Snowmass Alpacas Auction

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What have we learned about alpaca nutrition?

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1

Snowmass Alpaca Auction

Presentation Outline

Nutritional Advances Timeline

Are Camelids Different?

How Much Do Alpacas Eat?

Nutrient Requirements Research

Future Research Needs

R. Van Saun, Cuzco, Peru

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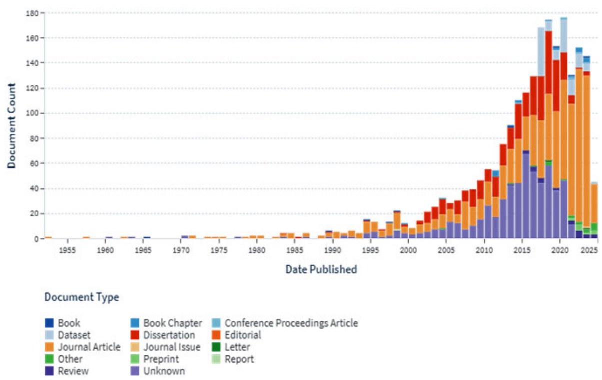
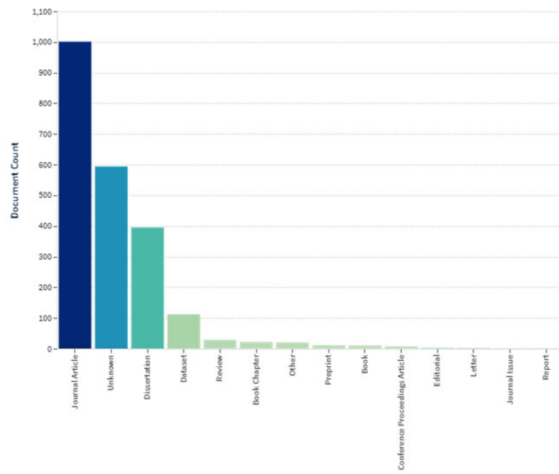
Search of Camelid Nutrition Publications

2,208 scholarly works identified





Search in Lens.org Scholarly Works

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Advances in Camelid Nutrition

1970's – Phase 1: Descriptive studies of digestive anatomy and physiology

1980's – Phase 2: Field studies of forage selectivity; Comparative digestion studies with ruminants; Energy & Protein maintenance requirements

1990's – Phase 3: Seminal publications on comprehensive description of camelid nutrition; Intake feed selection studies

2000's – Phase 4: Recognizing unique aspects of glucose homeostasis; Nutrient requirement modeling; Intensive feeding studies

2010's: Microbiologic comparisons; Intensive feeding, digestion trials; Camelid growth models; Milk and tissue composition studies

Current Research: Many opportunities to address camelid productive efficiency, nutritional impacts on reproduction and health; specific nutrient requirements

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Nutritional Advances through Research

- Recent collaborative research activities addressing alpaca nutrition

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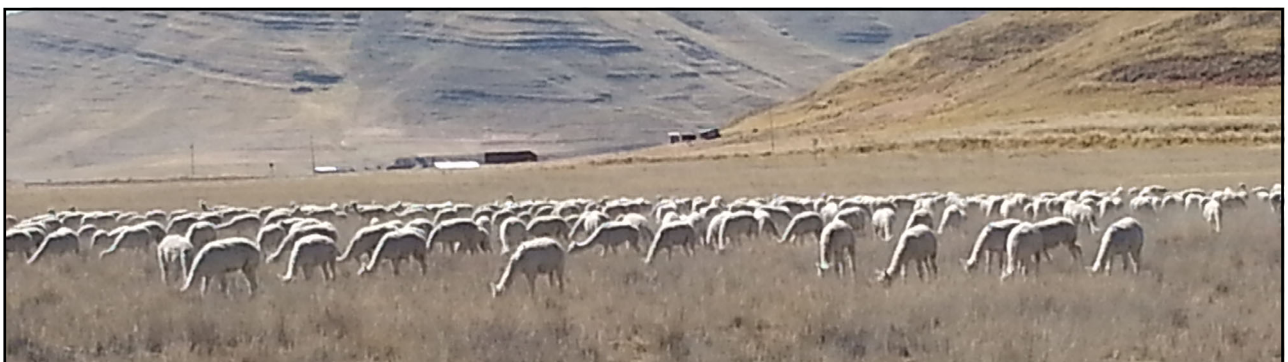
5



Understanding the Beast

How are alpacas similar or different from sheep and cows?

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Are Alpacas Unique?

Or are they just big sheep or small cows?

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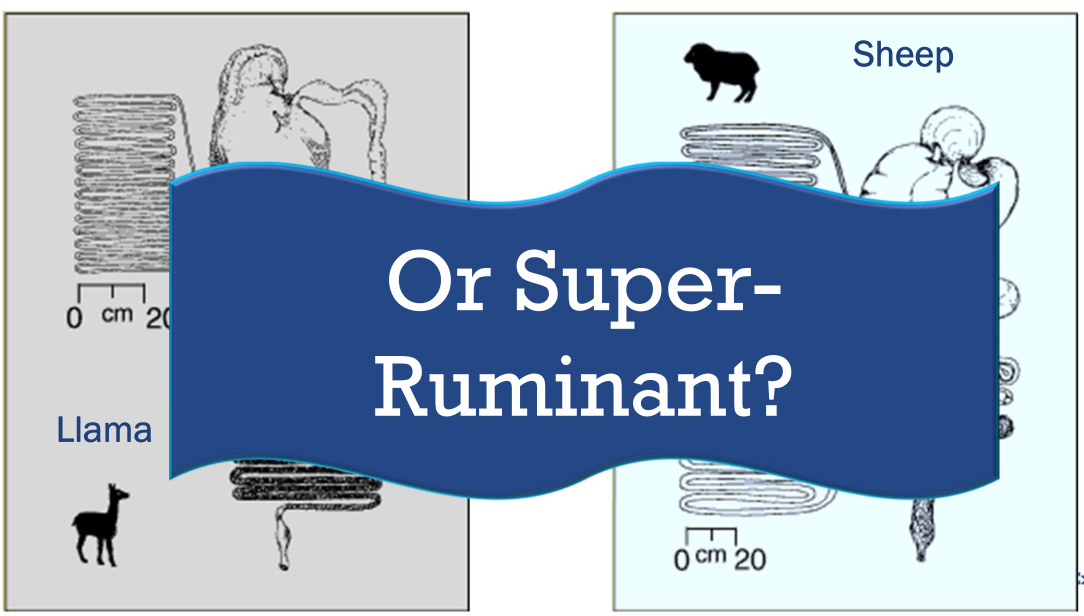
Pseudo-ruminant or Ruminant?



