EFFICIENT & ECOLOGICALLY-FRIENDLY PIG AND POULTRY PRODUCTION.

ECOFCE

A WHOLE-SYSTEMS APPROACH TO OPTIMISING FEED EFFICIENCY AND REDUCING THE ECOLOGICAL FOOTPRINT OF MONOGASTRICS.

BASIC DATA

Funding:
EU-FP7
(€ 6 million)

Start date:
1 February 2013

Duration:
48 months
(2013 to 2016)

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Improved feed efficiency in (broiler) chickens is associated with intestinal size and function

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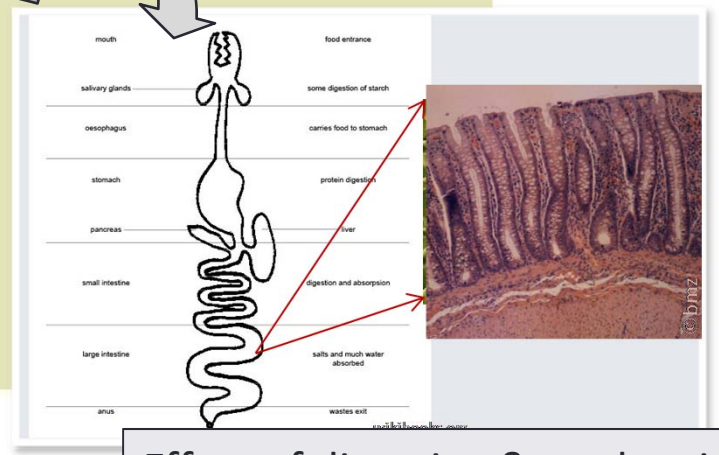
Introduction

Many physiological features involved in residual feed intake (RFI):

- gut microbiota
- digestive and absorptive processes
- nitrogen recycling
- lipid metabolism
- heat increment of feeding
- oxidative energy metabolism
- physical activity
- thermoregulation



Effect of digestive & gut barrier function?

- more information for duodenum
- less data available for jejunum

- In most studies, RFI was derived from one contemporary population of chickens
- Information about the contribution of the rearing environment on RFI-related variation in gut function is scarce

Hypothesis

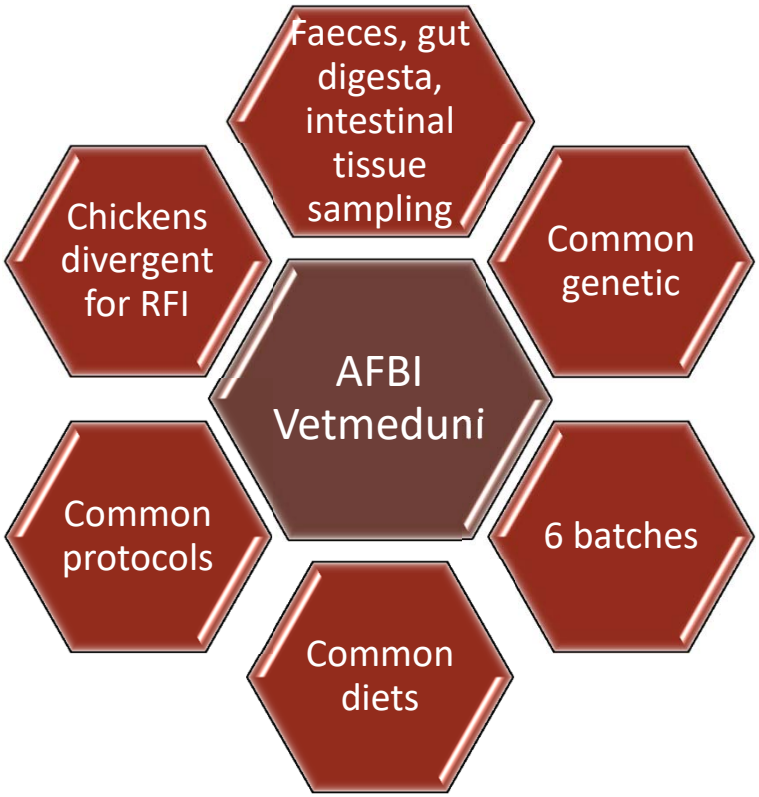
- Chickens of equal RFI should show analogous differences in the intestinal size, structure and functioning when raised at different experimental sites under controlled conditions.

