Genetic markers associated with bone properties in White Leghorn laying hens

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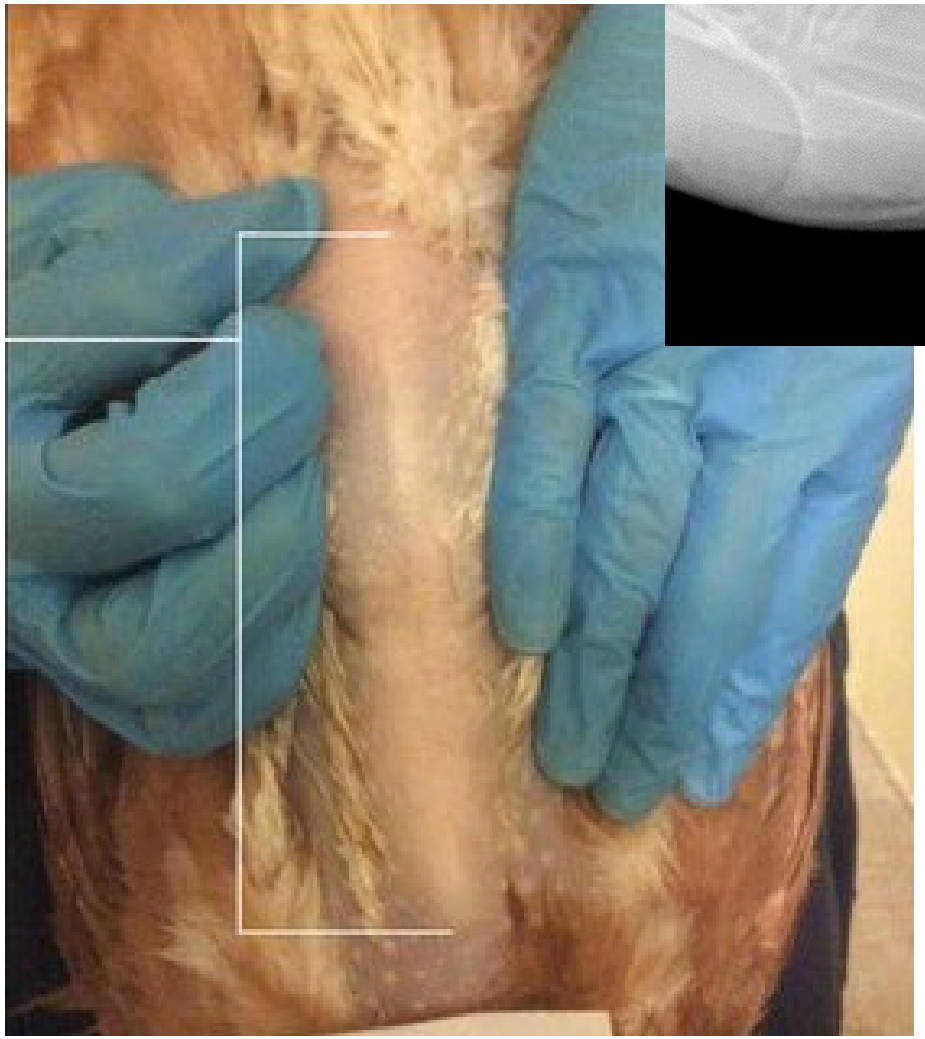
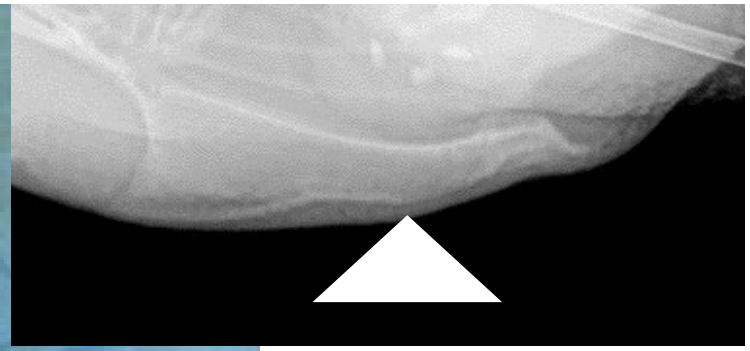
Introduction