Or Super-Ruminant?

8

Understanding the Beast

Unique Alpaca Adaptations

- Anatomic differences from ruminant animals allow for greater digestion of low-quality forage
  - Slower rate of passage – retains forage longer, lower intake capacity
  - Recycling of urea to support fiber fermentation
- Metabolic adaptations also allow for survival
  - Altered glucose metabolism due to low insulin secretion, sensitivity
  - Metabolism oxidizes fatty acids from fiber fermentation, not glucose
  - Greater use of amino acids for glucose production
  - Low insulin secretion allows for greater fat mobilization

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Understanding the Beast

Unique Glucose Metabolism

- Unlike ruminants, camelids maintain a higher blood glucose concentration
  - Glucose: 80 – 120 mg/dL (> 300 mg/dL)
  - Sugar, Starch ⟶ Propionate ⟶ Glucose
  - Minimal sugar and starch in native diet
- Adaptations
  - Insulin resistance (Type II diabetes) – readily mobilize fat
  - Greater VFA oxidation – use acetate, butyrate from fiber fermentation
  - Increased gluconeogenesis from amino acids – like a cat!

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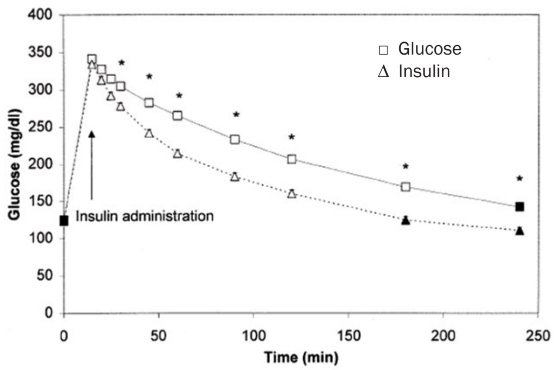
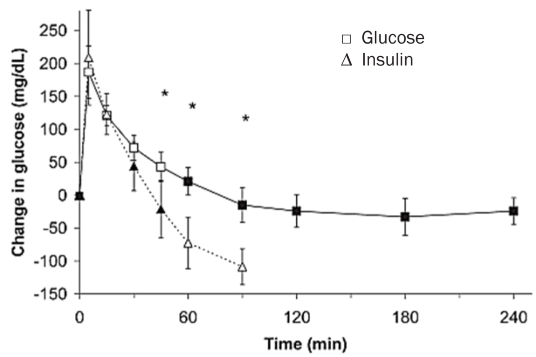
Insulin Regulation

Adult Alpacas
Cebra et al., AJVR 2001



Llama crias
Cebra and Tornquist, AJVR 2005



Younger animals showed a stronger insulin response and more pronounced hypoglycemia to insulin administration compared to adult animals.

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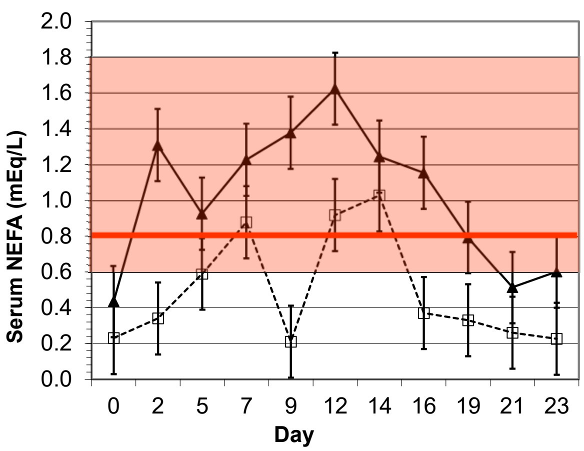
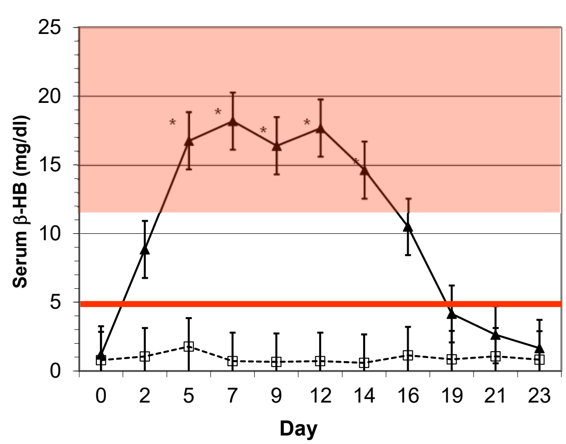
Energy Metabolism – Not Ketogenic Like Ruminants





Tornquist et al., AJVR 2001; 62:1081

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Unique Protein Metabolism

- Predominantly consume a low protein diet – dry season forage
- Allowing greater microbial fermentation of forage increases production of microbial protein (50-60% protein)
- Use of amino acids for glucose production produces large amounts of urea
- Recycle urea via saliva to C-1 to support microbial fermentation of plant fiber

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Understanding the Beast

Alpaca BUN Concentrations by Region

Region	N	BUN (mg/dL)	Maximum	Minimum	Dietary CP (% DM)
Cerro de Pasco	50	21.65 ± 5.30[c]	46.88	15.07	13.0 ± 0.76
Junín	50	24.82 ± 2.07[b]	28.67	19.88	7.53 ± 0.51
Puno	50	30.43 ± 6.11[a]	47.72	20.30	11.60 ± 0.69

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Understanding the Beast

Dietary Protein Effects on BUN Concentration

Treatment	Days relative to birth	n	Mean ± SD (mg/dL)
Low Protein, 9%	Day -7	16	25.34 ± 3.19
	Day 0	16	18.16 ± 7.01
	Day +7	16	14.14 ± 5.42
Medium Protein, 12%	Day -7	16	25.72 ± 5.25
	Day 0	16	20.46 ± 6.76
	Day +7	16	17.52 ± 5.32
High Protein, 15%	Day -7	16	26.29 ± 3.36
	Day 0	16	21.22 ± 6.11
	Day +7	16	24.03 ± 5.55

BUN concentrations differed by treatment group, P<0.05

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Understanding the Beast

Implications for Feeding Alpacas

- Feed a high forage diet with supplements that have fermentable fiber sources (beet pulp, soyhulls, wheat midds)
- Minimize feeding of high starch feed ingredients (corn, barley, wheat) to prevent forestomach acidosis
- Ensure sufficient C-1 degradable protein (25-30% soluble protein) in diet to support microbial fiber fermentation
- Camelids are predisposed to fatty liver disease
    - Inadequate dietary protein limits glucose production, fat transport
    - Inadequate intake leading to rapid fat mobilization

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How much do Alpacas eat?

