SUSFOOD2

POULTRYNSECT

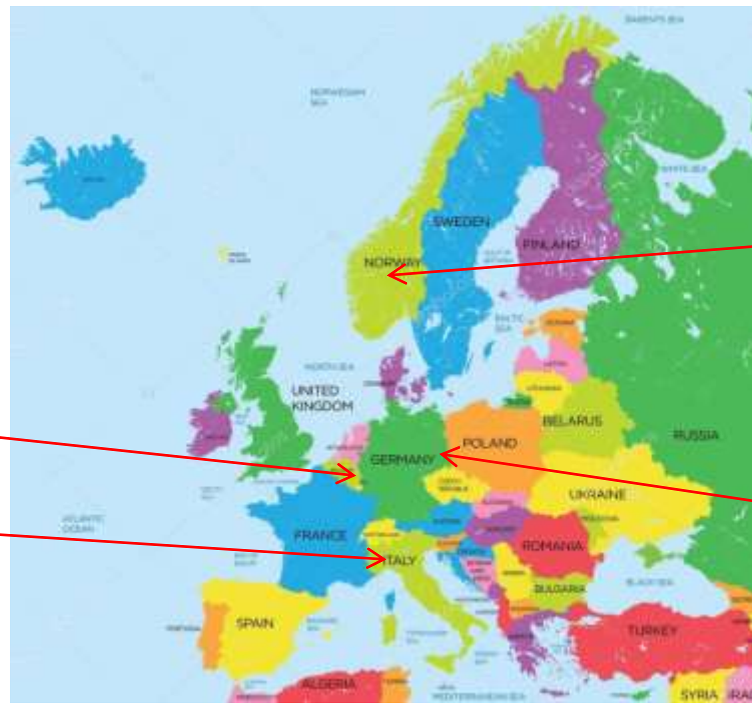
CORE organic

Poultry meat quality: could live larvae modify it?

Rune Rødbotten, (NOFIMA, Norway)

inagro
ONDERZOEK & ADVIES IN LAND- & TUINBOUW

Consiglio Nazionale delle Ricerche
(Coordinator)



Nofima

DIL

Final Symposium
Rome, 27th of October 2023

POULTRYNSECT FINAL MEETING
ROME 2023

Thaw loss

- Juiciness is a key parameter for eating satisfaction
- Thaw and dripp loss decreases juiciness

1st set (2022)

	fillet weight	thaw loss
	g	%
control male	196 +/- 23 A	8.2 +/- 2 A
larvae male	194 +/- 22 A	8.1 +/- 2.1 A
control female	151 +/- 17 B	8.7 +/- 2.2 A
larvae female	149 +/- 17 B	8.9 +/- 1.8 A

2nd set (2023)

	Time of slaughter	fillet weight	thaw loss
		g	%
CONTROL	1	115 +/- 6A	3.4 +/- 1.4A
LIVE LARVAE	1	115 +/- 10A	3.6 +/- 1.3A
CONTROL	2	113 +/- 13A	3.1 +/- 1.4A
LIVE LARVAE	2	115 +/- 14A	2.6 +/- 0.6A

- Less thaw loss in 2023

NIR screening

- Muscle abnormalities is a growing challenge for commercial broiler production

Figure 5. Myopathies in young broilers showing a normal fillet (A), spaghetti meat (B), the so-called woody-breast (C), and a fillet with white striping (D). Images by S. Barbut Lab.

Animals **2022**, 12, 2766. https://doi.org/10.3390/ani12202766

NIR screening

- Near Infrared Spectroscopy can fast and none-invasively detect muscle abnormalitis.

PLOS | ONE

RESEARCH ARTICLE

Rapid on-line detection and grading of wooden breast myopathy in chicken fillets by near-infrared spectroscopy

Jens Petter Wold[1]*, Eva Veiseth-Kent[1], Vibeke Høst[1], Atle Løvland[2]

1 Nofima AS, Norwegian Institute for Food and Fisheries Research, Muninbakken 9–13, Breivika, Tromsø, Norway, 2 Nortura SA, Lørenveien 37, Oslo, Norway

Table 1. Approximate chemical composition, color and pH in normal breast muscle and wooden breast muscle.

	Normal day 1&2	Normal day 3	Moderate WB	Severe WB
	Whole fillet	Upper 1 cm	Upper 1 cm	Upper 1 cm
	(n = 99)	(n = 15)	(n = 15)	(n = 13)
Moisture %	74.9 ± 0.86	75.3 ± 0.66	$79.1 \pm 1.49^{*}$*	$79.6 \pm 1.49^{*}$*
Protein %	23.5 ± 0.89	23.5 ± 0.64	$18.9 \pm 1.22^{*}$*	$18.4 \pm 1.47^{*}$*
Fat %	1.6 ± 0.62	$1.25 \pm 0.50^{*}$	1.8 ± 0.53	$2.0 \pm 0.67^{*}$*
	(n = 154)			
L*	56.10 ± 3.70	$52.7 \pm 2.68^{*}$	60.3 ± 1.7	$59.8 \pm 2.3^{*}$*
a*	2.97 ± 1.32	2.46 ± 0.62	2.34 ± 0.91	4.56 ± 2.9*
b*	7.41 ± 2.92	5.19 ± 1.22	8.84 ± 1.48*	$10.52 \pm 1.85^{*}$*
pH	5.99 ± 0.12	$6.3 \pm 0.10^{*}$	$6.3 \pm 0.16^{*}$	$6.3 \pm 0.09^{*}$

NIR measurements

1st set (2022)