It's all about performance

Keel bone fractures



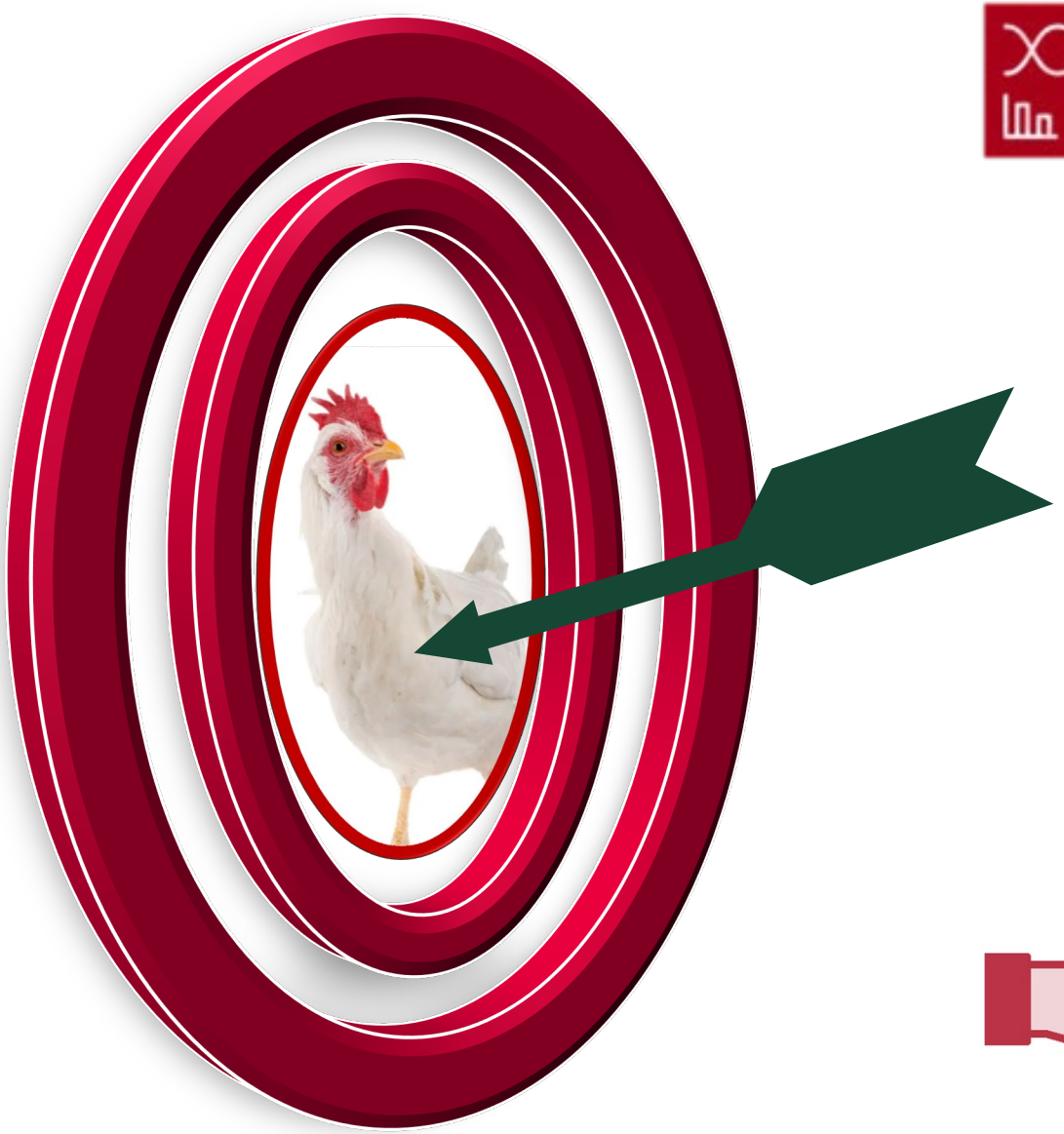


- ✓ In at least 90% of hens in the end of lay
- ✓ Affected by strain and age:
  - Older > Younger
  - Red line > White line
- ✓ Housing system:
  - Caged > Aviary systems

Baker S. L. et al., 2020

Garant R., et al., 2022

Aims



Genetics

To investigate genetic architecture and find markers that contribute to genetic variance in bone qualities in White Leghorn laying hens

Welfare

Address welfare impacts

Economic

Contribute to slowing economic issues

M&M: Workflow

1 Population

- ✓ The later generation of White Leghorn laying hens
- ✓ **n = 987**

LOHMANN BREEDERS

2 Phenotyping

- ✓ **n = 32** chemical composition traits
- ✓ **n = 12** strength traits

ROSLIN

UNIVERSIDAD DE GRANADA

3 Genotyping

- ✓ 50 K Illumina SNP array
- ✓ **17 K** effective SNPs
- ✓ MAF > **0.01**
- ✓ **Call rate > 95%**

SciLifeLab

SLU

4 GBLUP

- ✓ Blupf90 programs
- ✓ Fixed effect: **block with cages**
- ✓ Model 1: not adjusted for BW
- ✓ Model 2: adjusted for BW

SLU

5 GWAS

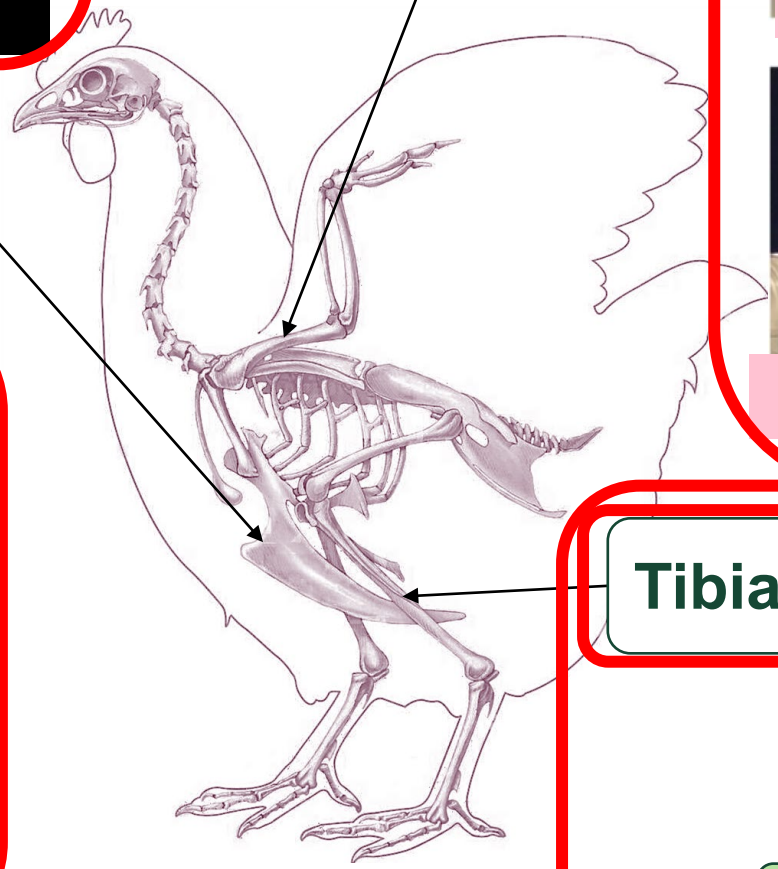
- ✓ Plink/GCTA
- ✓ Thresholds:
  - Bonferroni
  - Suggestive
- ✓ Model 1: not adjusted for BW
- ✓ Model 2: adjusted for BW
- ✓ Gene annotation

SLU

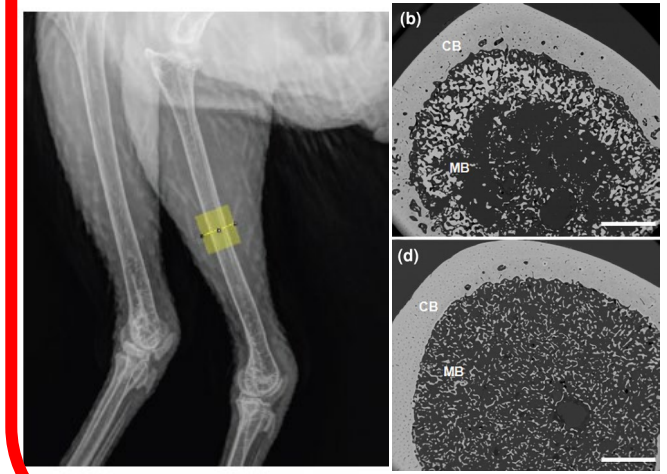
Radiographic density (RD)