Objective

To investigate the differences in
- nutrient digestion
- gastrointestinal size
- jejunal permeability
- related gene expression

in chickens of diverging RFI raised at two locations.

Screening on feed efficiency in chickens



- 2 different locations (Vetmeduni & AFBI)
- 3 batches with 52/64 (♂ and ♀) Cobb 500FF broiler chickens each
- Starter, grower and finisher maize-soybean meal diets
- Final selection of chickens on d 36 (Vetmeduni) / 38 (AFBI) using residual feed intake (RFI)
- Collection of feces for digestibility: d 34 to 36
- Collection of intestinal tissue, liver, pancreas: d 37 to 42

- 19 low / 18 medium / 18 high RFI males
- 15 low / 20 medium / 17 high RFI females

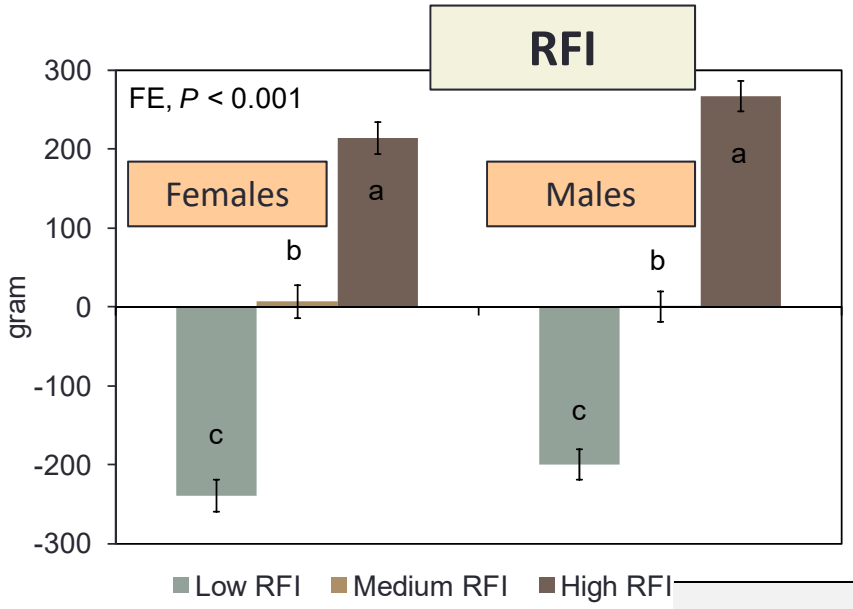
Lab analyses - gut function

Feces
- Acid insoluble ash as digestibility marker
- Protein retention
- Apparent total tract digestibility of real protein
- Protein excretion (total, real, uric acid)

Gut tissue	Duodenum	Jejunum	Ileum	Caeca
Length + weight	✓	✓	✓	✓
Histo-morphology	✓	✓	✓	✓
Ussing Chamber experiment		✓		
Mucosal disaccharidases activity		✓		
Candidate gene expression		✓		

Statistical analysis
- ANOVA using PROC MIXED (SAS)
- Fixed effects: RFI, location and RFI × location (if applicable)
- least-squares means ± pooled SEM
- Significance: $P \leq 0.05$; trends: $0.05 < P \leq 0.10$.