What controls intake, and how does this impact feeding practices?

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Alpaca Feed Intake

Understanding Feed Intake

- Consumption of dry matter is the cornerstone of nutrition
- Nutrient content of the diet is determined by how much the animal will consume
- Historically, it has been assumed camelids consume less compared to ruminants due to their ability to retain forage in C-1
  - Lower intake for low-quality forages
  - Similar intake for high-quality forages
- Ruminant animal intake is directed by NDF content of forage – is this the same for alpacas?

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Camelid Dietary Recommendations

Physiologic State	TDN %	CP%	Calcium %	Phosphorus %
Llamas				
Maintenance	41.8	7.5	0.34	0.24
Growth	54.5 – 61.4	7.8 – 9.0	0.36 – 0.40	0.25 – 0.28
Lactation	54.5 – 56.8	10.6 – 11.4	0.44 – 0.45	0.31
Pregnancy	54.5	7.9	0.45	0.31
Alpacas				
Maintenance	48.0	7.4	0.32	0.22
Growth	60.2 – 67.0	7.8 – 9.1	0.37 – 0.40	0.26 – 0.29
Lactation	60.2 – 62.5	8.1	0.42	0.30
Pregnancy	60.2	10.8 – 12.0	0.42 – 0.44	0.29 – 0.31
NRC 2007				
Maintenance	53.1%	9.2%	0.18%	0.14%
Growth	52 – 80%	8.9 – 12.5%	0.3 – 0.68%	0.17 – 0.33%
Lactation	52 – 80%	9.6 – 16%	0.3 – 0.75%	0.18 – 0.42%
Pregnancy	53 – 80%	8.5 – 15.76%	0.25 – 0.45%	0.17 – 0.24%

Lopez and Raggi, Arch Med Vet XXIV, Nº 2, 1992

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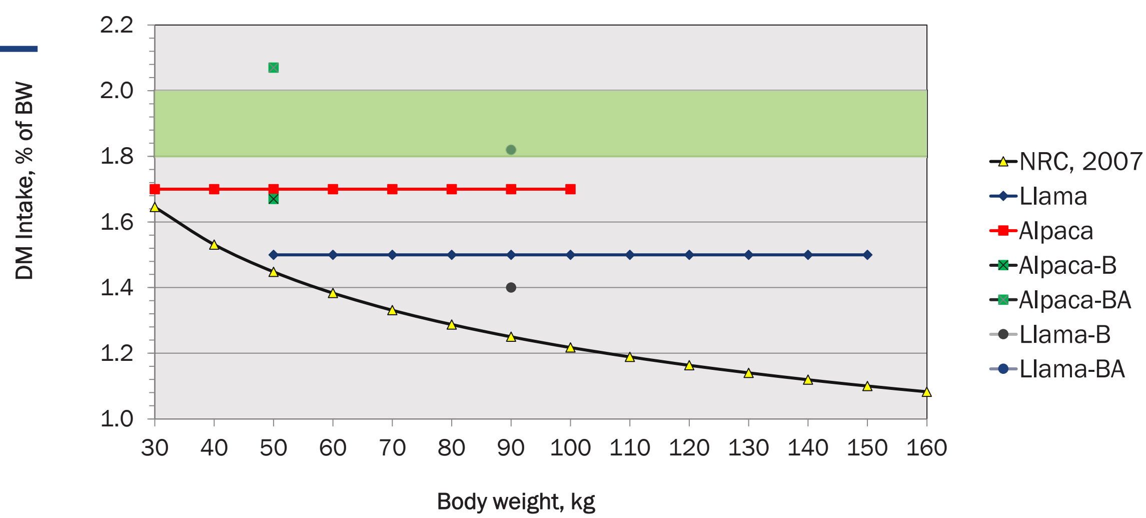
19

Feed Intake Comparisons



Measured Intake: 1.52 ± 0.45% BW for llamas and alpacas across 11 studies

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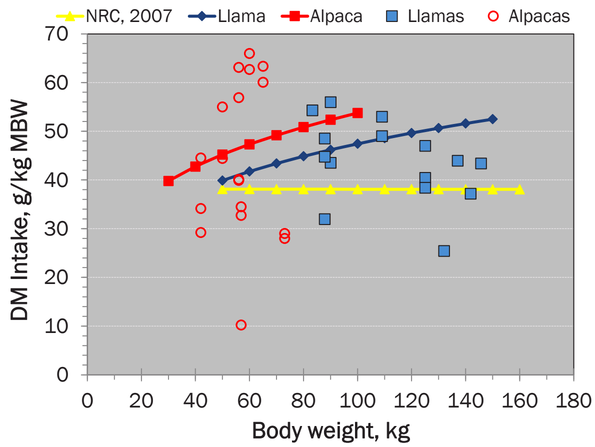
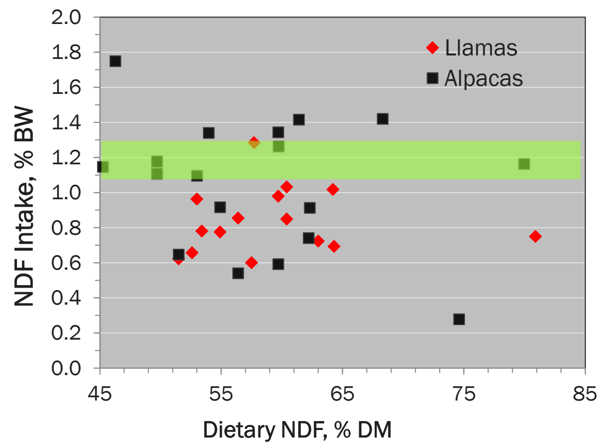
Alpaca Feed Intake

Estimated Feed Intake



Llama and alpaca data from Lopez and Raggi, 1992

11 Digestion studies, 84 total animals



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Comparative Forage Intake

Grass Hay vs. Grass Seed Straw

Chemical composition and degradation characteristics of green hay (GH) and grass seed straw (GSS).