Humerus

Keel

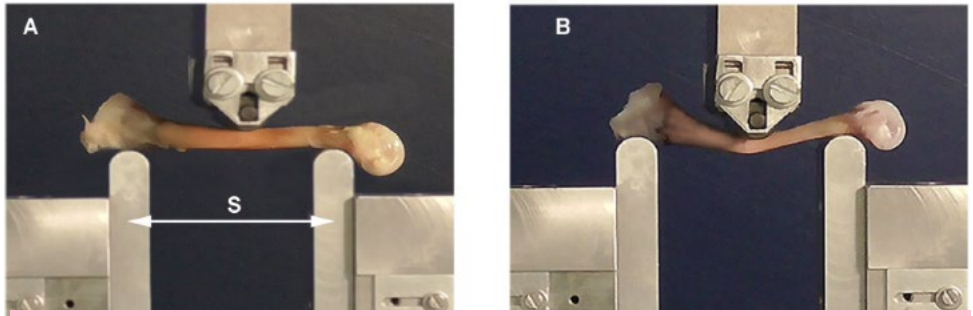


Radiographic density

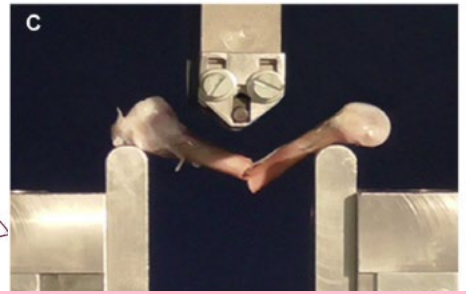


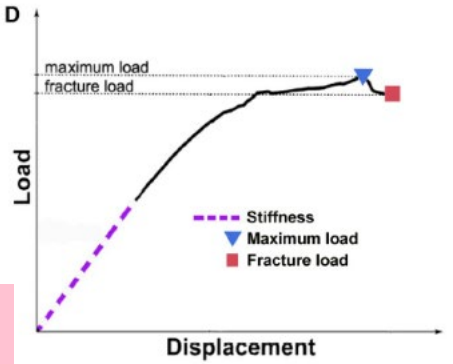
Martin Johnsson et al 2022

Strength parameters



Stiffness





Breaking strain

Pic from: George Harsh et al 2020

Tibia

Cortex & medulla content (Dunn et al. 2021)

Chemical composition parameters

Poultry Science
Volume 103, Issue 11, November 2024, 104214

Research Note: A deep learning method segments chicken keel bones from whole-body X-ray images

Moh Sallam *, Samuel Coulbourn Flores * †, Dirk Jan de Koning *, Martin Johnsson *

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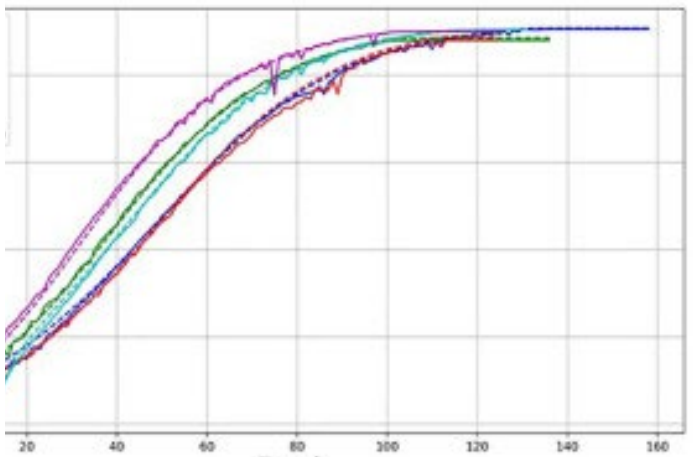
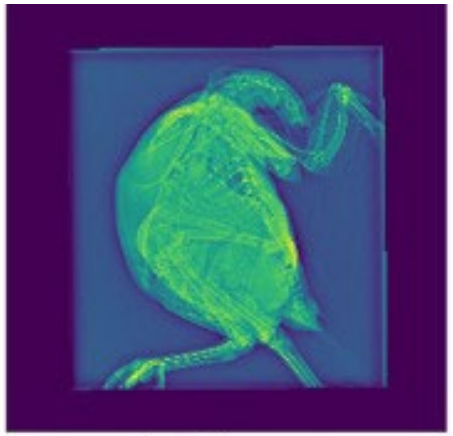
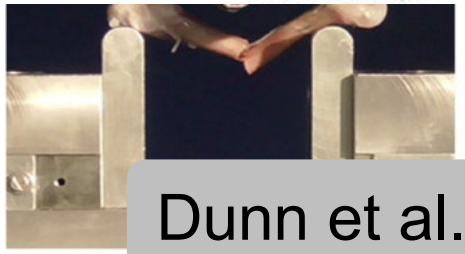




Input Image

Gold Standard Mask

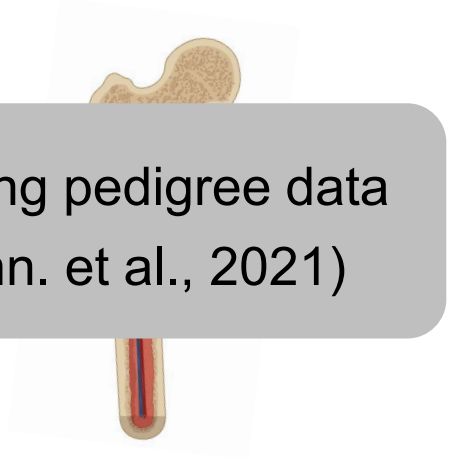
Predicted Mask



Dunn et al. (2021)

		Model 1: Heritability (SE)
	SE)	0.42 (0.05)
	)	0.41 (0.05)
	)	0.53 (0.05)
	)	0.26 (0.04)
	)	0.28 (0.05)
	)	0.21 (0.04)
	)	0.33 (0.05)
	)	0.16 (0.04)
	)	0.07 (0.04)
	)	0.09 (0.04)
	)	0.28 (0.05)
Hum bone score	0.18 (0.05)	0.18 (0.05)
Hum stiffness	0.23 (0.05)	0.29 (0.05)
Keel RD	0.01 (0.05)	0.05 (0.05)

Results: Heritability – Bone chemical composition



0.19 using pedigree data (Dunn. et al., 2021)