Residual feed intake, feed intake and growth of chickens of diverging feed efficiency



RFI = residual feed intake
Low RFI = good feed efficiency
High RFI = poor feed efficiency

[a,b]$P \leq 0.05$

Parameter	Low RFI	Medium RFI	High RFI	SEM	*P*-value, RFI rank
Females					
Total feed intake (g)	3415[b]	3483[b]	3755[a]	81.7	0.015
Total body weight gain (g)	2205	2140	2149	52.0	0.671
Males					
Total feed intake (g)	3756[c]	3914[b]	4252[a]	63.5	<0.001
Total body weight gain (g)	2524	2487	2529	57.7	0.850

Location effect on total body weight gain: Vetmeduni ↑, AFBI ↓; $P < 0.001$

Protein retention and total tract digestibility of real protein (Vetmeduni)

	RFI				*P*-values
Parameter	**Low**	**Medium**	**High**	**SEM**	**RFI**
Protein retention (% of intake)					
Females	57.7	52.2	52.7	1.83	0.088
Males	61.7	57.4	52.7	2.70	0.086
Apparent total tract digestibility of real protein (% of intake)					
Females	68.2	64.1	63.9	1.45	0.086
Males	70.7	67.6	63.4	2.25	0.090
Protein excretion (g/d)					
Females	13.6	16.4	16.7	1.03	0.079
Males	14.0	15.9	18.6	1.31	0.064
Real protein excretion (g/d)					
Females	11.4	13.7	14.2	0.86	0.065
Males	12.0	13.5	16.2	1.20	0.061
Uric-acid excretion (g/d)					
Females	0.35	0.43	0.40	0.05	0.563
Males	0.38	0.40	0.32	0.05	0.543

Location effect protein retention: Vetmeduni ↓, AFBI ↑; $P < 0.05$

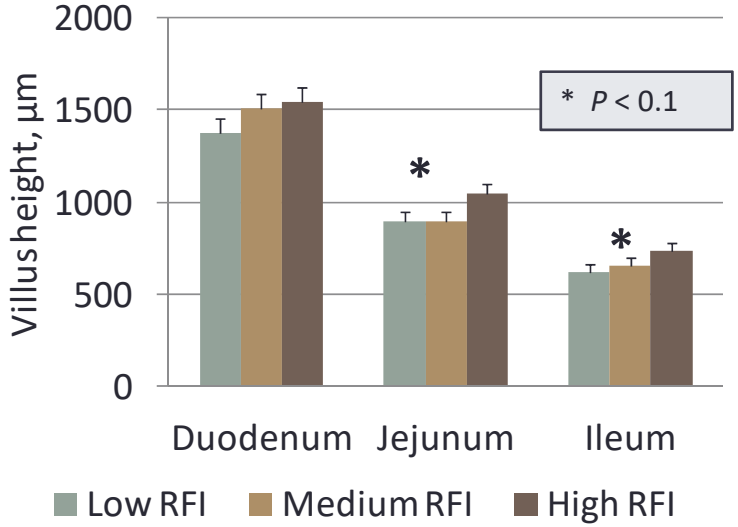
Histo-morphological results (Vetmeduni)

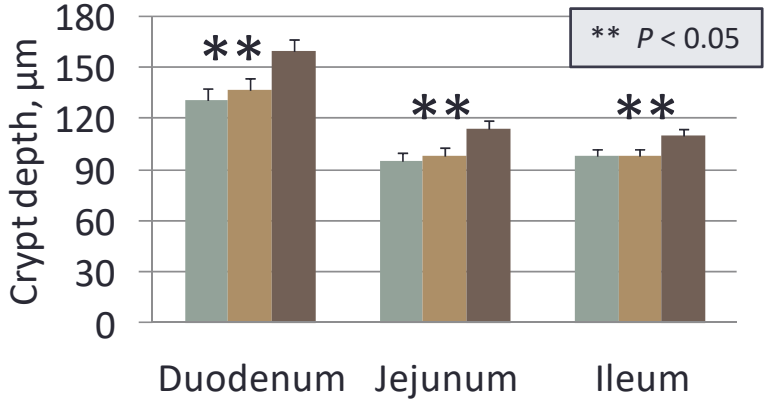
Females

Small intestine

Morphology

Low RFI: Villi ↓ and crypts ↓





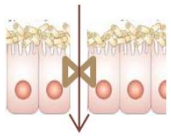
Mucosal enzyme activities in jejunum of chickens of diverging RFI