Forage type	GH ($n = 3$)	GSS ($n = 2$)
Dry matter, %	90.6 ± 0.6	91.8 ± 0.7
Ash, % of DM	8.43 ± 0.73	3.95 ± 0.61
Crude protein, % of DM	14.8 ± 0.8	6.5 ± 0.4
Crude fat, % of DM	3.10 ± 0.30	0.98 ± 0.03
NDF,[a] % of DM	57.7 ± 5.7	80.9 ± 0.7
ADF,[b] % of DM	32.2 ± 1.6	47.7 ± 0.7
ADL,[c] % of DM	3.68 ± 0.33	8.03 ± 0.27
INDF,[d] % of NDF	15.01 ± 0.45	28.14 ± 0.53
k_dDNDF,[e] %/h	5.2	0.9

Body weight (BW) and daily intake in goats, sheep, and llamas fed green hay (GH) or grass seed straw (GSS).

Forage type (F)	GH			GSS				*P*-value		
Species (S)	Goat	Sheep	Llama	Goat	Sheep	Llama	SEM	F	S	F × S
BW, kg	44	78	137	45	72	132	5.3	*	***	ns
Daily intake										
DM, kg/d	0.67^{d}	1.43^{b}	1.76^{a}	0.64^{d}	0.91^{cd}	0.99^{c}	0.10	***	***	**
DM, %BW	1.56^{ab}	1.83^{a}	1.28^{b}	1.43^{b}	1.27^{b}	0.76^{c}	0.10	***	**	**
DM, g/kg $BW^{0.75}$	40.1^{b}	54.3^{a}	43.8^{b}	36.9^{b}	37.0^{b}	25.8^{c}	2.83	***	*	**
NDF,[a] kg/d	0.39^{c}	0.82^{b}	1.02^{a}	0.52^{c}	0.74^{b}	0.80^{b}	0.06	ns	***	**
NDF, %BW	0.90^{bc}	1.05^{ab}	0.74^{c}	1.16^{a}	1.03^{ab}	0.62^{d}	0.06	ns	***	***
INDF,[b] %BW	0.14^{cd}	0.17^{bc}	0.12^{d}	0.36^{a}	0.32^{a}	0.19^{b}	0.01	***	***	***

[a–d] Within a row, means without common superscripts differ significantly ($P < 0.05$).
[a] NDF = neutral detergent fibre.
[b] INDF = indigestible NDF.

Jalali et al., Sm. Ruminant Research 2012

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Alpaca Feed Intake

Camelid Intake Comparisons

Summary data from 11 published feeding trials

Maintenance Feeding Trials	Alpacas	Llamas	P
Dry matter intake, g/day	801 ± 43	1565 ± 37	<0.0001
DMI/Metabolic BW, g/kg	37.1 ± 1.8	48.4 ± 1.5	0.0002
NDF intake, g/d	480 ± 22	913 ± 19	<0.0001
NDF % BW	0.78 ± 0.03	0.89 ± 0. 03	0.061
DMI % BW, mean	1.35 ± 0.06	1.53 ± 0.05	0.105
DMI % BW, range	0.37 – 2.4	0.75 – 1.8	
Peruvian Feeding Trials			
Growing alpaca	DMI % BW	1.52 to 2.6	
Pregnant alpaca	DMI % BW	2.25 to 2.5	
Lactating alpaca	DMI % BW	2.77 to 2.98	

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23

Alpaca Feed Intake

Camelid Intake Modeling

Summary data from 11 published feeding trials

Parameter	Llamas			Alpacas		
	NDF%BW	DMI%BW	DMI/MBW	NDF%BW	DMI%BW	DMI/MBW
CP	0.0102	NS	NS	<0.0001	<0.0001	<0.0001
CP^2	0.0425	NS	0.0004	<0.0001	<0.0001	<0.0001
CP^3	0.0707	NS	0.0024	<0.0001	<0.0001	<0.0001
NDF	NS	0.0003	0.0003	NS	NS	NS
NDF^2	<0.0001	<0.0001	0.0005	<0.0001	<0.0001	<0.0001
NDF^3	NS	NS	0.0007	<0.0001	<0.0001	<0.0001
CP*NDF	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
$CP*NDF^2$	0.0014	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
$CP*NDF^3$	0.0036	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Model r^2	0.70	0.77	0.84	0.76	0.75	0.78
P<F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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24

Alpaca Feed Intake

Implications for Feeding Alpacas

- Forage quality as defined by NDF and Crude Protein content will impact intake capacity
- When fed lower quality forages (>60% NDF) intake will be reduced to allow for greater microbial fermentation – dietary nutrient content will need to be increased
- When higher quality forages (30-55% NDF) are fed, intake will be higher and dietary nutrient content reduced – higher risk for obesity
- Intake guideline is to provide 0.8-0.9% body weight as NDF intake capacity

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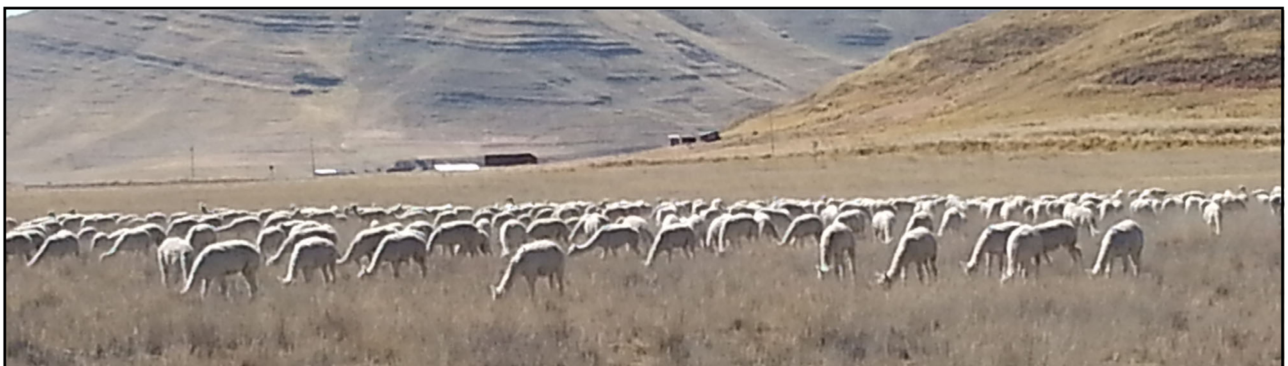
25



Forage and Nutrient Delivery

Recognizing limiting nutrients in forage
Nutrient – Reproduction Interactions

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Which is the better forage?

