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**UNIVERSIDADE ESTADUAL PAULISTA “JULIO DE MESQUITA FILHO”
FACULDADE DE CIÊNCIAS AGRÁRIAS E VETERINÁRIAS
CÂMPUS DE JABOTICABAL**

**MACROMINERAL REQUIREMENTS FOR MAINTENANCE AND GROWTH
OF SAANEN GOATS**

Julián Andrés Castillo Vargas

Chemist

2017

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OF SAANEN GOATS**

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BIOGRAPHY

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“Y una vez que la tormenta termine, no recordarás cómo lo lograste, como sobreviviste. Ni siquiera estarás seguro si la tormenta ha terminado realmente. Pero una cosa si es segura. Cuando salgas de esa tormenta, no serás la misma persona que entró en ella. De eso se trata la tormenta”.

Haruki Murakami

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SUMMARY

Abstract	iii
Resumo	v
List of abbreviations	vii
List of tables	ix
List of figures	x
Dissertation structure	xi
Chapter 1. General considerations.....	1
1. Introduction	1
2. Literature review	2
2.1 Classification and functions of minerals in the animal.....	2
2.2 Importance and metabolic fates of macrominerals in the maintenance and growth of tissues in ruminants.....	3
2.3 Macromineral metabolism and their concentrations in animal tissues differ between sheep and goats: two reasons to discriminate their macromineral requirements	4
2.4 Sex and maturity stage effects on macromineral requirements for ruminants: a perspective	7
2.5 Meta-analysis as a tool to get better estimations of macromineral requirements	8
3. References.....	11
Chapter 2. Sex effects on macromineral requirements for maintenance in Saanen goats: a meta-analysis	18
Abstract.....	18
1. Introduction	18
2. Materials and Methods.....	19
3. Results	27
4. Discussion.....	28
5. References.....	37
Chapter 3. Sex effects on macromineral requirements for growth in Saanen goats: a meta-analysis	41
Abstract.....	41

1. Introduction	42
2. Materials and Methods.....	43
3. Results.....	46
4. Discussion.....	52
5. References.....	59
Chapter 4. Implications.....	63
Appendix	66

MACROMINERAL REQUIREMENTS FOR MAINTENANCE AND GROWTH OF SAANEN GOATS

ABSTRACT -The objective of this study was to evaluate the effect of sex on the net macromineral requirements for maintenance and growth of Saanen goats from 5 to 45 kg body weight (BW). For this purpose, three dataset were used: the first dataset was assembled to evaluate the effect of sex on the net requirements for maintenance of Ca (NCa_m), P (NP_m), Mg (NMg_m), and K (NK_m), estimated using the comparative slaughter technique (CST). This dataset was composed by 154 individual records (53 castrated males, 46 females, and 55 intact males) from three comparative slaughter studies. The second dataset, was constructed to evaluate the effect of sex on NCa_m , NMg_m , and NK_m , estimated using the minimum endogenous losses method (MEL). This dataset was assembled with 155 individual records (67 castrated males, 40 females, and 48 intact males) from four feeding trials. The third dataset was constructed to evaluate the effect of sex on the net requirements for growth of Ca (NCa_g), P (NP_g), Mg (NMg_g), Na (NNa_g), and K (NK_g) considering or not the degree of maturity of the goat on the estimations. This dataset comprised by 209 individual records (69 castrated males, 69 females, and 71 intact males) from six comparative slaughter studies. Mineral requirements for maintenance using CST were calculated from the intercept of the linear regression between mineral retention and the mineral intake. Using the MEL, mineral requirements for maintenance were calculated from the intercept of a linear regression between mineral excreted (urine and feces) and mineral intake. The estimation of NP_m using MEL was not possible, because of the lack of enough information on P excretion and intake from feeding trials, to fit equations for calculating its requirements. The NCa_g , NP_g , NMg_g , NNa_g , and NK_g were estimated by the first derivative of the logarithmized allometric equations. The studies were performed as meta-analyses, considering sex as fixed effect and study as random effect. Sex did not affect NCa_m , NP_m , and NK_m estimated using CST ($P > 0.10$). Estimated NCa_m , NP_m , and NK_m using CST were 21.1, 22.8, and 3.99 mg/(kg BW·d), respectively, from 5 to 45 kg BW. On the other hand, NMg_m of intact males (2.65 mg/(kg BW·d)) were greater than that estimated for castrated males and females (1.39 mg/(kg BW·d); $P < 0.10$). Similarly, sex did not affect NCa_m , NMg_m , and NK_m estimated by MEL ($P > 0.10$). The NCa_m , NMg_m , and NK_m values were 38.0, 7.45, and 25.2 mg/(kg BW·d)