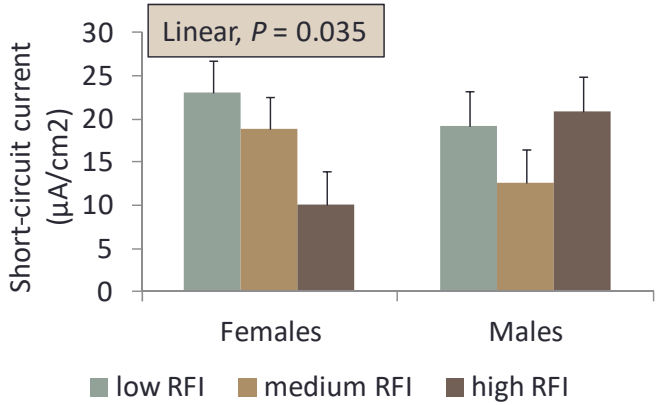
		RFI				*P*-values		
Enzyme	**Location**	**Low**	**Medium**	**High**	**SEM**	**RFI**	**Location**	**RFI x location**
Maltase (U/g protein)								
Females	1	2240	2033	2448	163.8	NS	<0.001	0.09
	2	1227	1527	1248	174.1			
Males	1	1989	3208	2755	290.5	NS	<0.001	0.04
	2	1687	1397	1573	285.5			
Sucrase (U/g protein)								
Females	1	123	188	231	19.4	NS	<0.001	0.07
	2	213	168	135	20.6			
Males	1	209	252	254	31.7	NS	0.008	NS
	2	172	161	169	31.1			

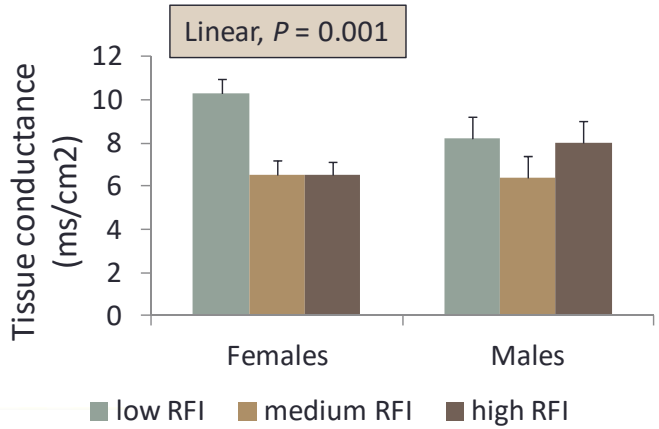
Location 1 = Vetmeduni Vienna
Location 2 = AFBI

Ussing Chamber results (Vetmeduni)