Photo credits: R. Van Saun

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27

Feed Analysis Reports

A — ANALYSIS RESULTS

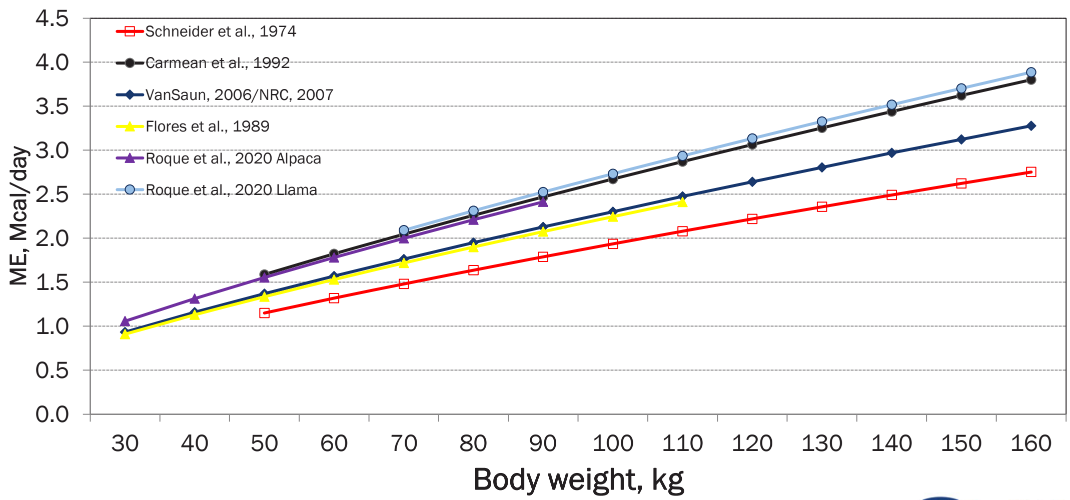
COMPONENTS	AS SAMPLED BASIS	DRY MATTER BASIS
% MOISTURE	9.0	******
% DRY MATTER	91.0	******
% CRUDE PROTEIN	12.1	13.3
% ADJUSTED CRUDE PROTEIN	12.1	13.3
% ACID DETERGENT FIBER	32.3	35.5
% NEUTRAL DETERGENT FIBER	46.5	51.1
% NonFiber Carbohydrates	24.0	26.4
% TDN	56	62
NEL, (MCAL/LB)	0.58	0.64
NEM, (MCAL/LB)	0.58	0.64
NEG, (MCAL/LB)	0.34	0.37
% CALCIUM	0.46	0.51
% PHOSPHORUS	0.23	0.25
% MAGNESIUM	0.17	0.19
% POTASSIUM	2.58	2.84
% SODIUM	0.013	0.014
PPM IRON	97	107
PPM ZINC	20	22
PPM COPPER	8	9
PPM MANGANESE	65	71
PPM MOLYBDENUM	1.6	1.8

B — ANALYSIS RESULTS

COMPONENTS	AS SAMPLED BASIS	DRY MATTER BASIS
% Moisture	8.9	******
% Dry Matter	91.1	******
% Crude Protein	6.3	6.9
% Adjusted Crude Protein	6.3	6.9
% Acid Detergent Fiber	34.0	37.3
% Neutral Detergent Fiber	52.8	58.0
% NonFiber Carbohydrates	23.7	26.0
% TDN	55	60
NEL. (Mcal/LB)	.51	.56
NEM. (Mcal/LB)	.51	.55
NEG. (Mcal/LB)	.27	.30
Relative Feed Value		96
% Calcium	.32	.35
% Phosphorus	.15	.16
% Magnesium	.14	.15
% Potassium	1.53	1.68
% Sodium	.021	.023
PPM Iron	95	104
PPM Zinc	19	21
PPM Copper	11	12
PPM Manganese	36	40
PPM Molybdenum	.9	1.0

28

Maintenance ME Models



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29

	Score	Animal Description	1 Spinous Process	2 Spinous to Transverse Process	3 Transverse Process	4 Paralumbar Fossa
Emaciated	1.0	No visible or palpable fat or muscle between skin and bones. Ribs, dorsal spinous and transverse processes, and pelvic bones are individually prominent. Extreme loss of muscle mass.	Sawtooth appearance to spine	Deep depression	Very prominent >1/2 length visible	Gaunt, tucked-in fossa
Poor	1.5				Between ½ - 1/3 of process visible	
Thin	2.0	Slight cover over bony structure. Ribs, spinous processes still visible and easily palpated as sharp. Less muscle mass loss.	Individual processes evident	Obvious depression	1/3 - ¼ visible	Prominent shelf
Borderline	2.5		Sharp, prominent ridge		<1/4 visible	
Moderate	3.0	Overall smooth appearance. Slight fat cover over ribs and other bony processes. Ribs and spinous processes can be palpated with slight pressure. No muscle mass loss present.		Smooth concave curve	Appears smooth, processes just discernable	Slight shelf
High Moderate	3.5		Smooth, spinous processes not evident	Smooth slope		
Excess	4.0	Fleshy appearance with visible coverage of fat. Moderate to firm pressure necessary to palpate bony structures under skin.	Flat, no dorsal processes discernable		Smooth, rounded edge	No shelf
Fat	4.5			Nearly flat	Edge barely discernable	
Grossly Obese	5.0	Excessive fat cover over entire body with smooth, rounded appearance. Bony prominences cannot be palpated, even with firm pressure. Bulging fat pads visible around tailhead.	Buried in fat	Rounded	Buried in fat	bulging

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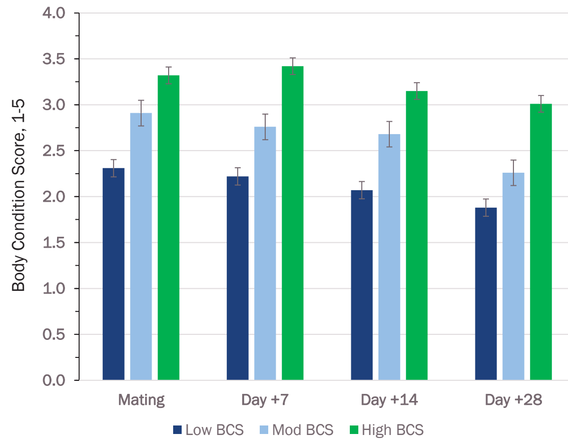
Adapted from Edmonson et al., JDS 1989;72:68 and Russel, A. Body condition scoring sheep, Sheep and Goat Practice 1991.