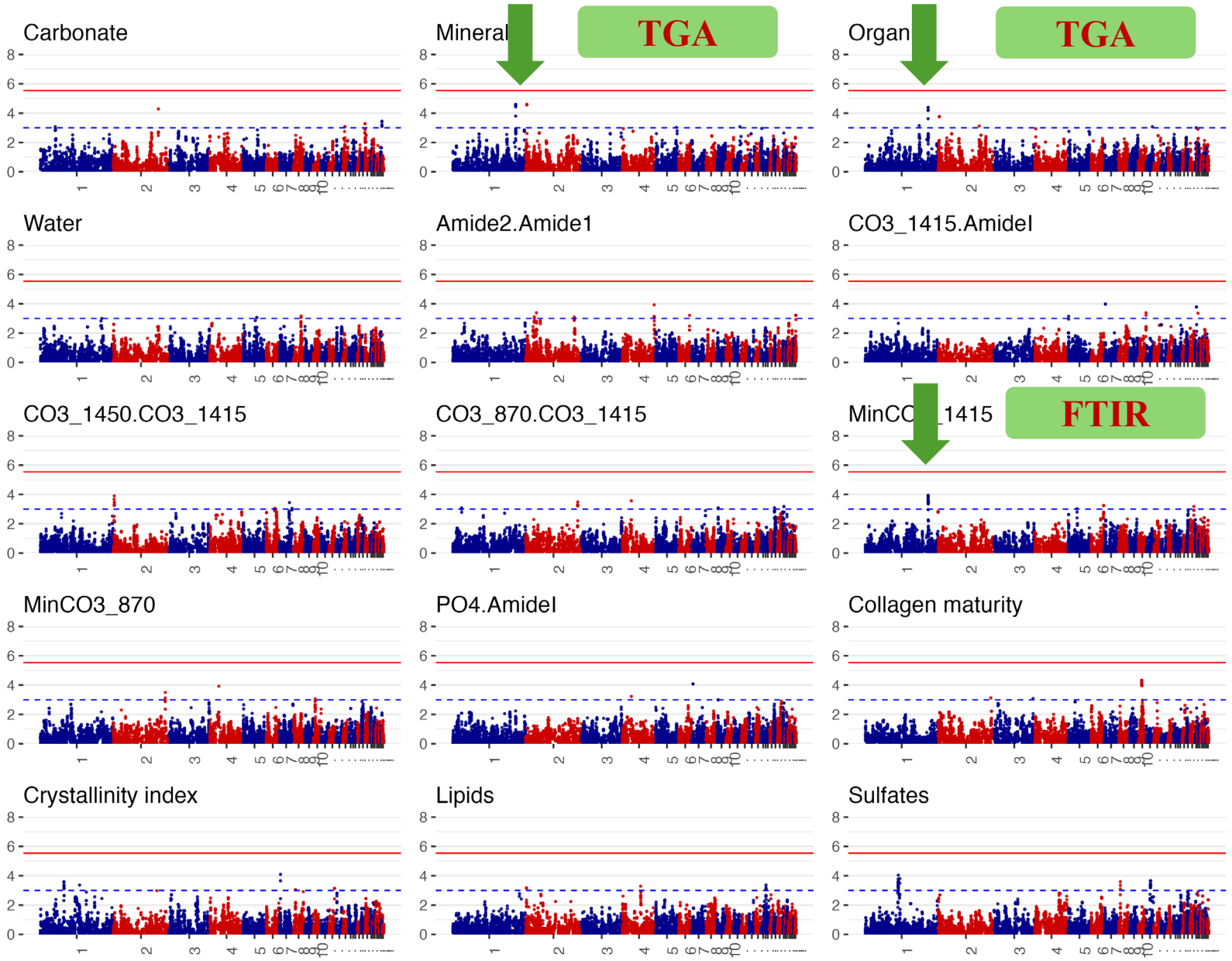
Thermogravimetry (TGA)

Trait	Heritability (SE)	Genetic correlation
Cortical water	0.02 (0.03)	0.17 (0.54)
Cortical organic	0.11 (0.04)	-0.1 (0.18)
Cortical carbonate	0.03 (0.03)	-0.05 (0.47)
Cortical mineral	0.12 (0.04)	0.09 (0.18)
Medullary water	0.01 (0.01)	0.92 (0.68)
Medullary organic	0.25 (0.05)	-0.72 (0.08)
Medullary carbonate	0.06 (0.03)	-0.02 (0.28)
Medullary mineral	0.26 (0.04)	0.71 (0.08)

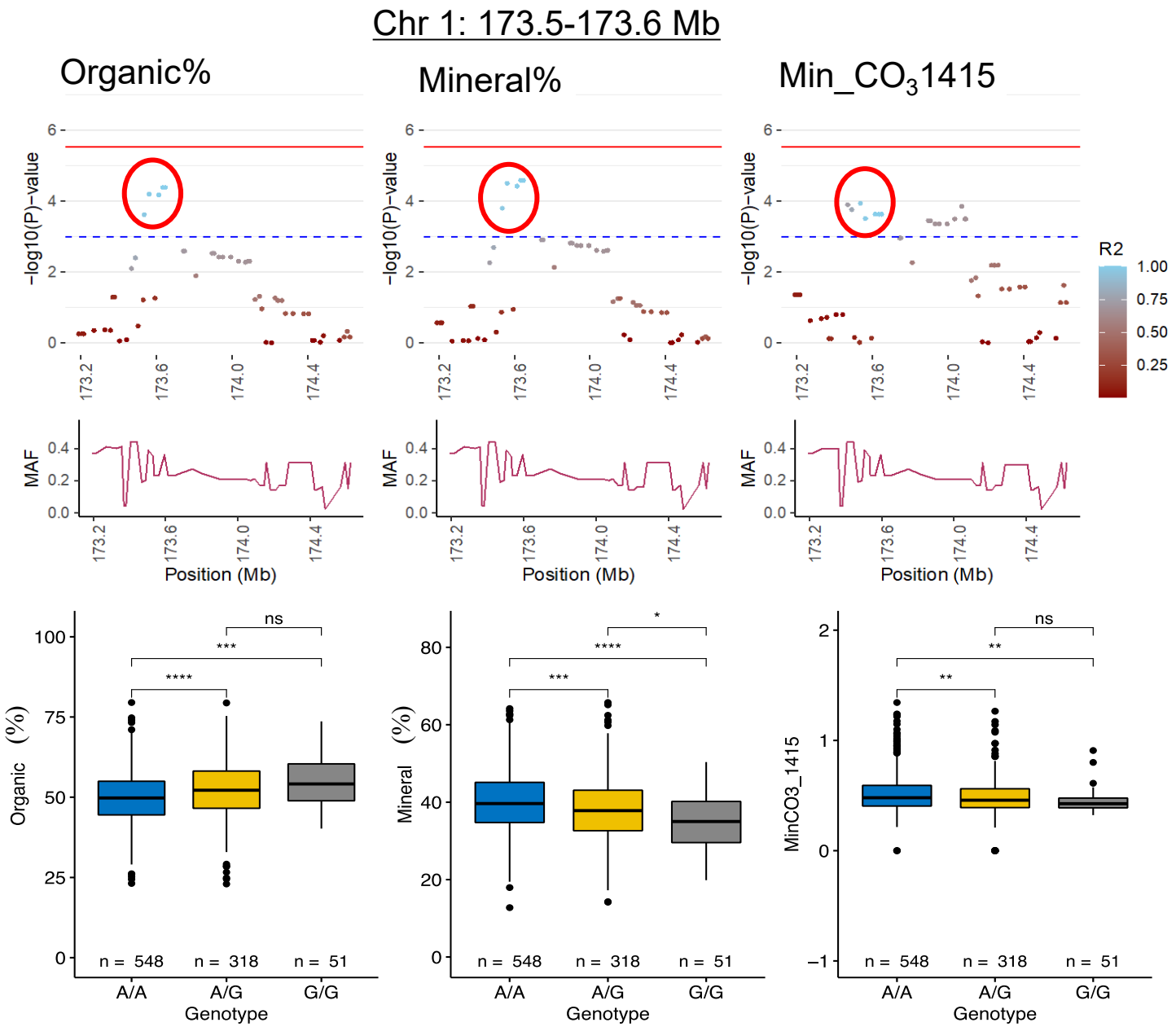
Infrared spectrometry (FTIR)