Distal jejunum → Ion flux
Paracellular permeability



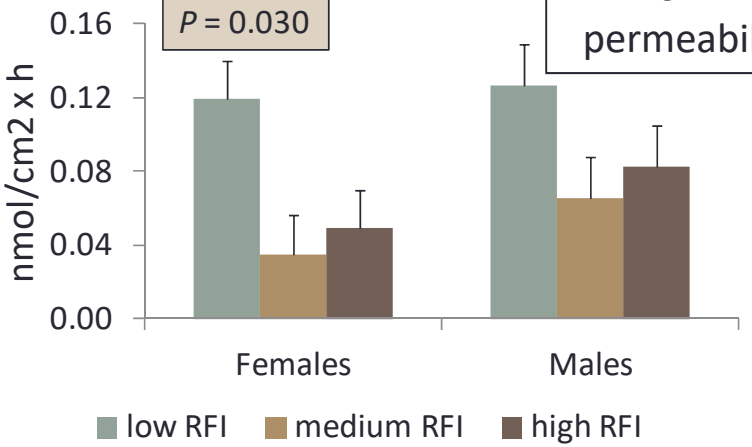




FITC = fluorescein isothiocyanate, low molecular weight marker

Mucosal-to-serosal flux of FITC

Low RFI : permeability ↑



Candidate gene expression in jejunal mucosa of chickens of low & high RFI

Mid jejunum

Candidate genes:

Tight-junction-proteins:

OCLN	=	occludin
ZO1	=	zona occludens 1
CLDN1	=	claudin 1
CLDN5	=	claudin 5

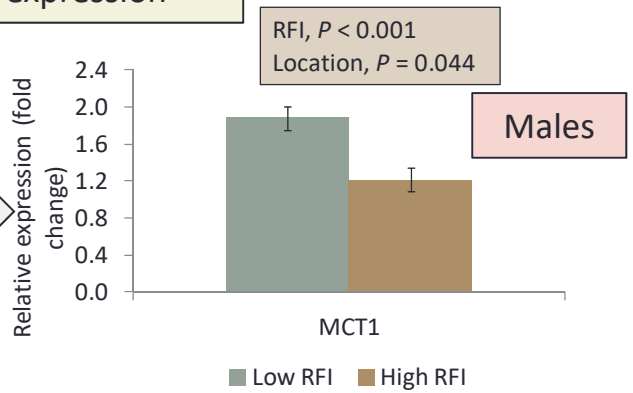
SCFA transporter:

MCT1	=	monocarboxylate transporter 1

Innate immune response:

IL1B	=	interleukin 1β
TNFA	=	tumor necrosis factor-α
TLR2	=	Toll-like receptor 2
TLR4	=	Toll-like receptor 4
IAP	=	intestinal alkaline phosphatase

No effect of RFI group on tight-junction protein expression



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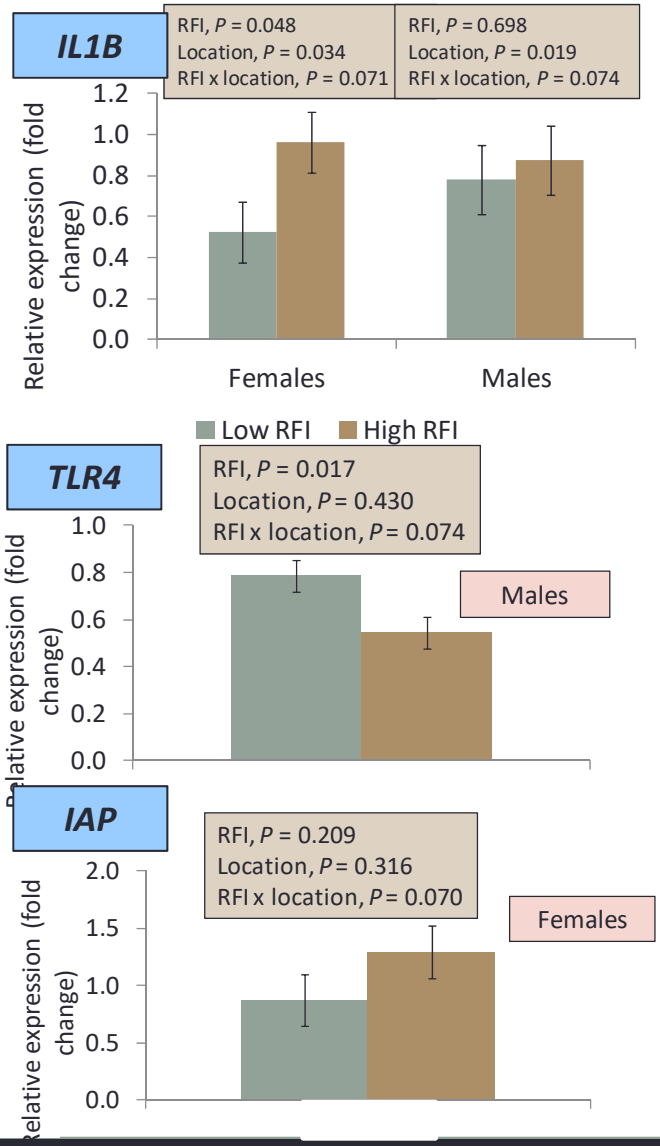
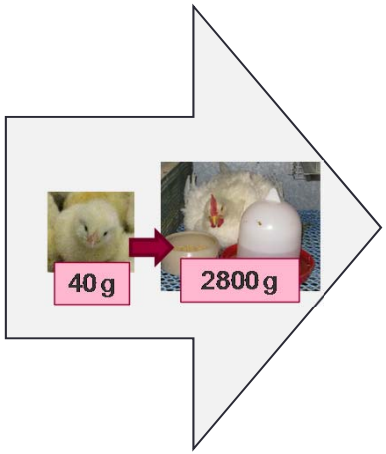
RFI × location interactions indicate that effect was more pronounced at L2 (AFBI) than at L1 (Vetmeduni)