30

Nutrient Requirements

Body Condition Score Effects

Reproductive Parameter	Body Condition Score (1-5 Scale)		
	Low (n=41)	Moderate (n=57)	High (n=25)
	< 2.5	2.75-3.5	>3.5
Ovulation, n	38/41	50/57	21/25
CL @ 14 days	25	45	18
Conception, %	65.8	90.0	85.7
Embryonic loss, %	12	6.7	0.0
Pregnancy, %	57.9	84.0	85.7



Deza Calsin et al., PhD Thesis, LaMolina 2019

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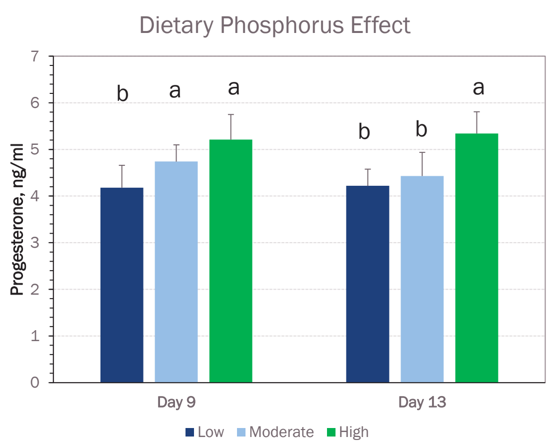
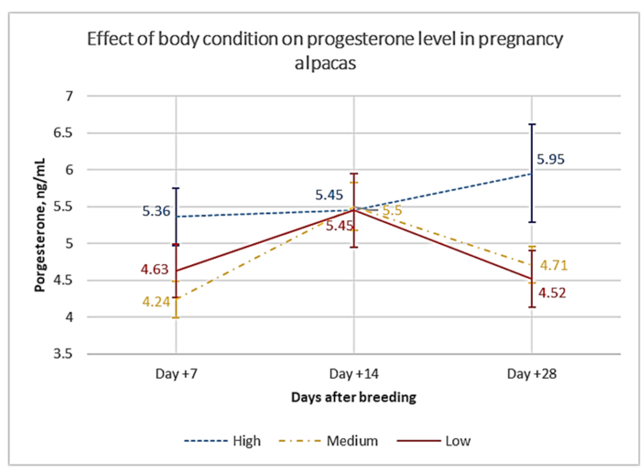
31

Nutrient Requirements

Body Condition Score Effects





Quispe et al., Rev Inv Vet Peru 30 (2019)

Deza Calsin et al., unpublished data 2019

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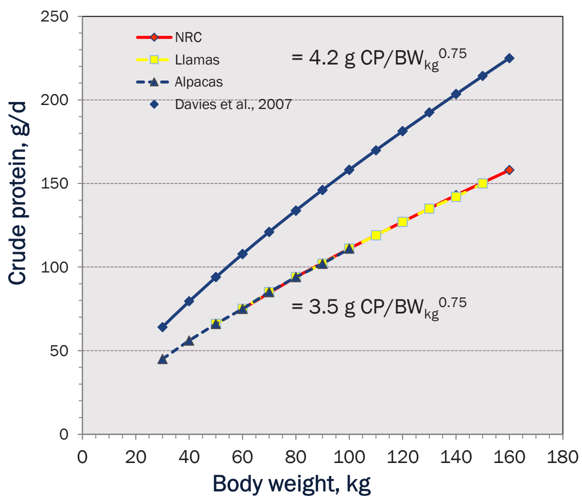
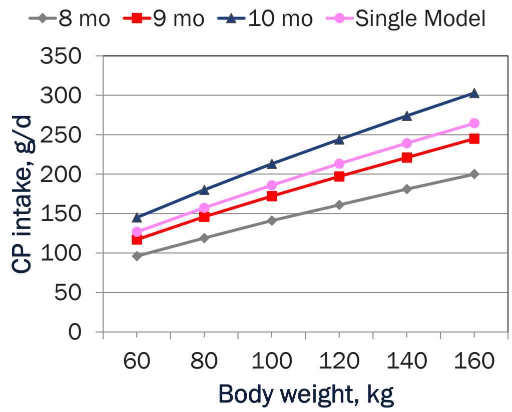
Nutrient Requirements

Crude Protein Requirement





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33

Protein Intake Study

	Dietary Crude Protein Content		
	Low (9%)	Medium (12%)	High (15%)
Prepartum			
Intake, kg/d	1.58 ± 0.67[c]	1.69 ± 0.51[b]	1.75 ± 0.79[a]
Intake, % of body weight	2.25	2.41	2.5
CP intake, g/day	142.2	202.8	262.5
Predicted CP Req, g/day	167.5 (10.6%)	167.5 (9.9%)	167.5 (9.6%)
Postpartum			
Intake, kg/d	1.64 ± 0.67[b]	1.72 ± 0.67[a]	1.77 ± 0.67[a]
Intake, % of body weight	2.77	2.92	2.98
CP intake, g/day	147.6	206.4	265.5
CP Req, g/day (%CP)	210 (13.75%)	215 (12.1%)	215 (11.8%)

Ancco, E PhD Thesis LaMolina

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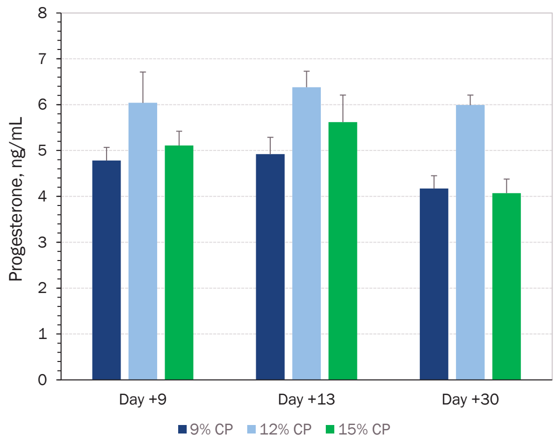
Nutrient Requirements