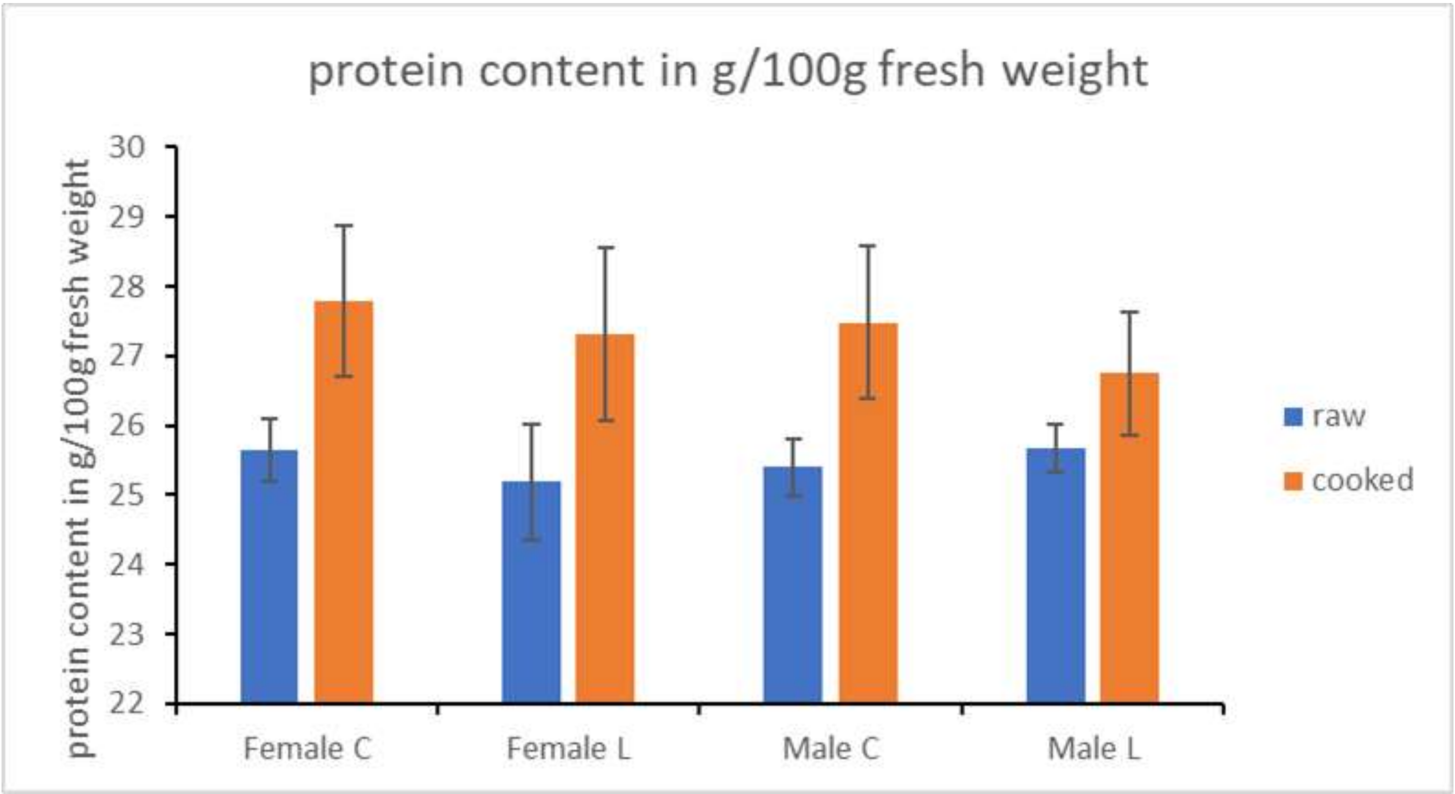
	estimated protein content with NIR %
control male	22.5 +/- 0.5 A
larvae male	22.4 +/- 0.4 A
control female	22.1 +/- 0.7 B
larvae female	22.3 +/-0.7 AB

2nd set (2023)

	Time of slaughter	estimated protein content with NIR %
CONTROL	1	23.4 +/- 0.3A
LIVE LARVAE	1	23.2 +/- 0.3A
CONTROL	2	23.6 +/- 0.7A
LIVE LARVAE	2	23.6 +/- 0.9A

- Significant interaction Sex * Feed in 2022-set

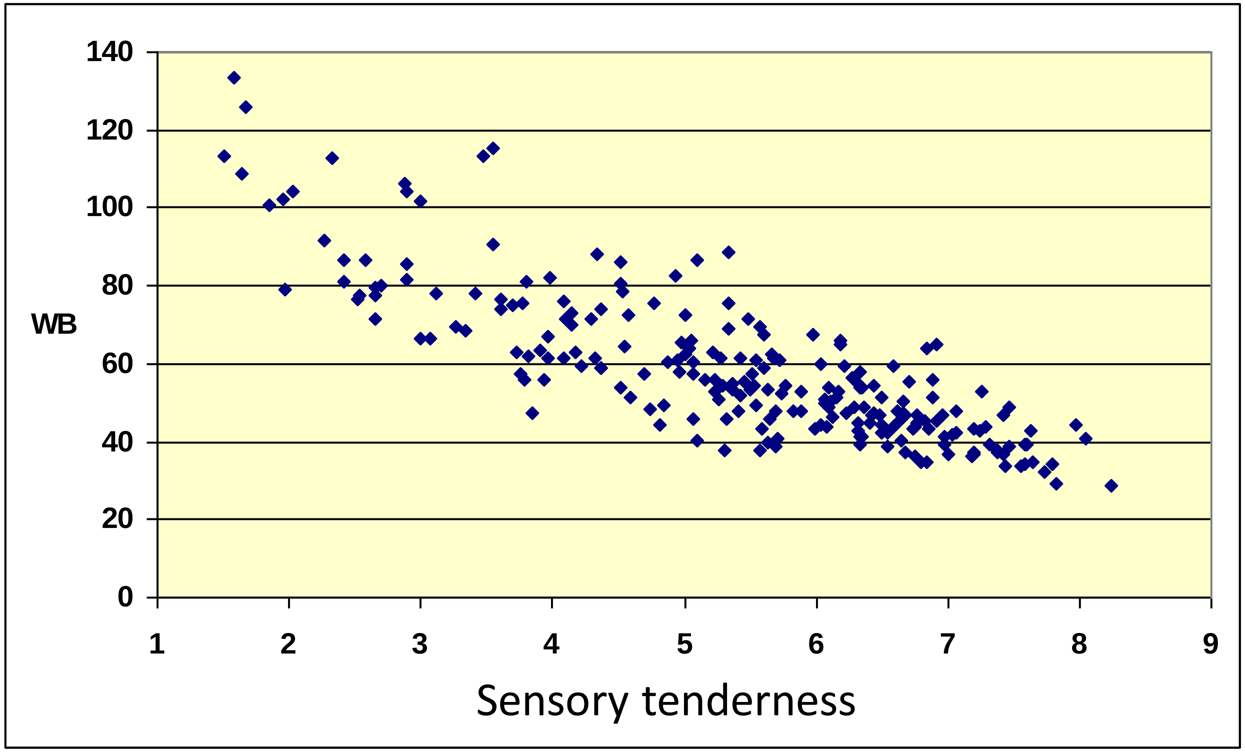
Measured protein (2022)