Trait	Model 1: Heritability (SE)	Genetic correlation
Cortical PO_4/Amidel	0.08 (0.001)	-0.99 (0.0)
Cortical Min$CO_3$870	0.003 (0)	0.99 (0.0)
Cortical Min$CO_3$1415	0.03 (0.03)	0.7 (0.86)
Cortical CO_3/Amidel	0.01 (0.001)	-0.99 (0.08)
Cortical CO_3 1450/1415	0.03 (0.03)	-0.09 (0.64)
Cortical $CO_3$870/$CO_3$1415	0.01 (0.00)	-0.99 (0.0)
Cortical crystallinity index	0.04 (0.03)	0.14 (0.68)
Cortical collagen maturity	0.02 (0.03)	-0.76 (0.98)
Cortical lipids	0.06 (0.04)	-0.1 (0.96)
Cortical sulfates	0.06 (0.04)	-0.18 (0.43)
Cortical AmideII/Amidel	0.06 (0.04)	-0.23 (0.51)
Medullary PO_4/Amidel	0.04 (0.03)	-0.35 (0.45)
Medullary Min$CO_3$870	0.03 (0.02)	0.04 (0.76)
Medullary Min$CO_3$1415	0.03 (0.03)	0.59 (0.68)
Medullary CO_3/Amidel	0.01 (0)	-0.99 (0.57)
Medullary CO_3 1450/1415	0.03 (0.03)	-0.46 (0.97)
Medullary $CO_3$870/$CO_3$14151	0.05 (0.03)	-0.04 (0.41)
Medullary crystallinity index	0.01 (0.00)	0.99 (0.0)
Medullary collagen maturity	0.05 (0.03)	0.56 (0.58)
Medullary lipids	0.01 (0.02)	-0.44 (2.24)
Medullary sulfates	0.08 (0.04)	-0.11 (0.3)
Medullary AmideII/Amidel	0.04 (0.03)	0.38 (0.46)

Results: Bone chemical composition properties - Medulla



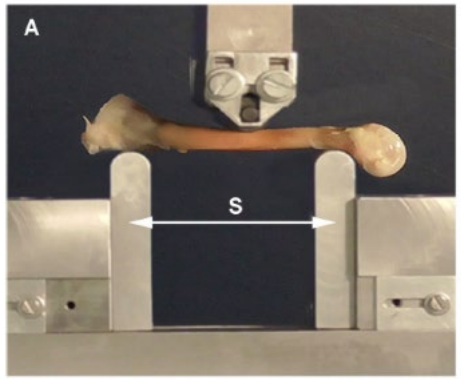
Results: Bone chemical composition properties: Medulla