respectively, from 5 to 45 kg BW. With respect to mineral requirement for growth, without considering the degree of maturity, sex did not affect the NCa_g , NP_g , NNa_g , and NK_g ($P > 0.10$). The NCa_g and NP_g remained constant, whereas NNa_g and NK_g decreased by 32 and 27%, respectively, from 5 to 45 kg BW. On the other hand, sex affected the NMg_g ($P = 0.054$), where the NMg_g of castrated and intact males were 8 and 18%, respectively greater than those female goats. The NMg_g of castrated and intact males increased 8 and 15%, respectively, whereas NMg_g of females decreased by 8% from 5 to 45 kg BW. Considering the degree of maturity, sex affected all net macromineral requirements for growth ($P < 0.10$). The NCa_g and NP_g of intact males were 5 and 2% respectively greater than those of castrated males and females. Besides, the NCa_g and NP_g remained constant from 5 to 45 kg BW across sexes. The NNa_g of males were 6% greater than those females. Irrespective of sex, NNa_g decreased by 32% from 5 to 45 kg BW. Regardless of sex, NK_g decreased by 26% from 5 to 45 kg BW. The NMg_g of castrated and intact males were 7 and 17%, respectively greater than those of female goats. The NMg_g of castrated and intact males increased 8 and 16%, respectively, whereas NMg_g of females decreased by 7% from 5 to 45 kg BW. Our studies indicate that sex influences mineral requirements for maintenance and growth as well as the mineral retention efficiency of Saanen goats. This information may be useful to design strategies for optimizing the mineral recommendations to goats.

Key words: allometry, comparative slaughter, mineral requirement, Saanen

EXIGÊNCIAS DE MACROMINERAIS PARA MANTENÇA E CRESCIMENTO DE CAPRINOS SAANEN

RESUMO - O objetivo deste estudo foi avaliar o efeito do sexo nas exigências líquidas de macrominerais para manutenção e crescimento para caprinos Saanen de 5 a 45 kg de peso corporal (PC). Para esse fim, foram utilizados três bancos de dados: o primeiro banco de dados foi construído para avaliar o efeito do sexo sobre as exigências líquidas de Ca (NCa_m), P (NP_m), Mg (NMg_m) e K (NK_m) para manutenção estimadas pelo método do abate comparativo (CST). O banco de dados foi composto por 154 observações individuais (53 machos castrados, 46 fêmeas e 55 machos inteiros) provenientes de três estudos de abate comparativo. O segundo banco de dados, foi construído para avaliar o efeito do sexo sobre as NCa_m , NMg_m e NK_m no corpo de caprinos Saanen, estimadas pelo método das perdas endógenas mínimas (MEL). Este banco de dados foi composto por 155 observações individuais (67 machos castrados, 40 fêmeas e 48 machos inteiros) provenientes de quatro ensaios de alimentação. O terceiro banco de dados foi construído para avaliar o efeito do sexo sobre as exigências líquidas de Ca (NCa_g), P (NP_g), Mg (NMg_g), Na (NNa_g) e K (NK_g) para crescimento, considerando e não considerando o grau de maturidade do caprino, na estimativa destas. Este banco de dados foi composto por 209 observações individuais (69 machos castrados, 69 fêmeas e 71 machos inteiros) provenientes de seis estudos de abate comparativo. As exigências de minerais para manutenção, obtidas pelo CST foram calculadas como o intercepto da regressão linear entre retenção mineral e ingestão mineral. Utilizando o MEL, as exigências de minerais para manutenção foram calculadas como o intercepto da regressão linear entre mineral excretado (urina e fezes) e ingestão mineral. A estimativa de NP_m usando MEL não foi possível, devido à falta de informações suficientes de excreção e ingestão de P desde os ensaios de alimentação, para ajustar equações com o intuito de calcular as suas exigências. Os valores de NCa_g , NP_g , NMg_g , NNa_g e NK_g foram estimados a partir da primeira derivada das equações alométricas logaritmizadas para cada mineral. Os estudos foram desenvolvidos como meta-análises, considerando-se o sexo como efeito fixo e estudo como efeito aleatório. Sexo não afetou as NCa_m , NP_m , e NK_m estimadas pelo CST ($P > 0,10$). Os valores de NCa_m , NP_m e NK_m estimados pelo CST foram de 21,1, 22,8 e 3,99 mg/(kg de PC·d), respectivamente, de 5 a 45 kg PC. Por outro lado,

