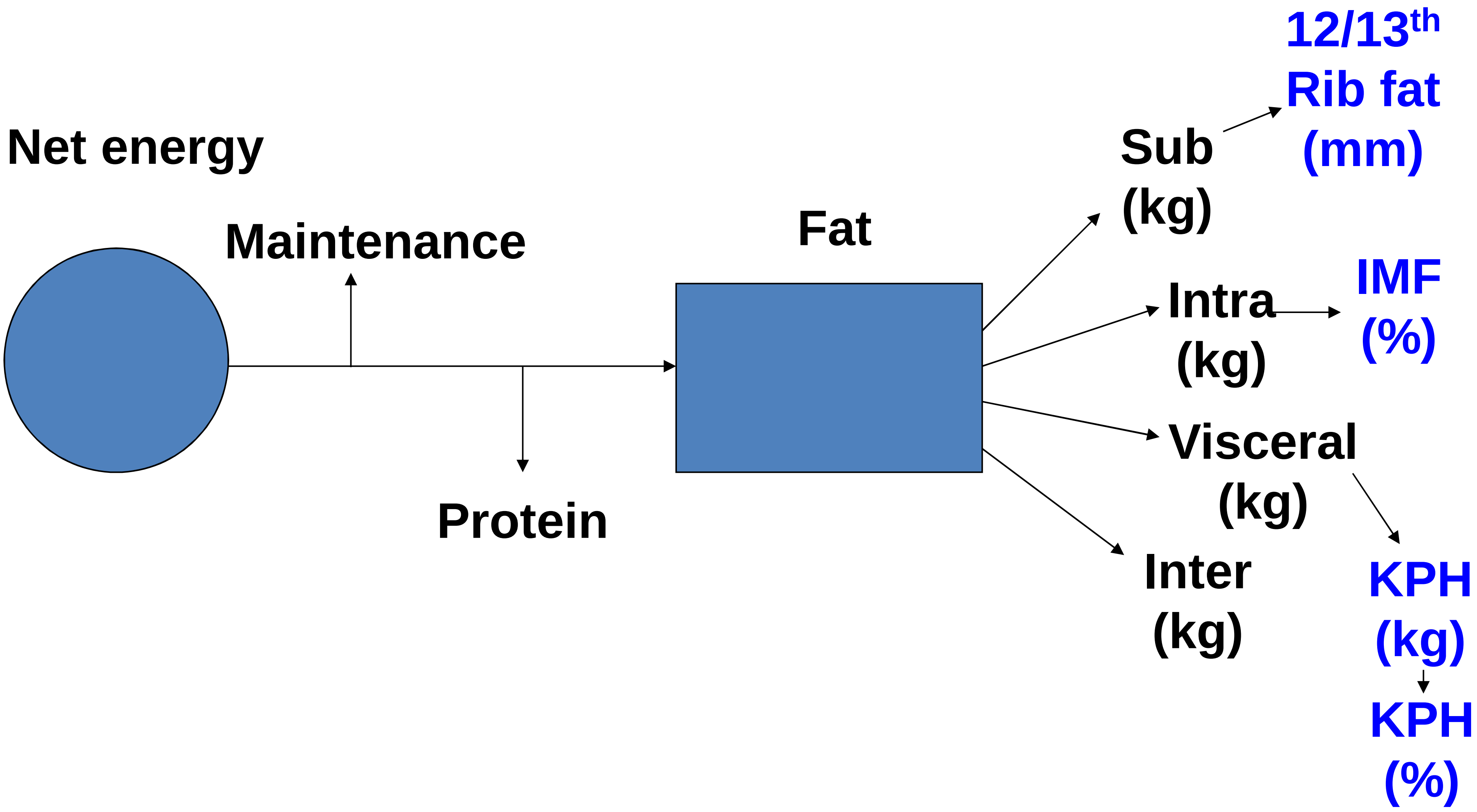


Intermuscular Fat

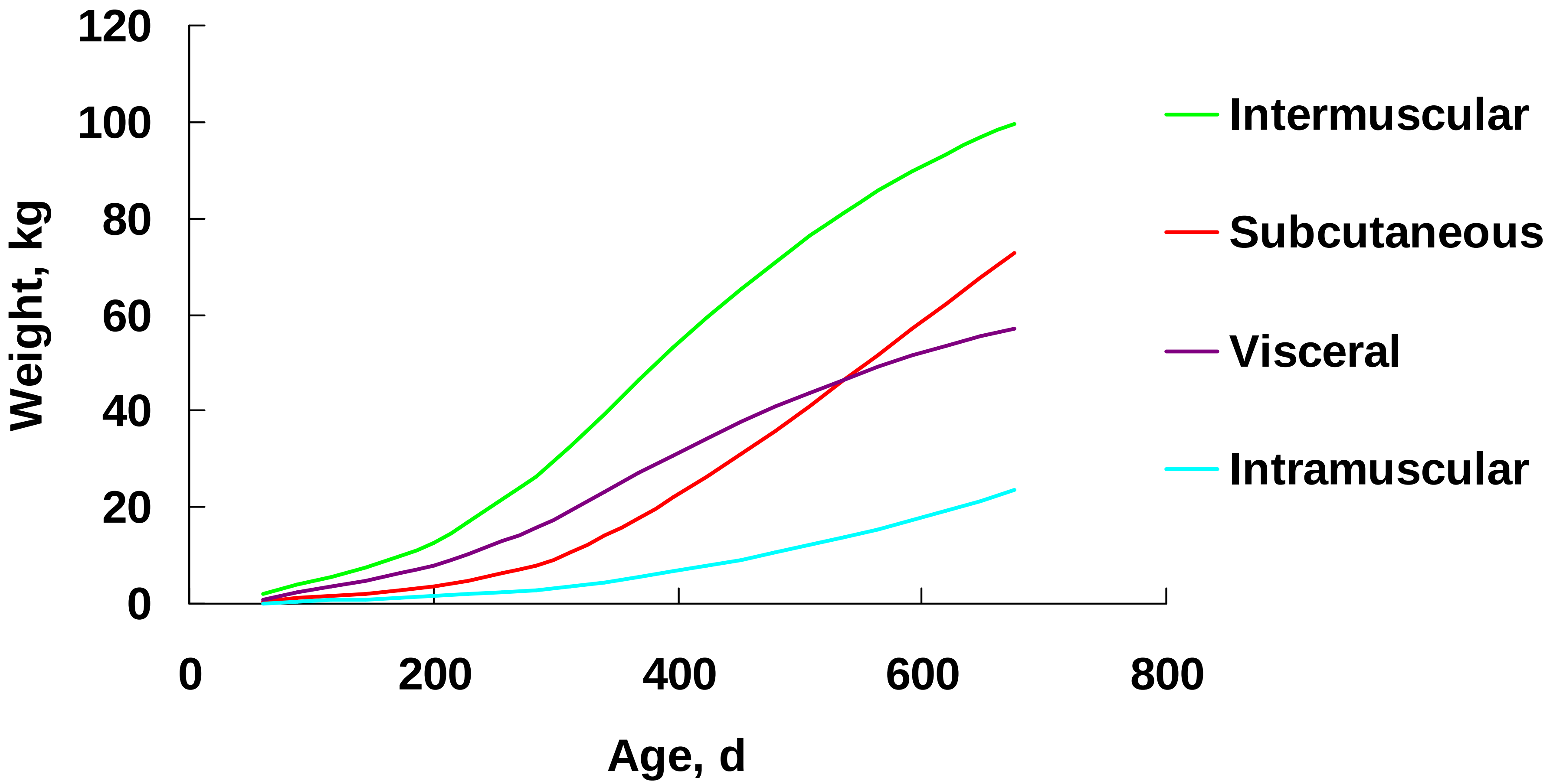
Subcutaneous Fat

Intramuscular Fat

Davis Growth Model



Growth of four body fat depots



A Hybrid Algorithm to Optimize Beef Feedlot Operations

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R.D. Sainz

Mathematical formulation

- Evaluating feedlot economic performance as calculated by:

$$GM_t = N.(LW_t.LWV_t - LW_0.LWV_0 - DMI_t.CDM) - O_t$$

GMt - Gross margin evaluated at time t

N - Number of animals

LW_t, LW_0 – liveweights of the animals at time t and zero, respectively

LWVt, LWV_0 - monetary values per unit of LW at time t and 0, respectively

DMI_t is the acumulated dry matter intake at time t

CDM is the dry matter cost

O_t is the acumulated overhead at time t

Mathematical formulation

- Using a beef growth model can estimate performance as a function of energy density and animal characteristics, we have that:

$$(LW, DMI)_t = f\left(\varepsilon, it, LW_0, t \mid A\right)$$

- LWt – Liveweight at time t
- DMIt – Accumulated dry matter intake at time t
- ε – Diet enegy density
- It – Initial time for the feeding period
- LW0 – Initial liveweight
- t – Feeding time
- A – vector of animal characteristics