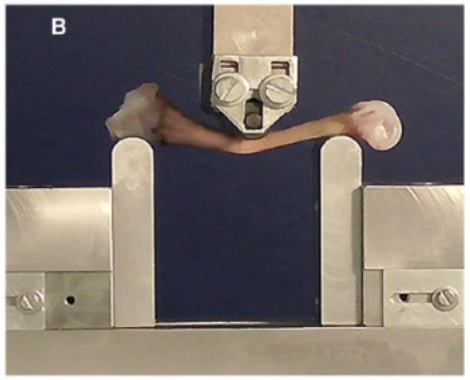


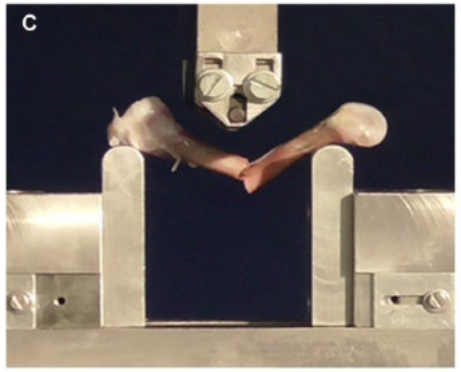
Gene annotation

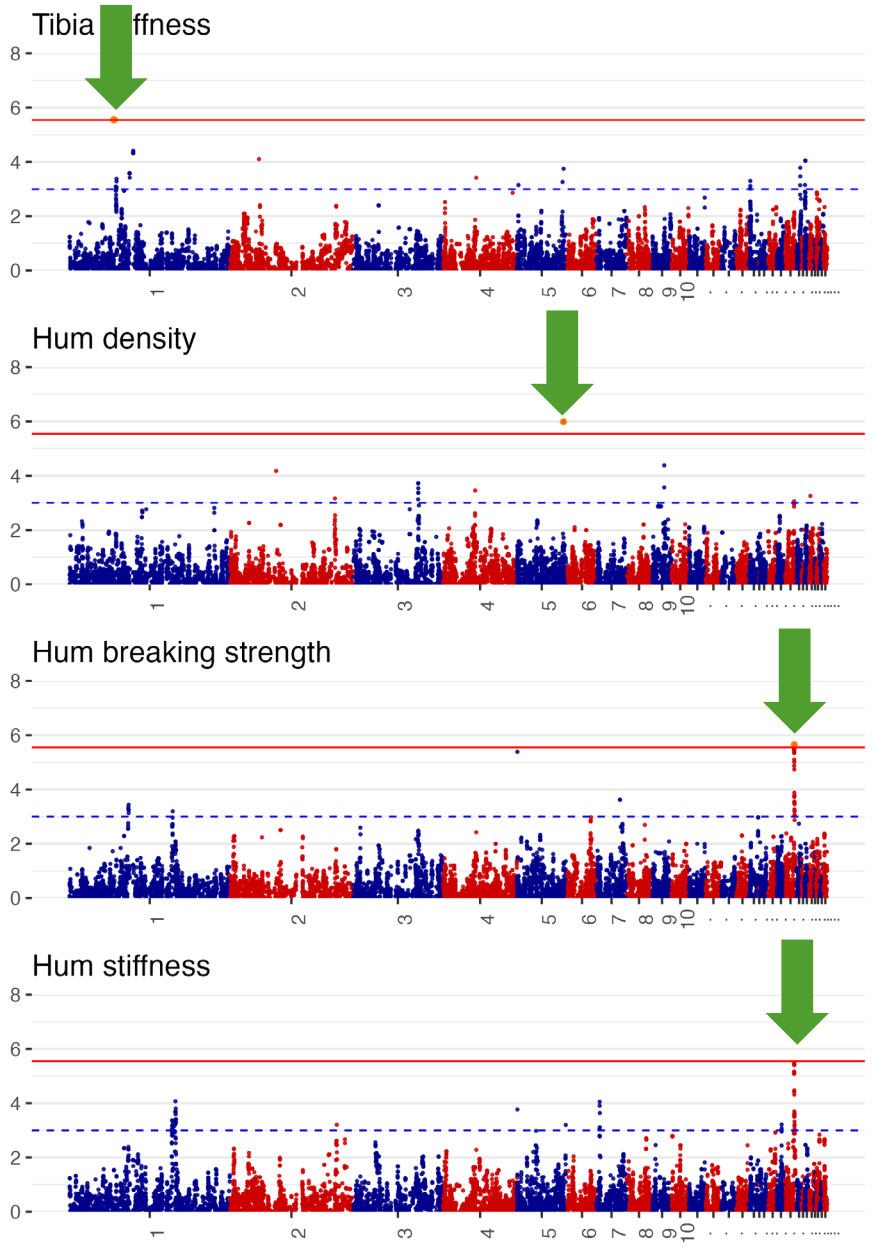
- Top significant SNP within 5 genes
- **ALG5** - involved in regulation of cell functions in the bone marrow micro-environment (Li et al., 2015).
- **SMAD9** - plays a role in the bone morphogenetic protein signaling pathway (Tsukamoto et al., 2014)

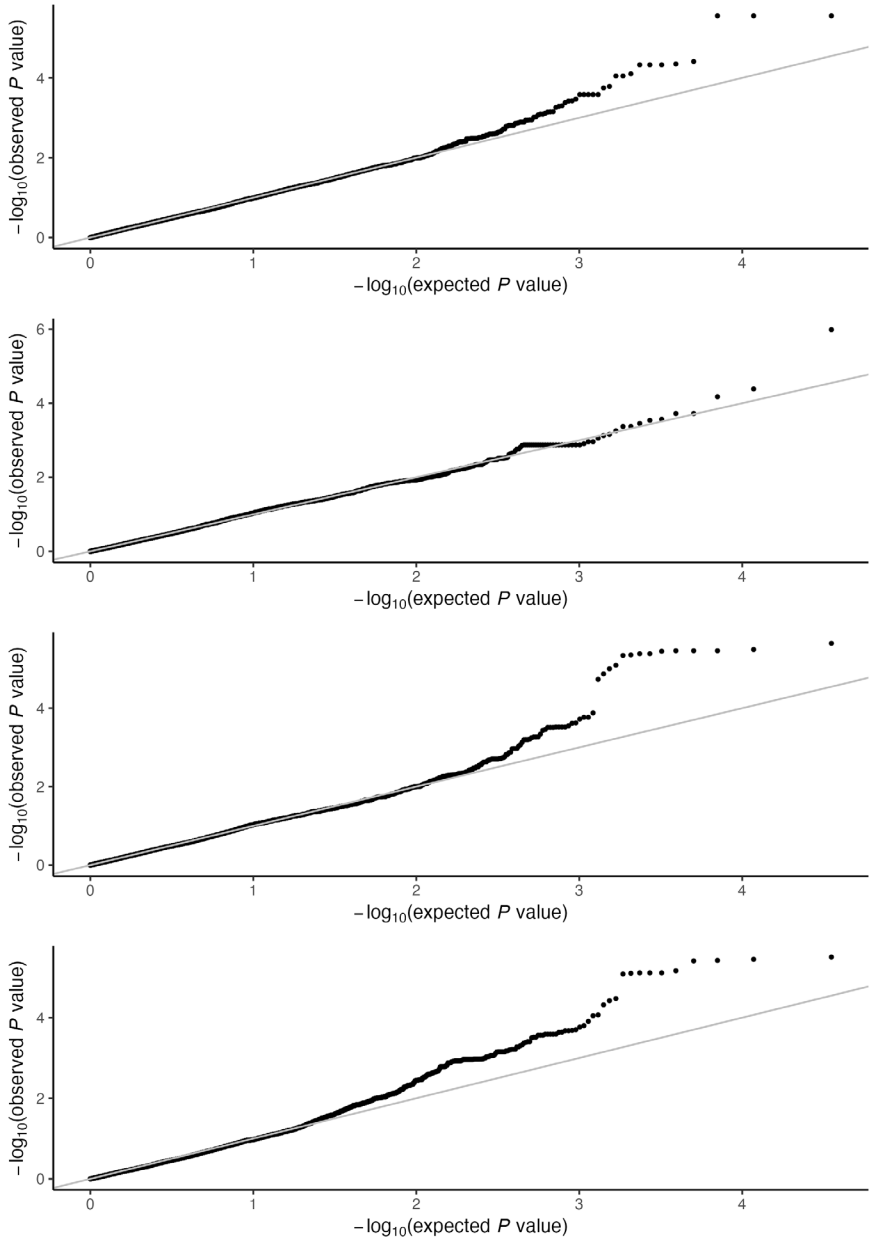
Results: Bone strength properties: Tibia and Humerus