o valor de NMg_m de machos inteiros (2,65 mg/(kg PC·d)) foi maior que o estimado para machos castrados e fêmeas (1,39 mg/(kg PC·d); $P < 0,10$). Da mesma forma, o sexo não afetou as NCa_m , NMg_m e NK_m estimadas pelo MEL ($P > 0,10$). Os valores de NCa_m , NMg_m e NK_m foram 38,0, 7,45 e 25,2 mg/(kg de PC·d), respectivamente, de 5 a 45 kg PC. Com relação as exigências de macrominerais para crescimento, quando o grau de maturidade não foi considerado, o sexo não afetou as NCa_g , NP_g , NNa_g e NK_g ($P > 0,10$). Os valores de NCa_g e NP_g permaneceram constantes, enquanto que os de NNa_g e NK_g diminuíram em 32 e 27%, respectivamente, quando o PC aumentou de 5 para 45 kg. Por outro lado, o sexo afetou as NMg_g ($P = 0,054$), onde os valores de NMg_g de machos castrados e inteiros foram 8 e 18%, respectivamente, maiores do que os das fêmeas. Os valores de NMg_g de machos castrados e inteiros aumentaram em 8 e 15%, respectivamente, enquanto que os de NMg_g de fêmeas diminuíram 8%, quando PC aumentou de 5 para 45 kg. Quando o grau de maturidade foi considerado, o sexo influenciou as exigências para crescimento de todos os minerais ($P < 0,10$). Os valores de NCa_g e NP_g de machos inteiros foram 5 e 2%, respectivamente, maiores do que os de machos castrados e fêmeas. Além disso, os valores de NCa_g e NP_g permaneceram constantes à medida que o PC dos caprinos aumentou de 5 para 45 kg, em todos os sexos. Os valores de NNa_g de machos foram 6% maiores que os das fêmeas. Independentemente do sexo, os valores de NNa_g diminuíram em 32%, a medida que o PC aumentou de 5 para 45 kg. Independentemente do sexo, os valores de NK_g diminuíram 26%, à medida que o PC aumentou de 5 para 45 kg. Os valores de NMg_g de machos castrados e inteiros foram 7 e 17%, respectivamente maiores do que os das fêmeas. Os valores de NMg_g de machos castrados e inteiros aumentaram em 8 e 16%, respectivamente, enquanto que os valores de NMg_g de fêmeas diminuíram 7%, a medida que o PC aumentou de 5 para 45 kg. Nossos estudos indicam que o sexo afeta as exigências de macrominerais para manutenção e crescimento, como também as eficiências de retenção de macrominerais no corpo de caprinos Saanen. Essas informações podem ser úteis para definição de estratégias visando otimizar as recomendações de minerais em rações para caprinos.