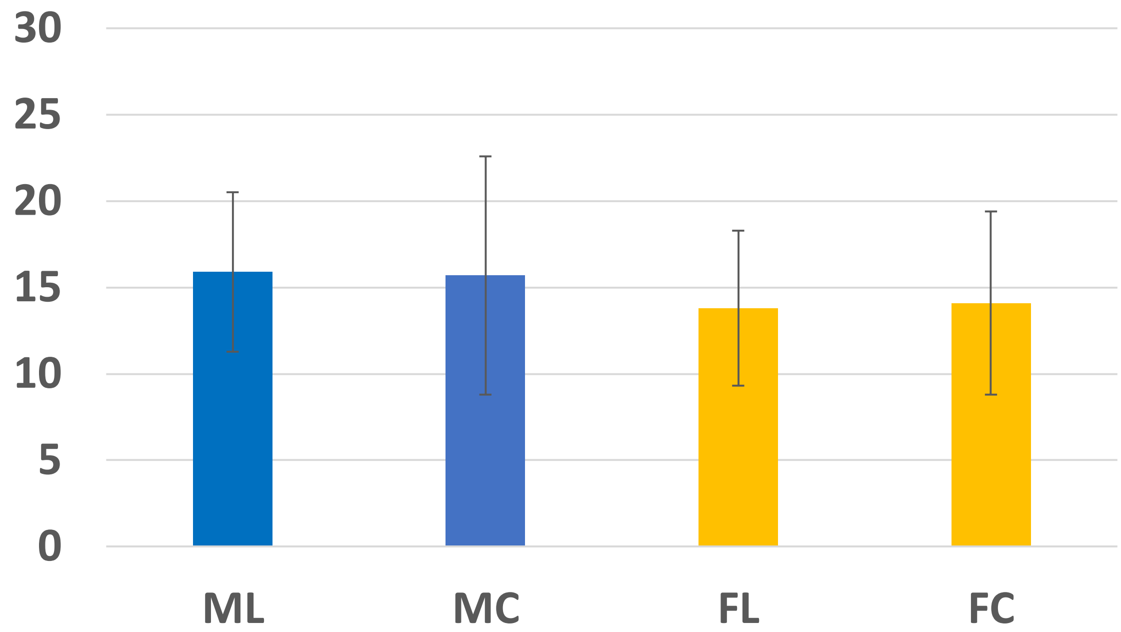
- NIR predicted less protein than actuall

Instrumental Tenderness

- Warner-Bratzler (WB) shear force
- Highly correlated with sensory tenderness



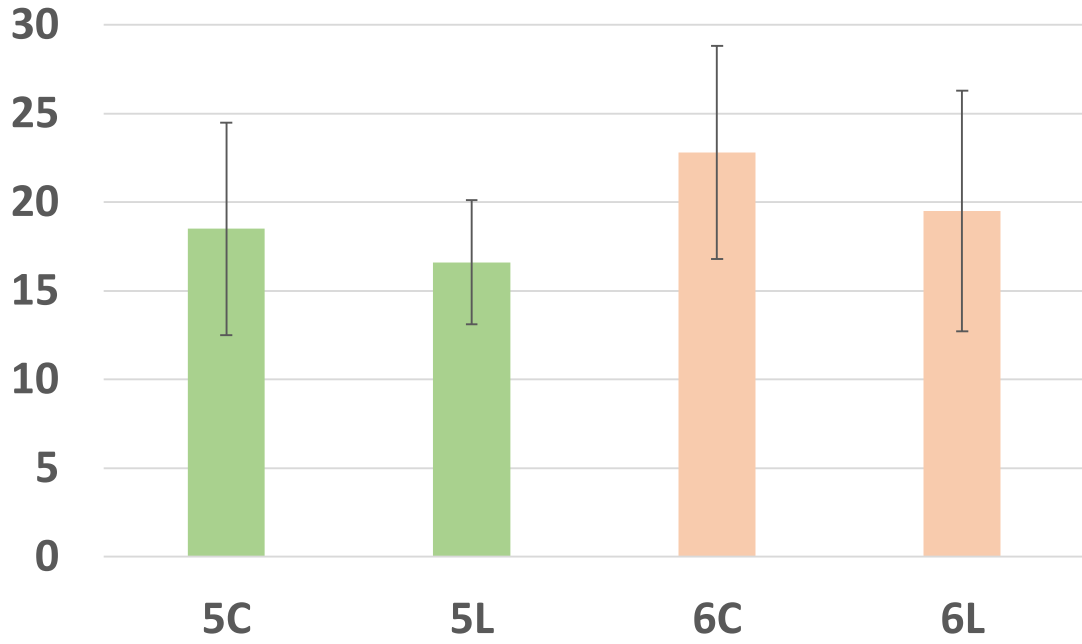
WB Shear force, 2022



M: male
F: female
L: Feed with larvea
C: Control feed

- No significant differences
- Tendency for higher female tenderness

WB Shear force, 2023



5: slaughtered after 5 months
6: slaughtered after 6 months
C: Controle feed
F: Feed with live larvea