Protein Effects



Reproductive Parameter	Dietary Protein Content		
	9%	12%	15%
Ovulatory Follicle, n	14/16	16/16	16/16
Ovulation rate, %	71.4	93.8	93.8
Pregnancy, n			
Day 13	10/16	13/16	12/16
Day 35	9/10	13/13	6/12
Embryonic loss, %	10	0	50
Pregnancy, %	56.3	75.0	37.5
Positive Dx	6/16	4/16	7/16
Endometritis, %	37.5	25.0	43.7

Endometritis diagnosed by cytological evaluation with PMN > 3-5%

Annco et al., PhD Thesis LaMolina 2019

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35

Nutrient Requirements

Growth Responses to Phosphorus

Treatment	Middle of the Study			End of the Study		
	kg/d DM	% BW	g/day	kg/d DM	% BW	g/day
Low Phosphorus	0.458 ± 0.16[c]	1.52	0.73	0.717 ± 0.82[c]	2.07	1.15
Medium Phosphorus	0.562 ± 0.78[b]	1.73	1.41	0.826 ± 0.82[b]	2.24	2.07
High Phosphorus	0.652 ± 0.53[a]	1.97	2.22	0.967 ± 0.49[a]	2.60	3.29

Treatment	Initial BCS	Middle	Final BCS
Low Phosphorus	2.95 ± 0.06[a]	2.92 ± 0.08[b]	2.94 ± 0.08[b]
Medium Phosphorus	2.89 ± 0.10[a]	3.03 ± 0.09[ab]	3.25 ± 0.08[a]
High Phosphorus	3.01 ± 0.09[a]	3.36 ± 0.08[a]	3.52 ± 0.07[a]

[a, b] **different letter in the same column differed significantly (*P<0.05*)**

Quispe, C. PhD Thesis LaMolina

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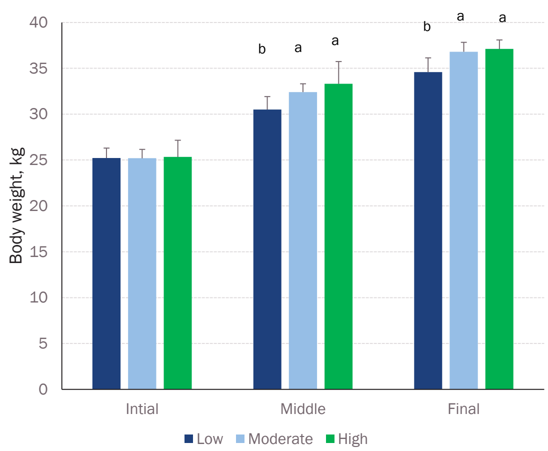
36

Nutrient Requirements

Phosphorus and Reproduction



Reproductive Parameter	Dietary Phosphorus		
	Low 0.16%	Moderate 0.25%	High 0.34%
Puberty	12/16	15/16	16/16
Ovulation rate, %	77.7	91.6	86.6
Embryonic mortality, %	30.0	12.5	9.1
Pregnancy following Mating			
13 days	6/16	8/16	11/16
60 days	4/6	7/8	10/11
Pregnancy rate, %			
Exposed	33.3	50	66.7
Overall	25	43.8	62.5

Quispe et al., Rev Inv Vet Peru 30 (2019)

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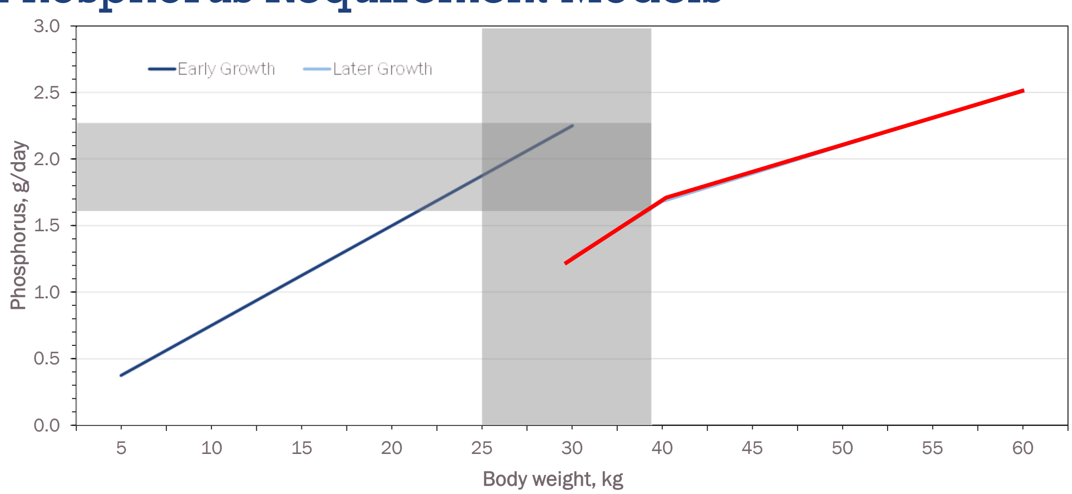
37