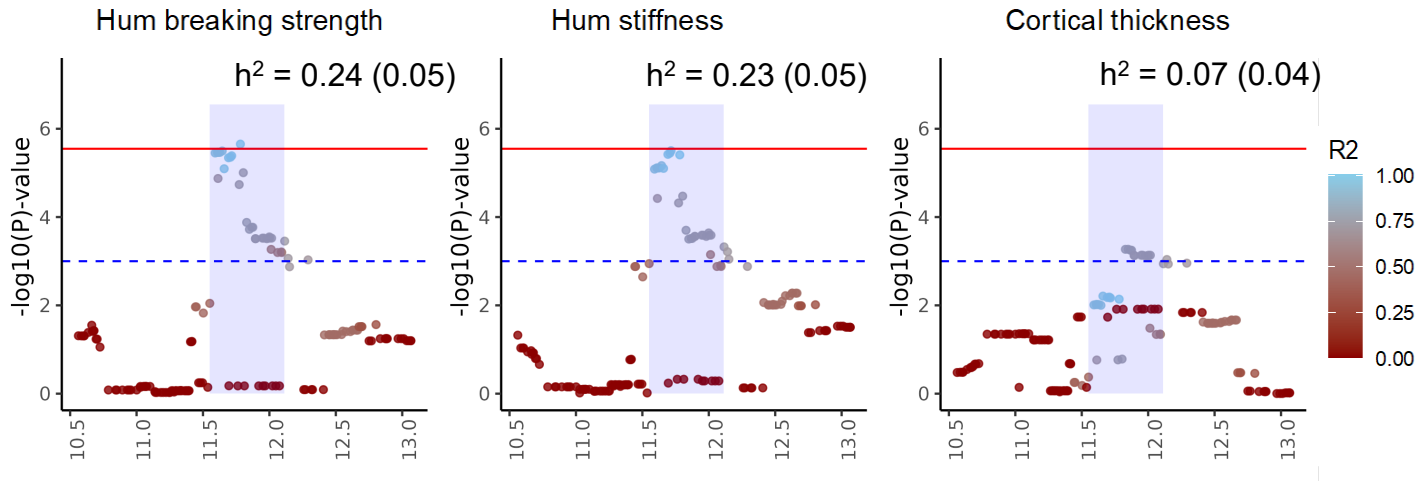




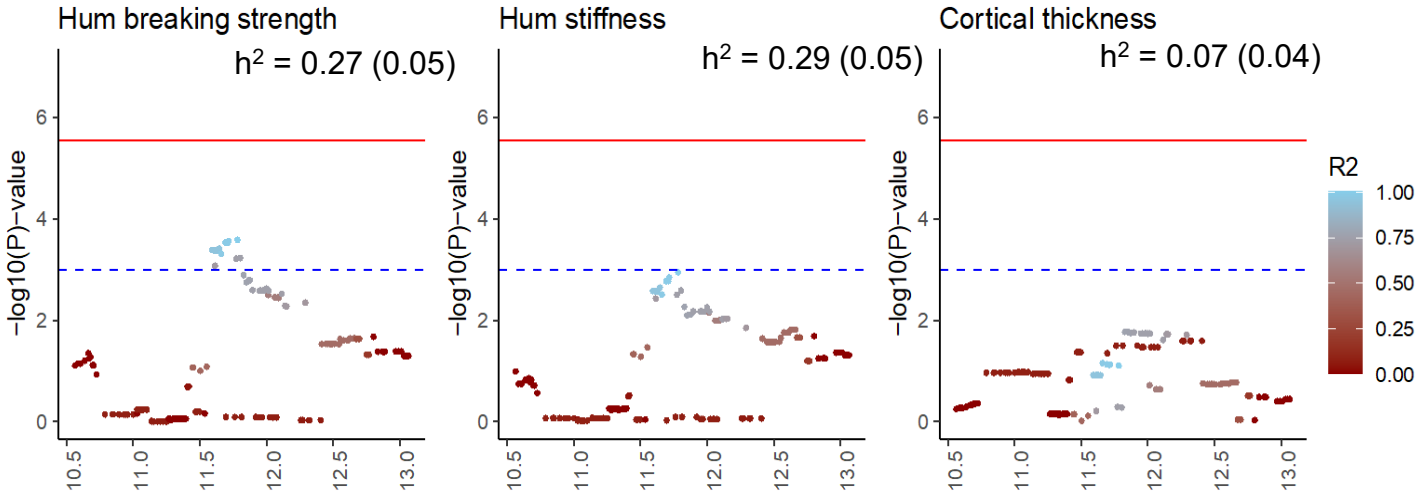


Results: Bone strength properties - Humerus

Model 1: not adjusted for body weight



Model 2: adjusted for body weight



Chromosome 20, position (Mb)

Genetic correlation with BW

~ **0.38**

Results: Bone strength properties - Humerus

Quantitative trait loci for BMD and bone strength in an intercross between domestic and wildtype chickens

Carl-Johan Rubin [1], Helena Brändström, Dominic Wright, Susanne Kerje, Ulrika Gunnarsson, Karin Schutz, Robert Fredriksson, Per Jensen, Leif Andersson, Claes Ohlsson, Hans Mallmin, Sune Larsson, Andreas Kindmark

Affiliations + expand

PMID: 17181401 DOI: 10.1359/jbmr.061203

Free article

Genetics

Associations between variants of bone morphogenetic protein 7 gene and growth traits in chickens

Y. Wang, F. Guo, H. Qu, C. Luo, J. Wang & D. Shu

Pages 264-269 | Received 20 Sep 2017, Accepted 30 Jan 2018, Published online: 11 Jun 2018