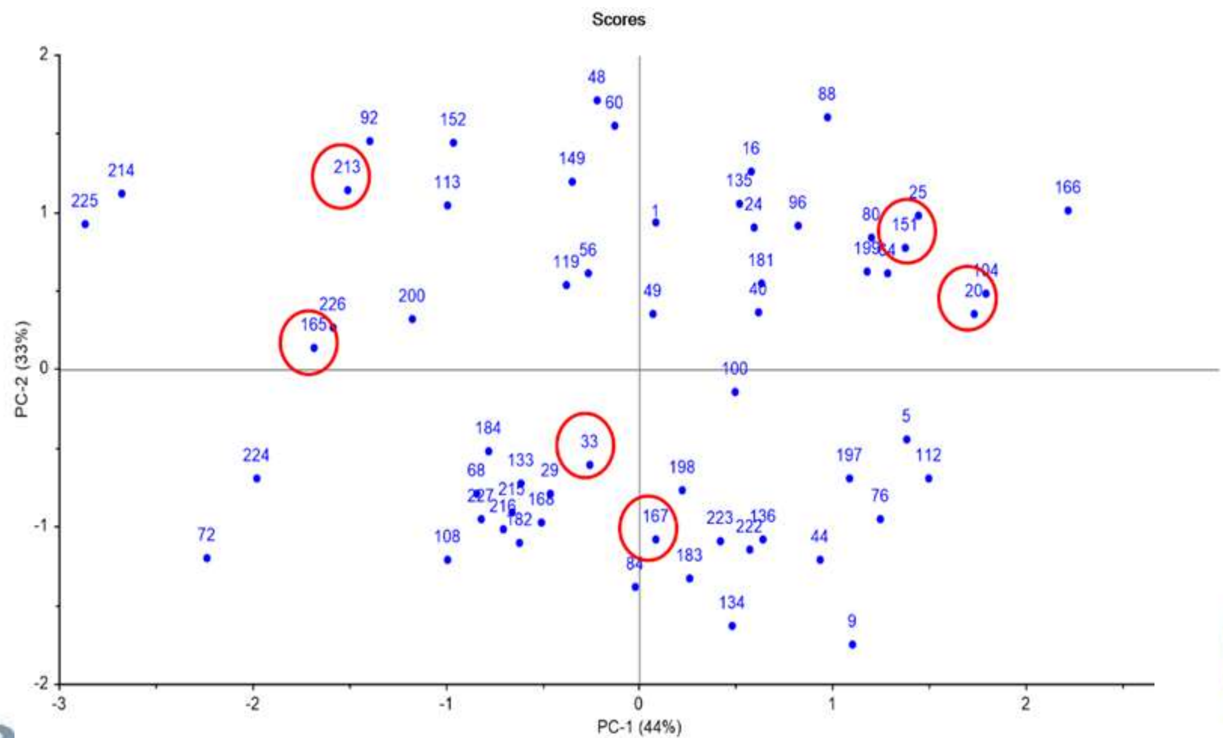
- No significant differences
- Tendency that larvae feed gave lower shear force
- Tendency that younger chicken had lower shear force

In-vitro digestion

- Laboratory method which mimic the human digestion
- SEC (Size Exclusion Chromatography) of peptides gives information about digestibility
- TBARS (Thiobarbituric acid reactive substances) indicates lipid oxidation and oxidative stress

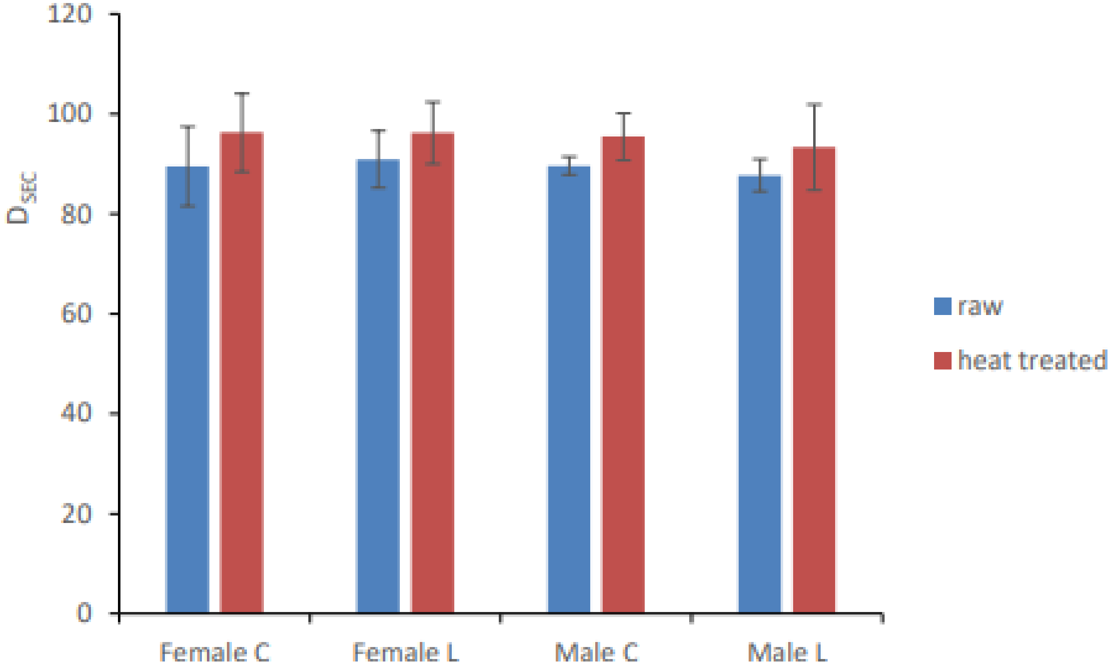
Selection of samples

- PCA based on Protein, thaw loss and sample weight.