Summary - Gut function of chickens of diverging RFI

Low versus high RFI	Females	Males
Protein retention	↑	↑
Liver weight	↓	↓
Villi and crypts in small intestine	↓	No effect
Mucosal disaccharidase activity in mid jejunum	No effect	No effect
Mucosal permeability in distal jejunum	↑	No effect
Relative gene expression		
Tight-junction proteins	No effect	No effect
MCT1	No effect	↑
Innate immune response	*IL1B*, *IAP* ↑	*IL1B* ↑, *TLR4* ↓

Conclusion



RFI-related effects on intestinal structure & function were affected by
… sex (expected)
… **environment**

Low RFI was associated with
… differences in jejunal structure and function
… reduced energy and nutrient needs for maintenance
… enhanced paracellular nutrient flow

Jejunal relative gene *MCT1, IL1B, TNFA & IAP* expression suggested …
… impact of **local** intestinal microbiota

Similar RFI and feed intake, **BUT** location-specific differences in intestinal functions contributing to RFI gain in current chicken populations

Acknowledgments

- **Vetmeduni**
  - Lab staff of Inst. of Animal Nutrition and Functional Plant Compounds
  - PD Dr. Kirsti Witter (Inst. of Anatomy, Histology and Embryology)
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Determination of feed efficiency

Selection of high and low feed efficient animals - based on **Residual Feed Intake**

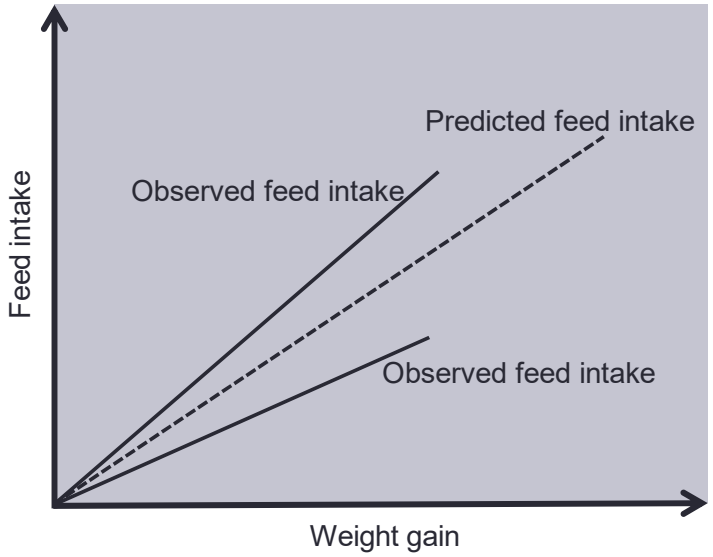
Residual Feed Intake (RFI) = difference between observed and predicted feed intake, with lower RFI values indicating greater energy efficiency