Palavras-chave: abate comparativo, alometria, exigência mineral, Saanen

LIST OF ABBREVIATIONS

ADG	Average daily gain
AIC _c	Corrected Akaike's Information Criterion
Al	Aluminium
As	Arsenic
ATP	Adenosine triphosphate
B	Boron
BGHE	High energy diet given to Boer goats
BGLE	Low energy diet given to Boer goats
BW	Body weight
Ca	Calcium
Ca _{int}	Calcium intake
Ca _{ret}	Calcium retention
Cd	Cadmium
Cl	Chlorine
Co	Cobalt
CST	Comparative slaughter technique
Cu	Copper
Cr	Chromium
DM	Dry matter
DG	Degree of maturity
EBW	Empty body weight
EWG	Empty weight gain
F	Fluorine
Fe	Iron
Hg	Mercury
I	Iodine
IGF-1	Insulin-like Growth Factor 1
K	Potassium
K _{int}	Potassium intake
K _{ret}	Potassium retention
Li	Lithium
Mature EBW	EBW at maturity
MEL	Minimum endogenous losses method
Mg	Magnesium
Mg _{int}	Magnesium intake
Mg _{ret}	Magnesium retention
MMHE	High energy diet given to Mutton Merinos
MMLE	Low energy diet given to Mutton Merinos
Mn	Manganese
Mo	Molybdenum
Na	Sodium
NCa _g	Net Ca requirement for growth
NCa _m	Net Ca requirement for maintenance
Ni	Nickel
NK _g	Net K requirement for growth
NK _m	Net K requirement for maintenance
NMg _g	Net Mg requirement for growth

NMg _m	Net Mg requirement for maintenance
NNa _g	Net Na requirement for growth
NP _g	Net P requirement for growth
NP _m	Net P requirement for maintenance
P	Phosphorus
Pb	Lead
PC	Peso corporal
P _{int}	Phosphorus intake
P _{ret}	Phosphorus retention
PO ₄ ³⁻	Phosphate
Rb	Rubidium
RECa	Ca retention efficiency
REP	P retention efficiency
REMg	Mg retention efficiency
REK	K retention efficiency
S	Sulfur
SD	Standard deviation
Se	Selenium
Si	Silicon
Sn	Tin
Unesp	Universidade Estadual Paulista “Julio de Mesquita Filho”
V	Vanadium
WAD	West Africa Dwarf
Zn	Zinc
σ_e^2	Variance due to error
σ_s^2	Variance due to study

LIST OF TABLES

Chapter 1

Table 1. Mineral concentrations in carcass (mg/100g) and plasma (mmol/L) of goats and sheep	6
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Chapter 2

Table 1. Summary of the dataset used in the meta-analysis developed for estimating mineral requirements for maintenance and mineral retention efficiency by the comparative slaughter method.	21
Table 2. Descriptive statistics of dataset used for estimating mineral requirements for maintenance and mineral retention efficiency, using comparative slaughter method.....	22
Table 3. Summary of the dataset used in the meta-analysis developed for estimating mineral requirements for maintenance by the minimum endogenous losses method.	23
Table 4. Descriptive statistics of dataset used for estimating mineral requirements for maintenance using the minimum endogenous losses estimated by feeding trials.	24
Table 5. Daily net macromineral requirements for the maintenance in Saanen goats of different sexes using the comparative slaughter (CST) and minimum endogenous losses (MEL) methods.	29

Chapter 3

Table 1. Data sources and information of included studies.....	47
Table 2. Summary statistics of the macromineral body composition of Saanen goats used in this study.	48

LIST OF FIGURES

Chapter 2

- Figure 1. Relationship between retention efficiencies of Ca (RECa) and P (REP) (g mineral retention/g mineral intake) and average body weight (kg) in growing Saanen goats of different sexes 30
- Figure 2. Relationship between retention efficiencies of Mg (REMg) and K (REK) (g mineral retention/g mineral intake) and average body weight (kg) in growing Saanen goats of different sexes 31
- Figure 3. Relationship between retention efficiencies of Ca (RECa) and P (REP) (g mineral retention/g mineral intake) and average daily gain (ADG; kg BW/day) in growing Saanen goats of different sexes 32
- Figure 4. Relationship between retention efficiencies of Mg (REMg) and K (REK) (g mineral retention/g mineral intake) and average daily gain (ADG; kg BW/day) in growing Saanen goats of different sexes 33

Chapter 3

- Figure 1. Relationship between Log_{10} Ca, Log_{10} P, Log_{10} Na, Log_{10} K, and Log_{10} Mg (g), and Log_{10} empty BW (EBW) (kg) of growing Saanen goats of different sexes..... 49
- Figure 2. Estimated values of net Ca (NCa_g), P (NP_g), Na (NNa_g), K (NK_g), and Mg (NMg_g) requirements for growth (g/kg empty BW gain - EWG) of growing Saanen goats using the classical approach. 50
- Figure 3. Relationship between Log_{10} Ca, Log_{10} P, Log_{10} Na, Log_{10} K, and Log_{10} Mg (g), and Log_{10} degree of maturity (i.e., degree of maturity = DG) of growing Saanen goats of different sexes 53
- Figure 4. Estimated values of net Ca (NCa_g), P (NP_g), Na (NNa_g), K (NK_g), and Mg (NMg_g) requirements for growth (g/kg empty BW gain - EWG) of growing Saanen goats using the degree of maturity approach 54