In-vitro digestion, 2022

- D_{SEC}: proportion of peptides MW< 1 kDa



- No significant effects

In-vitro digestion, 2022

- TBARS values

	raw fillet	heat treated fillet	digested fillet
	µmol MDA/kg	µmol MDA/kg	µmol MDA/kg
control male	0.2 +/-0.7 [A]	5.9 +/- 1.7 [A]	24.8 +/-15.1 [A]
larvae male	0.02 +/- 0.2 [A]	5.2 +/- 2.8 [A]	20.7 +/- 15.7 [A]
control female	0.14 +/- 0.2 [A]	6.8 +/- 3.1 [A]	22.5 +/-12.8 [A]
larvae female	0.24 +/- 0.3 [A]	7.7 +/- 4.9 [A]	26.4 +/-19.0 [A]

- No significant effects

In-vitro digestion, 2023

- D_{SEC}: proportion of peptides MW< 1 kDa

	Time of slaughter	Soluble protein	Small peptides	Protein digestibility (D_{SEC})
		%	%	%
CONTROL	1	98.2 +/- 0.5	93.2 +/- 0.1	91.6 +/- 0.5
LIVE LARVAE	1	98.2 +/- 0.2	93.3 +/- 0.1	91.6 +/- 0.2
CONTROL	2	97.7 +/- 1.7	93.3 +/- 0.1	91.2 +/- 1.7
LIVE LARVAE	2	98.2 +/- 0.1	93.4 +/- 0.1	91.7 +/- 0.1

- No significant effects

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In-vitro digestion, 2023

- TBARS values

	Time of slaughter	raw fillet	heat treated fillet
		µmol MDA/kg	µmol MDA/kg
CONTROL	1	1.8 +/- 0.2^{A}	51.5 +/- 2.5^{A}
LIVE LARVAE	1	1.8 +/- 0.3^{A}	37.3 +/- 2.6^{B}
CONTROL	2	1.6 +/- 0.2^{A}	23.6 +/- 4.1^{C}
LIVE LARVAE	2	1.8 +/- 0.4^{A}	24.8 +/- 3.4^{C}

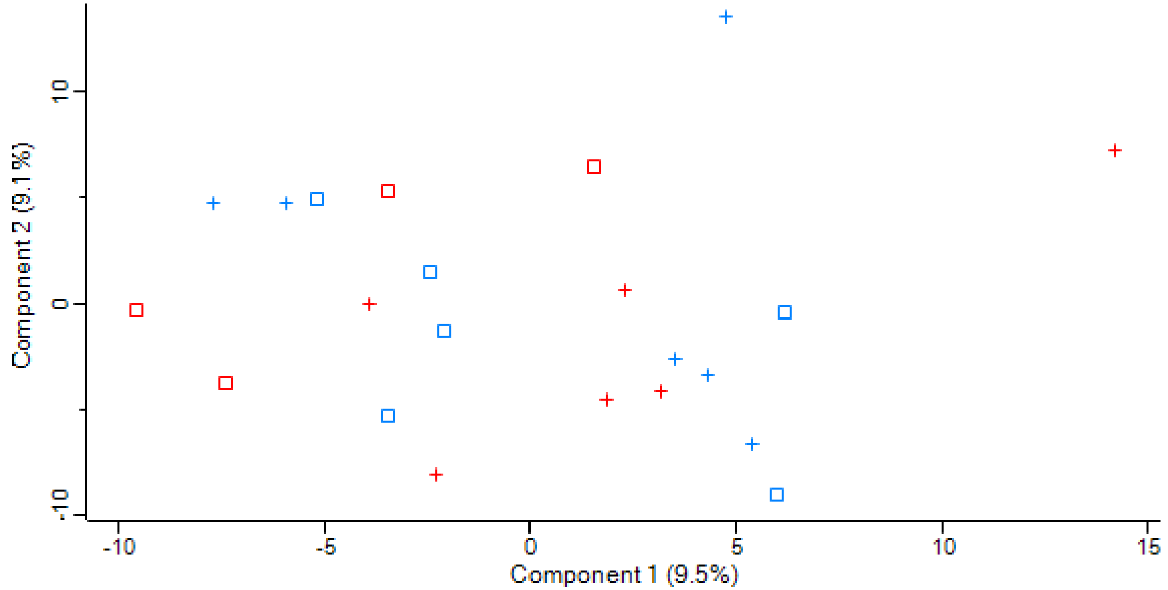
- Slaughter time2 had lower values for the heat treated samples

Proteomics

- Method(s) where large number of proteins are studied to reveal effects of factors like feed, age, sex, rearing, slaughtering, *p.m* meat handling,….

Proteomics

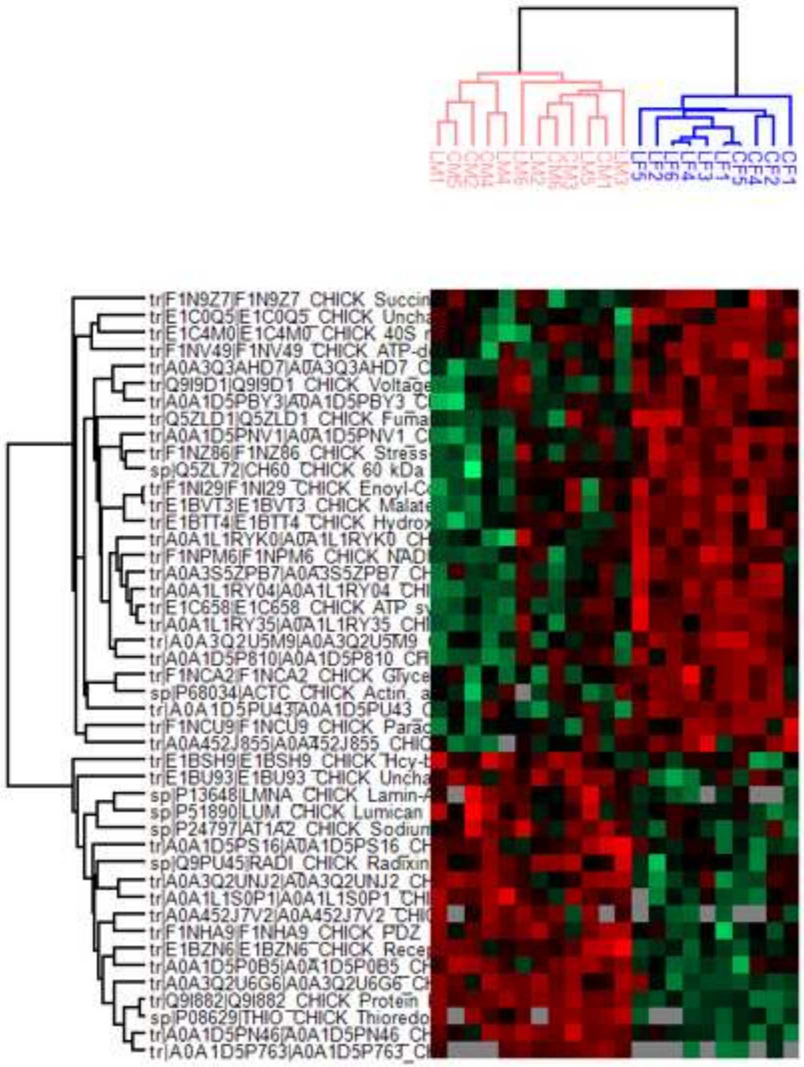
- 24 samples selected from the 2022 set
- Approximately 500 different proteins were identified
- Principal component analysis showed no clear separation according to their diet or sex