Phosphorus Requirement Models



Van Saun, Sm Ruminant Research 2006

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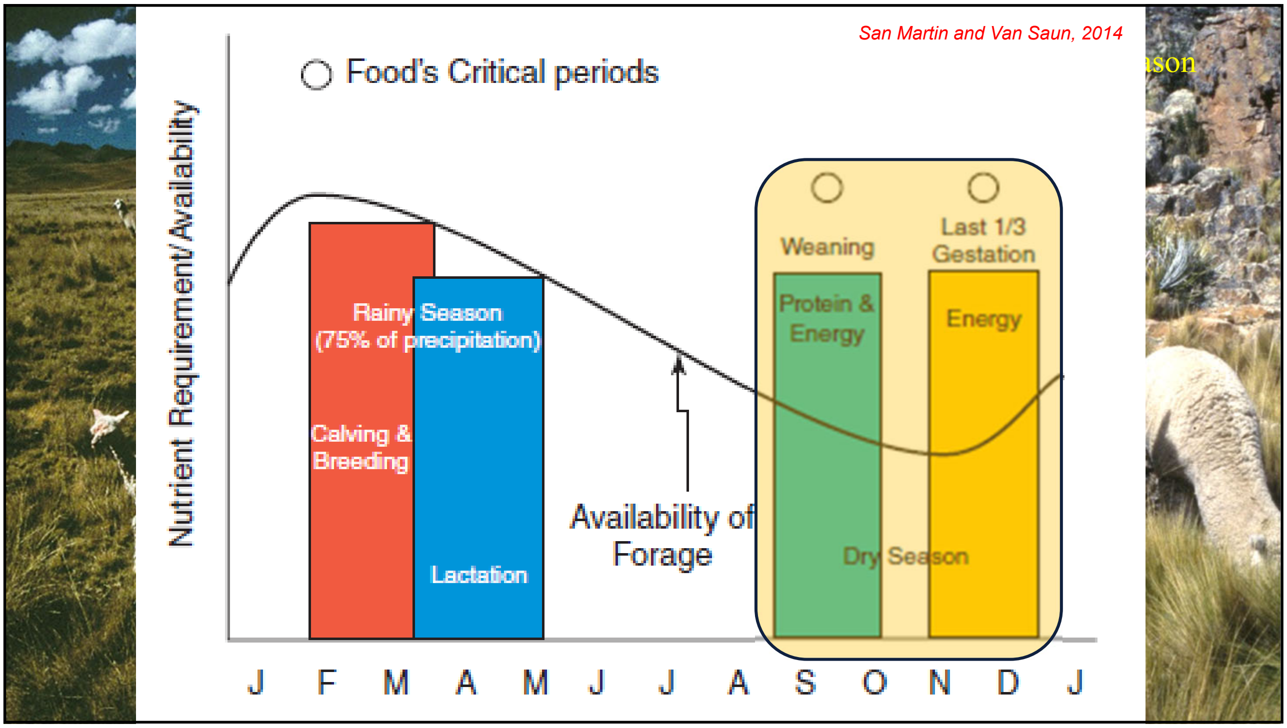
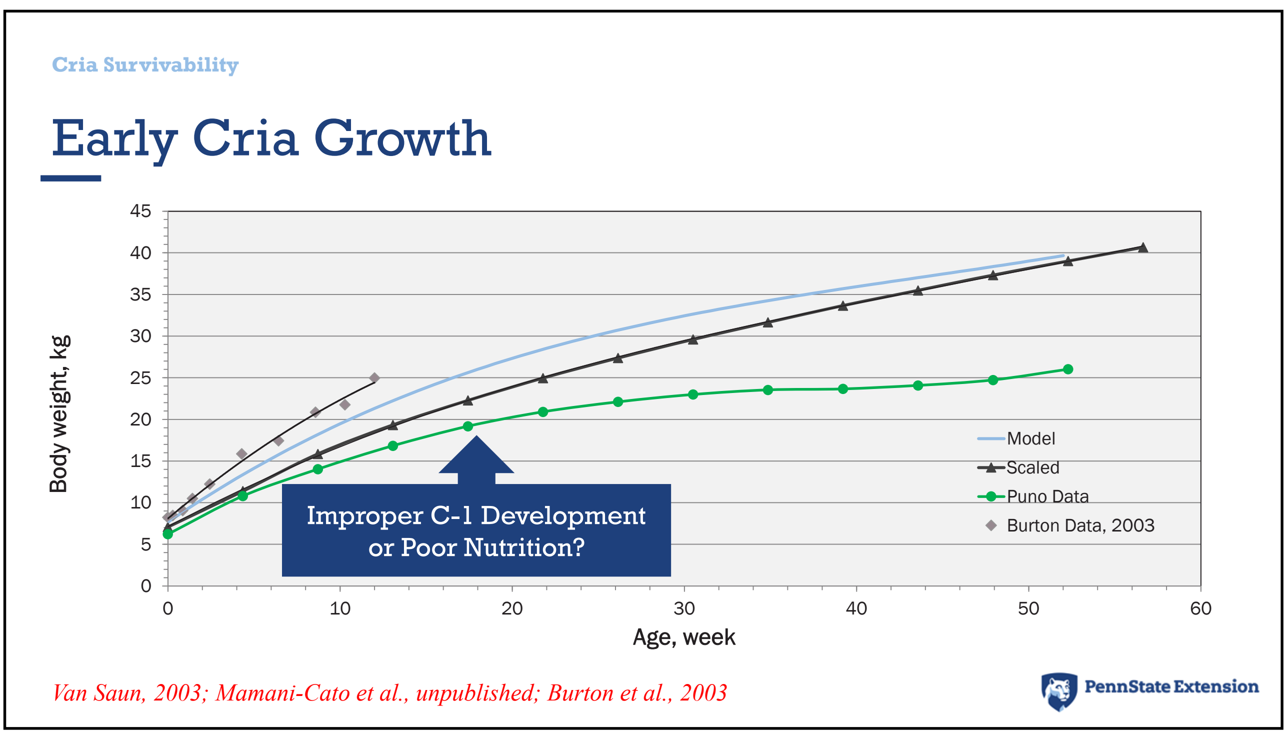
38


San Martin and Van Saun, 2014
Food's Critical periods
Nutrient Requirement/ Availability
Rainy Season
(75% of precipitation)
Calving &
Breeding
Lactation
Availability of
Forage
Weaning
Last 1/3
Gestation
Protein &
Energy
Energy
Dry Season
J F M A M J J A S O N D J

39


Cria Survivability
Early Cria Growth
Body weight, kg
Age, week
Model
Scaled
Puno Data
Burton Data, 2003
Improper C-1 Development
or Poor Nutrition?
Van Saun, 2003; Mamani-Cato et al., unpublished; Burton et al., 2003
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40

Camelid Nutrition Future Needs

What are critical needs in better understanding camelid nutrition?

What research is needed for sustainability of SA camelid production?

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41

Snowmass Alpaca Auction

What are our future SAC nutritional needs?

- Controlled feeding trials to determine mineral and vitamin requirements for differing physiologic states are needed.
- Further evaluation and modification of factorial nutrient requirement models.
- Further characterize potential forestomach degradation of protein sources to define degradable and undegradable protein fractions in feeds in more precisely feeding the camelid.
- Characterize nutritional factors controlling feed intake, including protein and NDF, at different physiologic states.
- Composition of gain over the growth period to improve requirements for growing animals.
- What factors influence the development of the forestomach to improve transition of nursing cria to solid feed without negatively impacting growth and health.
- Potential nutritional effects on colostrum formation and quality.
- Interaction of late pregnancy diet on cria survival and growth and reproduction of the female.

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42

Thank you for your attention

Questions?

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43

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44