Other measures of feed efficiency

Feed conversion ratio

Residual body weight gain

Residual feed intake and body weight gain



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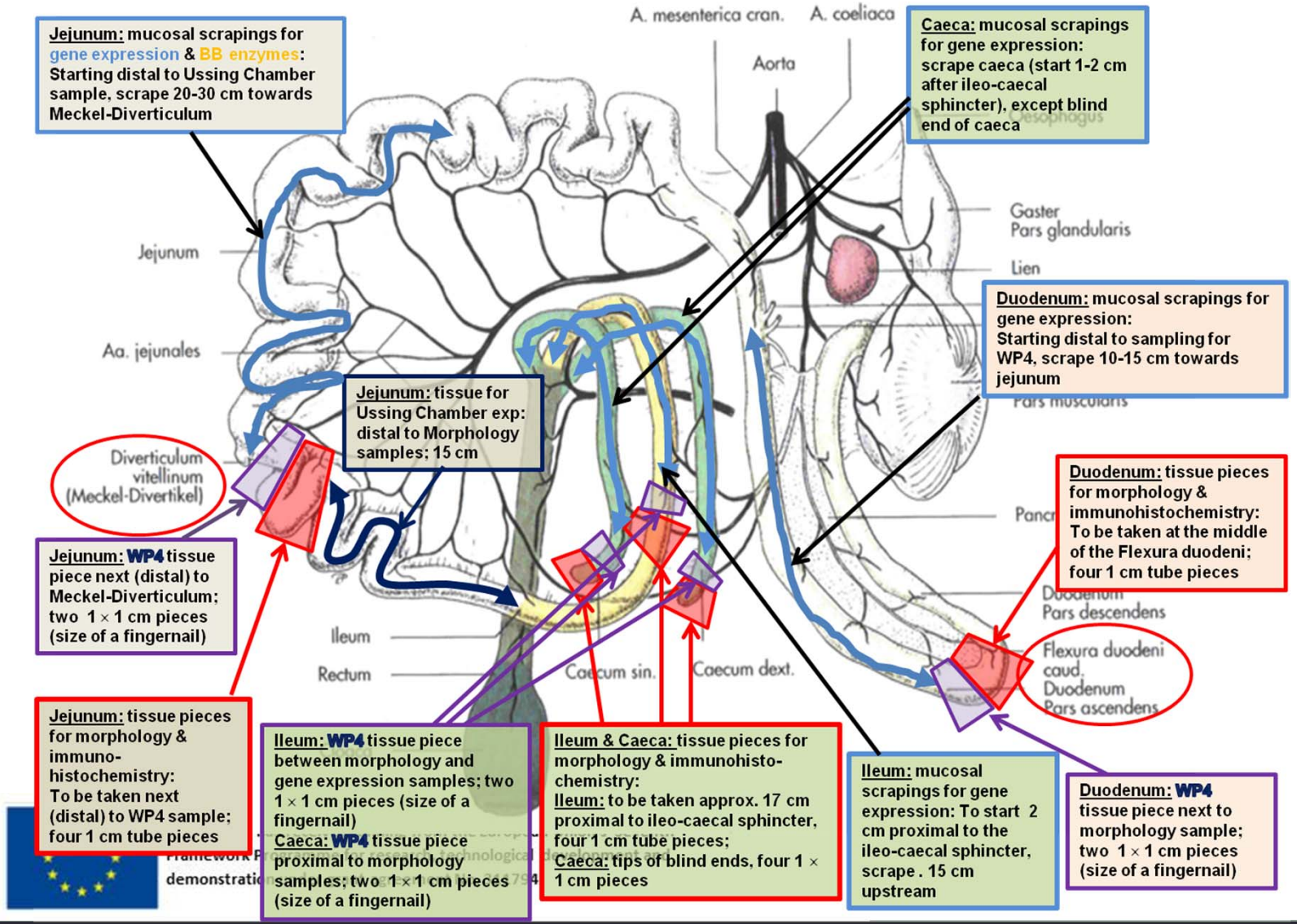
Item	Starter day 1-10 of life	Grower day 11-21 of life	Finisher day 22-42 of life
Ingredient, g/kg (as-fed basis)			
Corn	612	660	679
Soybean meal	331	282	260
Soybean oil	17.5	20.6	27.7
Limestone flour	11.0	9.8	7.0
Salt	2.0	2.0	2.3
Dicalcium phosphate	16.1	15.0	13.4
Vitamin-Mineral-Premix	11.0	11.0	10.0
Analyzed composition (g/kg DM)			
DM	926	923	914
ME (MJ/kg), calculated	13.7	14.3	14.6
Crude protein	243	223	216
Crude fat	50	52	59
Crude fiber	31	27	28
Crude ash	69	62	55
Starch	462	506	514
Sugar	40	46	49
Ca	11.9	10.7	8.9
P	8.2	7.2	6.9