Proteomics

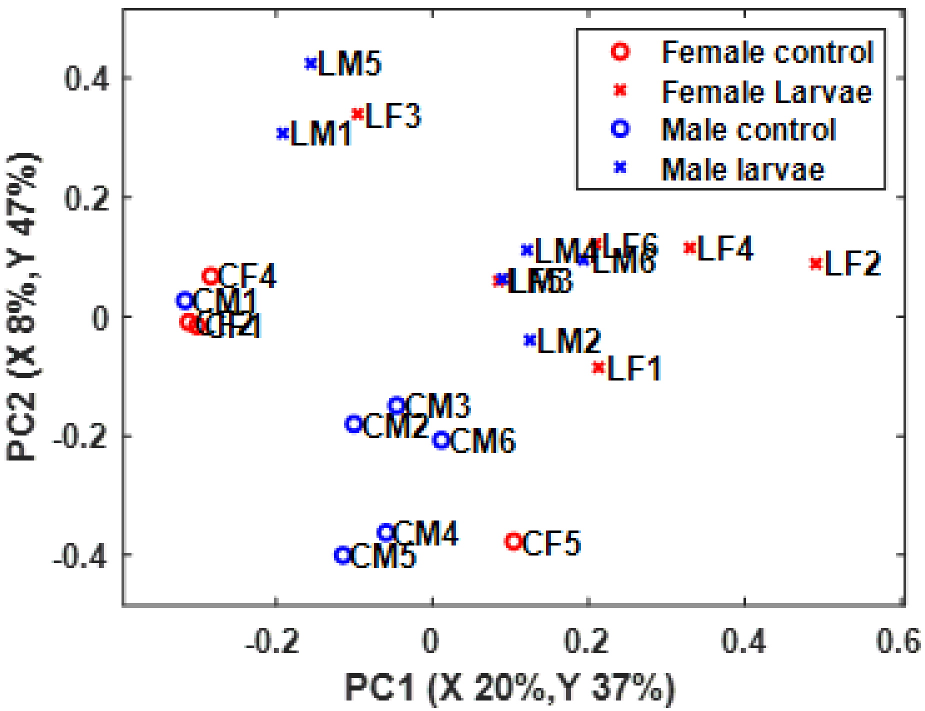
- Effect of sex

  45 proteins were differently expressed between males and females



Proteomics

- Multivariate techniques were used to cluster samples
- Feed had no practical impact on protein expression



summary

- Larvae feeding had no negative (or beneficial) effects on the measured meat quality parameters

POULTRYNSECT

SENSORY ANALYS OF THE MEAT FROM INSECT-FED CHICKEN

Giulia Maria Daniele
Institute for BioEconomy - Bologna
BioAgrofood Department
CNR - Italian National Research Council

Final Symposium
Rome 27 October 2023

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IBE-CNR SENSORY TEAM

Stefano Predieri
(coordinator)

Marta Cianciabella

Giulia Maria Daniele

Massimiliano Magli

Edoardo Gatti

Chiara Medoro

Nico Lippi

- Research projects (Poultrynsect, Breeding Value, Ecofrutta, ONFOOD)

- Collaboration with private companies (DOP certification, Quality control and Shelf Life studies)

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POULTRYNSECT FINAL MEETING
ROME 2023

IBE-CNR SENSORY LABORATORIES



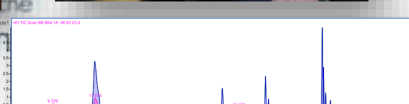
Laboratory:
- 14 booths
- Tablet online
- Software for data collection
- Trained judges

PANEL TEST

- Test with consumers
- Questionnaires and online survey

CONSUMER SCIENCE




- Gas Chromatography (GC) and Gas Chromatography/Olfactometry (GC/O)
- Chemical and physical analysis (Texturometers, Colorimeter)

INSTRUMENTAL ANALYSIS

“Sensory evaluation is a scientific discipline used to evoke, measure, analyse and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing”

Institute of Food Technologists, 1975; Lawless, H.T. 2010

THE KEY DISTINCTION IN THE SENSORY EVALUATION APPROACH

(By O'Mahoney M.)

TYPE I: reliability and sensitivity are key factors, and the judges are trained to be reliable and consistent like an **analytical instrument,** used to detect and measure the attributes of a food product.

Sensory properties

PANEL TEST

CONSUMER TEST

TIPE II: participants are chosen as representative of the consuming population, they are not trained and should evaluate food under ‘naturalistic’ conditions. The emphasis here is on the prediction of **consumer** preferences.

Hedonic properties

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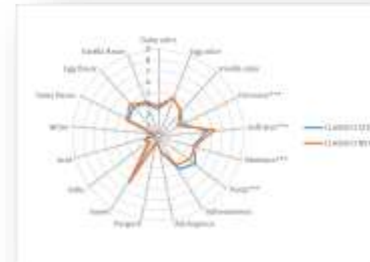
SENSORY SCIENCE GOALS

- Sensory description of a food product (sensory profile)
- Monitoring the conformity to standards
- Compare products after changing formulation
- Assessment of off-flavour or taint due to product treatment
- Monitoring the shelf life effect on products
- Sensory evaluation of new product developed



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TRIALS I & II, 2021-2022
Methodology

- Vacuum-packed bags, stored for a night at a temperature of **4°C**
- Boiling in a water bath at a range temperature of **75 - 85 °C for 40 minutes** using induction plates
- **color** (CIELab) after cooking
- **loss of weight** after cooking