Mathematical formulation

- Therefore, for a given diet, with energy density ε and cost of dry matter CDM, the gross margin of each animal at a given time in the feedlot operation can be calculated as a function of:

$$GM_t = Z\left(\varepsilon, it, LW_0, t \mid A, DMC\right)$$

Algorithm

- Internal loop, LP ration formulation
- External loop, non-linear evolutionary algorithm maximizes profit, constrained by capital and feed availability
- Optimum slaughter time based on DGM simulations for an average animal
- Iterate--external loop sets a new a new diet constraint, LP formulates new diet, and DGM used to converge to a new optimum slaughter date for the diet and seasonal prices

Algorithm

1. Start a non-linear optimization algorithm with values of N, ε, *it, ilw* within a feasible range and set a first estimate of slaughter liveweight (510 kg by default)
2. Simulate animal growth to determine time series of LW and DMI
3. From animal performance determined in step 2, calculate nutrient requirements
4. Determine the minimum dry matter cost through a linear programming algorithm for the animals and feeds available with nutrient requirements calculated in step 3
5. Determine optimum slaughter time and repeat steps 3 and 4 to re-estimate requirements and dry matter cost with optimum slaughter weight until difference less than a tolerance τ.
6. Calculate the total feed use and inform the non-linear algorithm for checking non-linear constraints
7. Modify N, ε, *it, ilw* by using a non-linear optimization algorithm and repeat steps 2 to 5.

Application

Optimization of a feedlot (Brazil) with two combination of feed prices and seasonal variation of beef prices:

	Cheap Grain	**Expensive Grain**
Corn	140,00	230,00
Soybean meal	415,00	607,00
Cotton seeds	171,00	330,00
Sugarcane	22,00	22,00
Urea	490,00	660,00
Minerals	500,00	500,00

Results

Feed Prices	Cheap Grain	Expensive Grain	Cheap Grain	Expensive Grain	Expensive Grain
Animal number constraint	1000	1000	800-1500	800-1500	800-1500
Capital constraint (R$)	-	-	800.000,00	800.000,00	800.000,00
Sugarcane constraint (kg DM)	-	-	-	-	300000
Purchase date	5/6	23/6	15/6	23/6	3/7
Number of animals	1000	1000	985	1122	1037
Initial liveweight (PV)	250	326	250	295	333
Feeding time (days)	193	115	175	115	105
Slaughter weight (kg)	496	462	475	463	461
Optimum TDN	77,89	74,84	76,60	76,19	76,25
VPc	151,24	59,96	150,02	59,06	56,68
IRR(%)	23,64	8,43	23,45	8,39	8,38
Slaughter date	15/12	16/10	15/12	16/10	16/10
Sale Price (R$/kg CWT)	3,14	3,18	3,18	3,18	3,18
Sugarcane/head (kg DM)	487,64	381,21	432,23	435,54	301,93
VPc/t MS	310,15	157,29	310,15	157,29	187,72
Purchase Price (R$/head)	358,9	454,7	358,9	454,7	466,6
LWG (kg/dia)	1,27	1,19	1,23	1,23	1,22
Sugarcane percentage (DM)	30,8	39,7	34,0	35,8	34,9

Conclusions

- Feeding period and optimum liveweight are strongly affected by the feed ing cost. For high grain prices, optimum strategies include buying heavier animals and having shorter feeding periods.
- Diets with minimum cost of gain were not always those with maximum expected net present value to the operation because of beef prices seasonality . Results indicate that as important as having low cost of production is to provide liveweight gains that allow slaughter in periods of highter prices.
- The combination of a linear (simplex) and a non-linear (evolution strategy) and dinamic simulation of animal growth produced robust solutions for the problem of optimizing feedlot operations allowing the identification of more promissing strategies.

Future Improvements

- Include risk analysis of beef prices
- Test alternative non-linear optimization algorithms (for the deterministic case evolution strategy is slow)
- Include qualitative variables as sex and breed in the optimization of strategies