DISSERTATION STRUCTURE

Chapter 1 is a literature review, about macromineral requirements for maintenance and growth in ruminants covering the main functions of macrominerals, the macromineral metabolic fates through maintenance and growth processes in ruminants, and the potential influence of specie, sex, and maturity stage on the macromineral requirement estimations. It was written following the guidelines of the Graduate Program in Animal Science of Unesp, Jaboticabal Campus.

Chapter 2 describes the results about the evaluation of sex effect on macromineral requirement for maintenance of Saanen goats from 5 to 45 kg BW. This chapter was written following the guidelines of the Journal of Animal Physiology and Animal Nutrition, except by the letter style, spaces between lines, and position of tables. The paper authors are J. A. C. Vargas, A. K. Almeida, A. P. Souza, M. H. M. R. Fernandes, K. T. Resende, and I. A. M. A. Teixeira.

Chapter 3 describes the results about evaluation of sex effect on macromineral requirement for growth of Saanen goats from 5 to 45 kg BW. This chapter was written following the guidelines of the Journal of Animal Science except by the letter style, spaces between lines, and position of tables. The paper authors are J. A. C. Vargas, A. K. Almeida, A. P. Souza, M. H. M. R. Fernandes, K. T. Resende, and I. A. M. A. Teixeira.

Chapter 4 describes the main implications of this study, written following the guidelines of the Graduate Program in Animal Science of Unesp, Jaboticabal Campus.

CHAPTER 1 – GENERAL CONSIDERATIONS

1. INTRODUCTION

The importance of goats as providers of meat and dairy products for human consumption has increased around the world, due to the beneficial nutritional properties of goat products (HAENLEIN, 2004; WEBB et al., 2005; PARK et al. 2007). This importance is reflected in the number of animals, meat, and milk production increase (47, 100, and 64%, respectively) during the last 20 years (FAOSTAT, 2016). In this regard, efficient management practices, proper selection for profitable breeding, adequate animal welfare practices, and accurate nutrition plans in production systems are needed to favor sustainability and improve goat production in the world (TEIXEIRA & RESENDE, 2005; WEBB et al., 2005).

From the nutritional standpoint, it is remarkable that there is a lack of information related to nutritional requirements of goats. It may be critical, considering that the low accuracy of nutritional requirements may affect the animal production and health (ARC, 1980).

Minerals constitute important nutrients in the feed, because of the roles in metabolic (e.g., as cofactors of organic nutrient catabolism), and physiological processes (e.g., bone formation and neuromuscular processes) in the body (SUTTLE, 2010). However, the recommendations of the most recent nutritional systems for small ruminants (CSIRO, 2007; INRA, 2007; NRC, 2007), regarding goat mineral requirements (i.e., maintenance, growth, lactation, gestation, and fiber production), usually adopt data from sheep and cattle to fit prediction equations for mineral requirements, which may lead to inaccurate recommendations for goats, considering the differences in mineral metabolism (WILKENS et al., 2012; HERM et al., 2015) and tissue mineral composition (VAN NIEKERK et al., 1990; HAENLEIN & ANKE, 2011) between ruminant species.

In addition, the current nutritional systems (CSIRO, 2007; INRA, 2007; NRC, 2007) do not address the potential effect of sex and degree of maturity of the goat on the mineral requirement estimation. It could introduce an additional inaccuracy on these values, considering that goats of different sexes exhibit different mature weights (ALMEIDA et al., 2016; MARCONDES et al., 2016) as well as different patterns of growth (GHAVI, 2015).

Thus, it is necessary to define mineral requirements for goats without extrapolating information from other species, as well as to assess the effect of sex on mineral requirements, considering the impact of degree of maturity of the goat on body composition. Therefore, the objective of this study was to evaluate the effect of sex on the net macromineral requirements of Saanen goats from 5 to 45 kg BW, considering or not the degree of maturity on their estimations.

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