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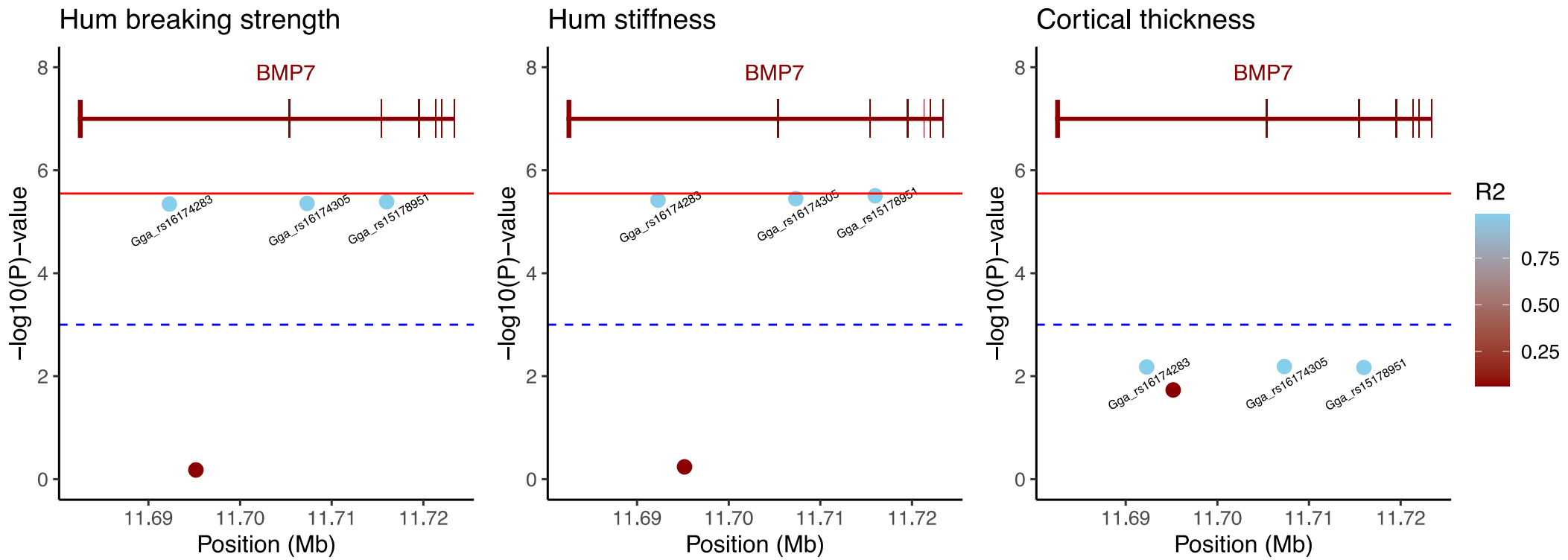
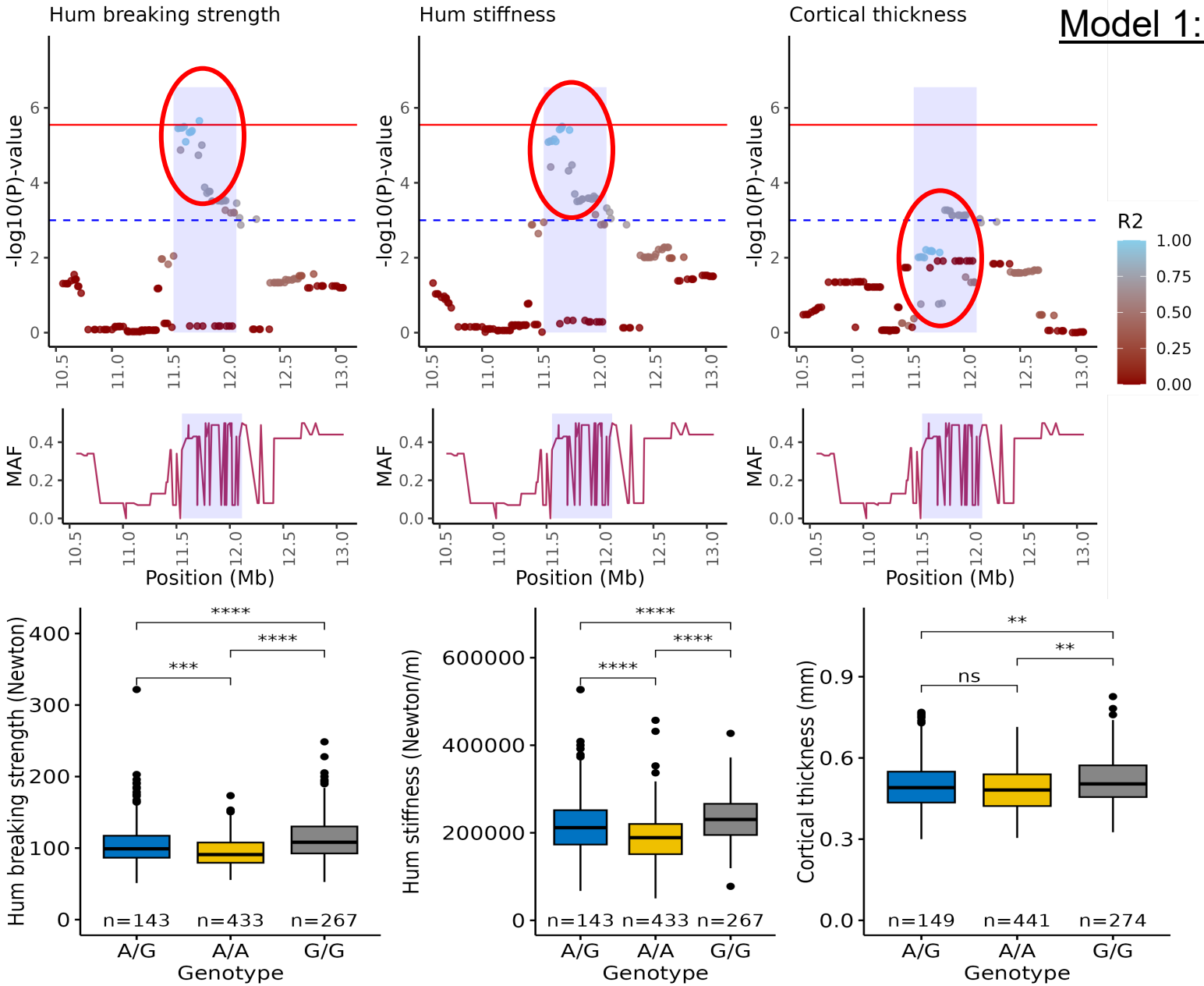


Results: Bone strength properties- Humerus

Model 1: not adjusted for body weight



Conclusions

1. Keel density heritability was was close to 0, implying that another approach is needed to phenotype the trait - **WE ARE WORKING ON IT!**
2. Medullary organic and mineral contents were the most heritable traits (0.25) and highly correlated with tibia density.
3. We detected suggestive SNPs that contribute to genetic variance with the strongest effect in medullary mineral and organic contents.
4. We highlighted a set of markers that significantly influence humeral bone strength and cortical thickness.
   - Those are located within the previously identified QTLs on Chr20 for bone strength and body weigh.

Acknowledgments

Concept

Swedish University of Agricultural Sciences, Sweden

Martin Johnsson
Dirk-Jan De Koning

Sample collection

Lohmann Breeders, Cuxhaven, Germany

Björn Andersson, Matthias Schmutz

H&N International, Cuxhaven, Germany

David Cavero

Bone strength analysis

Roslin Institute, University of Edinburgh, Scotland, UK

Peter W. Wilson, Ian C. Dunn

Bone chemical analysis

Universidad de Granada, Granada, Spain

Alejandro B. Rodriguez-Navarro,
Tattiana Enrich-Essvein,
Laura Crespo-Lopez