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POULTRYNSECT

TRIAL I 2021

Sensory analysis of fresh breast from insect-fed chicken

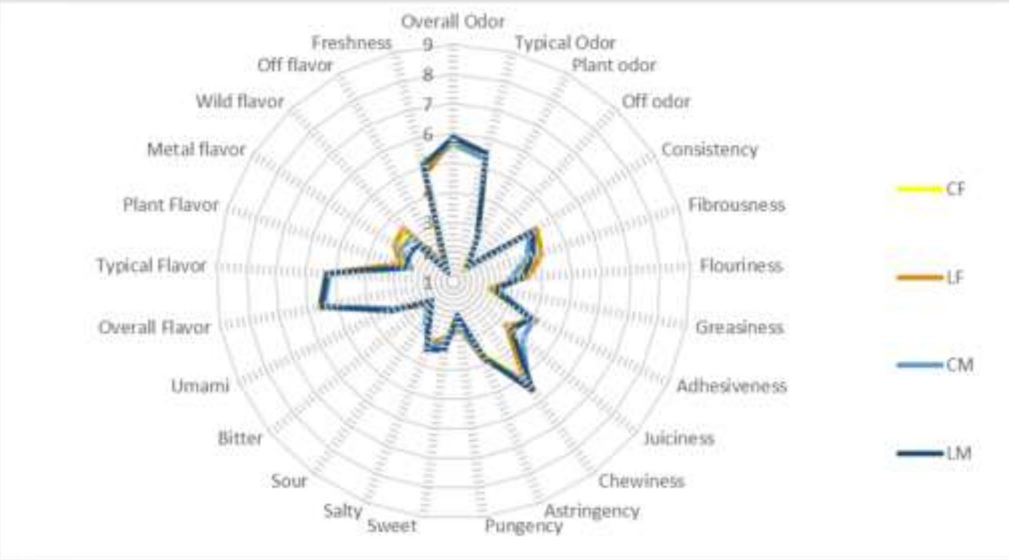
TRIAL I 2021
Instrumental Results

Breast Type	L	a	b*
CF	83.2	1.1	**17.1 a**
	78.7	2.8	**19.2 a**
	72.8	3.5	**18.0 a**
CM	81.6	2.4	**15.4 b**
	82.1	1.7	**16.4 b**
	80.6	2.4	**14.9 b**
LF	81.7	1.2	**17.4 a**
	79.4	2.3	**15.4 a**
	81.2	1.5	**16.8 a**
LM	81.2	2.1	**15.8 b**
	82.3	2.1	**14.0 b**
	80.5	2.9	**14.8 b**

Breasts Type	**Weight Loss % (µ)**
CF	26.0 n.s.
CM	21.0 n.s.
LF	23.6 n.s.
LM	19.6 n.s.

CF = Control Female CM = Control Male LF = Larvae Female LM = Larvae Male

TRIAL I 2021
Sensory Results



Breast Type	CF	LF	CM	LM
Overall Odor	5.6	5.8	5.7	5.9
Typical Odor	5.3	5.5	5.3	5.5
Plant Odor	2.8	2.7	2.6	2.7
Off Odor	1.5	1.7	1.6	1.7
Consistency	4.4	4.3	4.0	4.2
Fibrousness	3.7	4.1	3.6	3.8
Flouriness	3.3	3.5	3.0	3.3
Greasiness	2.2	2.3	2.5	2.4
Adhesiveness	4.0	4.1	4.0	3.9
Juiciness	3.5	3.3	4.0	3.5
Chewiness	5.2	5.1	5.3	5.5
Astringency	3.6	3.8	3.7	3.8
Pungency	2.2	2.6	2.5	2.1
Sweet	3.0	2.9	3.1	3.3
Salty	3.3	3.3	3.3	3.5
Sour	2.4	2.5	2.6	2.3
Bitter	2.1	2.3	2.1	2.0
Umami	3.1	3.2	3.2	3.3
Overall Flavor	5.6	5.6	5.5	5.5
Typical Flavor	5.3	5.3	5.2	5.3
Plant Flavor	2.8	2.9	2.5	2.6
Metal Flavor	3.3	3.4	3.1	2.8
Wild Flavor	3.1	3.5	3.0	2.7
Off Flavor	1.6	1.7	1.5	1.4
Freshness	5.2	4.8	5.1	5.0

Cullere *et al.*, 2018;
Cullere *et al.*, 2019;
Pieterse et *al.*, 2019

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POULTRYNSECT

TRIAL II 2022

Sensory analysis of fresh breast from insect-fed chicken at two different slaughtered ages

TRIAL II 2022
Instrumental Results

Slaughter age	Breast Type	L	a	b***
150 days	MS	77.8	2.7	17.7 a
	LV	76.0	3.1	16.1 a
	MC	77.0	3.4	13.7 b
180 days	MS	79.1	2.5	15.4 a
	LV	79.8	2.3	15.4 a
	MC	79.3	2.8	12.8 b

Slaughtered age	Weight Loss % (µ)
150 DAYS	26,3
	25,1
	28,2
180 DAYS	18,3
	16,0
	17,6

MS = Sustainable Feed LV = Live Larvae based feed MC = Commercial Feed

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TRIAL II 2022
Sensory Results

150 DAYS

	LV 150GG	MC 150GG	MS 150GG
Overall odor	5,8	6,0	6,3
Typical odor	5,5	5,6	5,9
Plant odor	2,6	2,6	2,6
Off odor	1,4	1,3	1,3
Consistency*	5,2 a	5,0 ab	4,4 b
Fibrousness	4,4	4,1	3,9
Flouriness	3,0	2,8	2,7
Greasiness	2,5	2,5	2,9
Adhesiveness	3,9	3,7	3,7
Juiciness	3,3	3,3	3,5
Chewiness	4,7	4,7	4,9
Astringency	3,5	3,7	3,5
Pungency	2,1	1,9	2,1
Sweet	3,0	3,1	3,0
Salty	3,5	3,4	3,5
Sour	1,7	1,7	1,8
Bitter	1,6	1,6	1,7
Umami	3,7	3,7	3,6
Overall flavor	5,6	5,8	5,9
Typical flavor	5,3	5,3	5,4
Plant flavor	2,6	2,6	2,6
Metallic flavor	2,2	2,4	2,4
Wild/animal flavor	2,4	2,3	2,5
Off flavor	1,6	1,3	1,5
Freshness	5,0	5,0	4,9