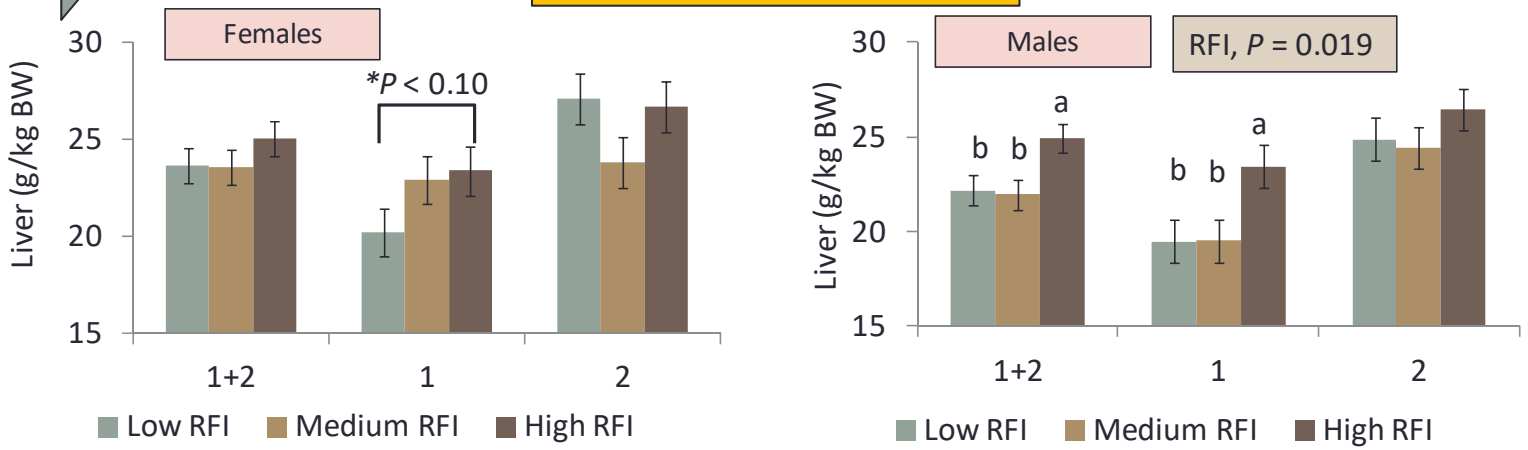
Gut sampling sites



Visceral organ size in chickens of diverging RFI

Pancreas and **gastrointestinal tract**: little RFI-related differences mostly affected by location

Location effect: $P < 0.01$



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