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TRIAL II 2022
Sensory Results

	LV 180GG	MC 180GG	MS 180GG
Overall odor	5,3	5,4	5,7
Typical odor*	5,1b	5,4ab	5,7a
Plant odor	2,2	2,3	2,4
Off odor	1,5	1,4	1,4
Consistency**	4,9a	4,5ab	3,8b
Fibrousness*	4,4a	4,0ab	3,6b
Flouriness	2,9	2,7	2,8
Greasiness	2,7	2,7	2,7
Adhesiveness	3,4	3,5	3,5
Juiciness	3,1	3,4	3,2
Chewiness**	4,3b	4,8ab	5,5a
Astringency	3,2	3,5	3,5
Pungency	1,6	1,6	1,8
Sweet*	2,8a	2,4b	2,6ab
Salty	3,6	3,9	3,7
Sour	1,9	1,9	2,0
Bitter	1,8	1,6	1,8
Umami	4,0	4,1	4,1
Overall flavor	5,3	5,4	5,6
Typical flavor	5,2	5,3	5,5
Plant flavor*	2,1b	2,4ab	2,5a
Metallic flavor	2,5	2,6	2,4
Wild/animal flavor	2,2	2,1	2,0
Off flavor	1,3	1,3	1,4
Freshness	4,9	4,9	5,2

180 DAYS

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Consumer opinion about the use of live insect larvae in poultry organic farming

Nico Lippi
IBE-CNR, Italy

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Dipartimento di Scienze Bio Agroalimentari

Final Symposium
Rome 27 October 2023

POULTRYNSECT FINAL MEETING
ROME 2023

IBE-CNR SENSORY LAB






- Sensory analysis (trained judges)
- Consumer science (tests with consumers, questionnaires, online survey)
- Instrumental Analisys

Laboratory equipped with:

- 14 booths
- Tablet online
- Software for data collection

TABLE OF CONTENTS

- INTRODUCTION
- QUESTIONAIRE DESIGN
- RESULTS

INTRODUCTION

Online survey, Why??

COST

COMFORT & PRIVACY

WIDER CONNECTION

POULTRYNSECT

What??

ACCEPTANCE

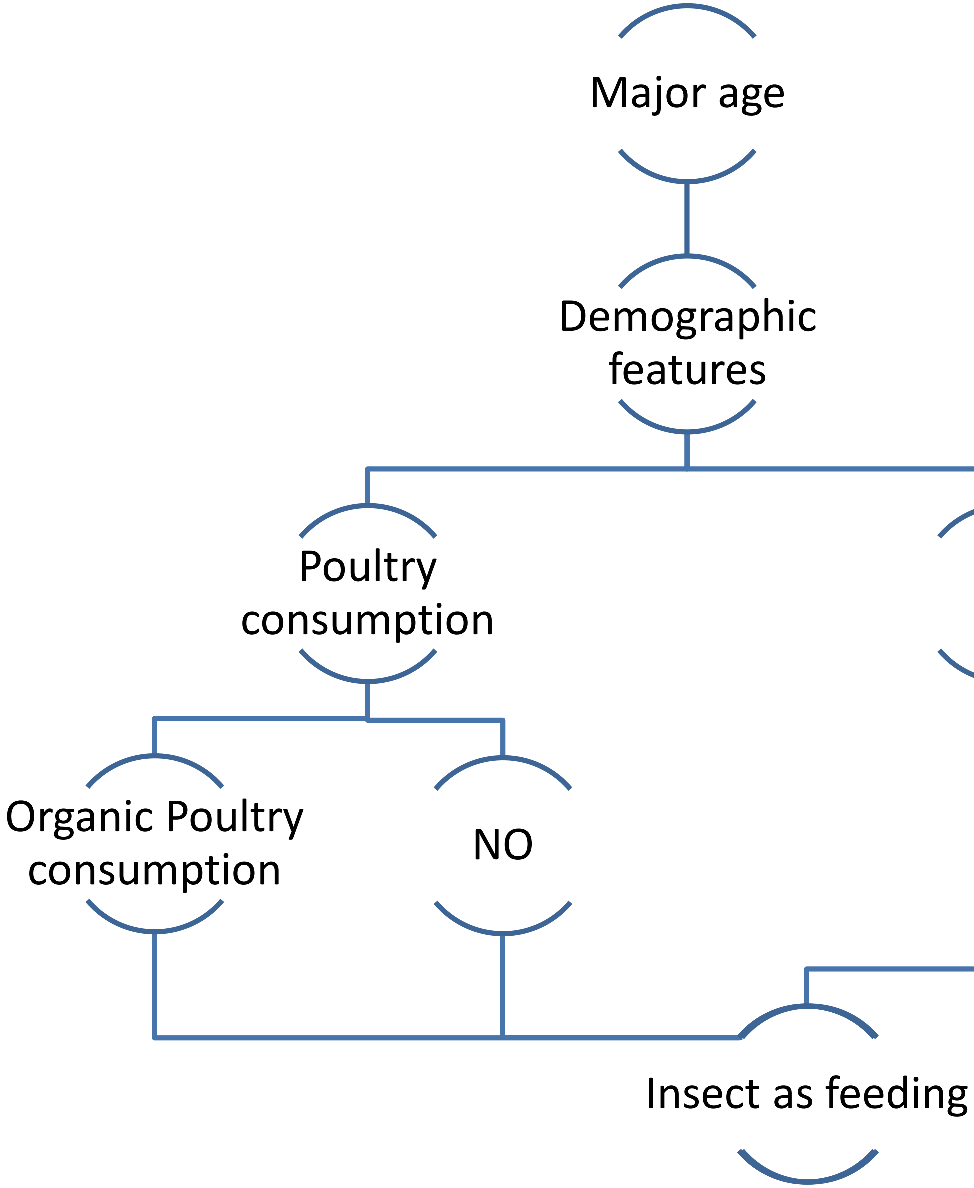
DRIVERS

WILLINGNESS TO PAY

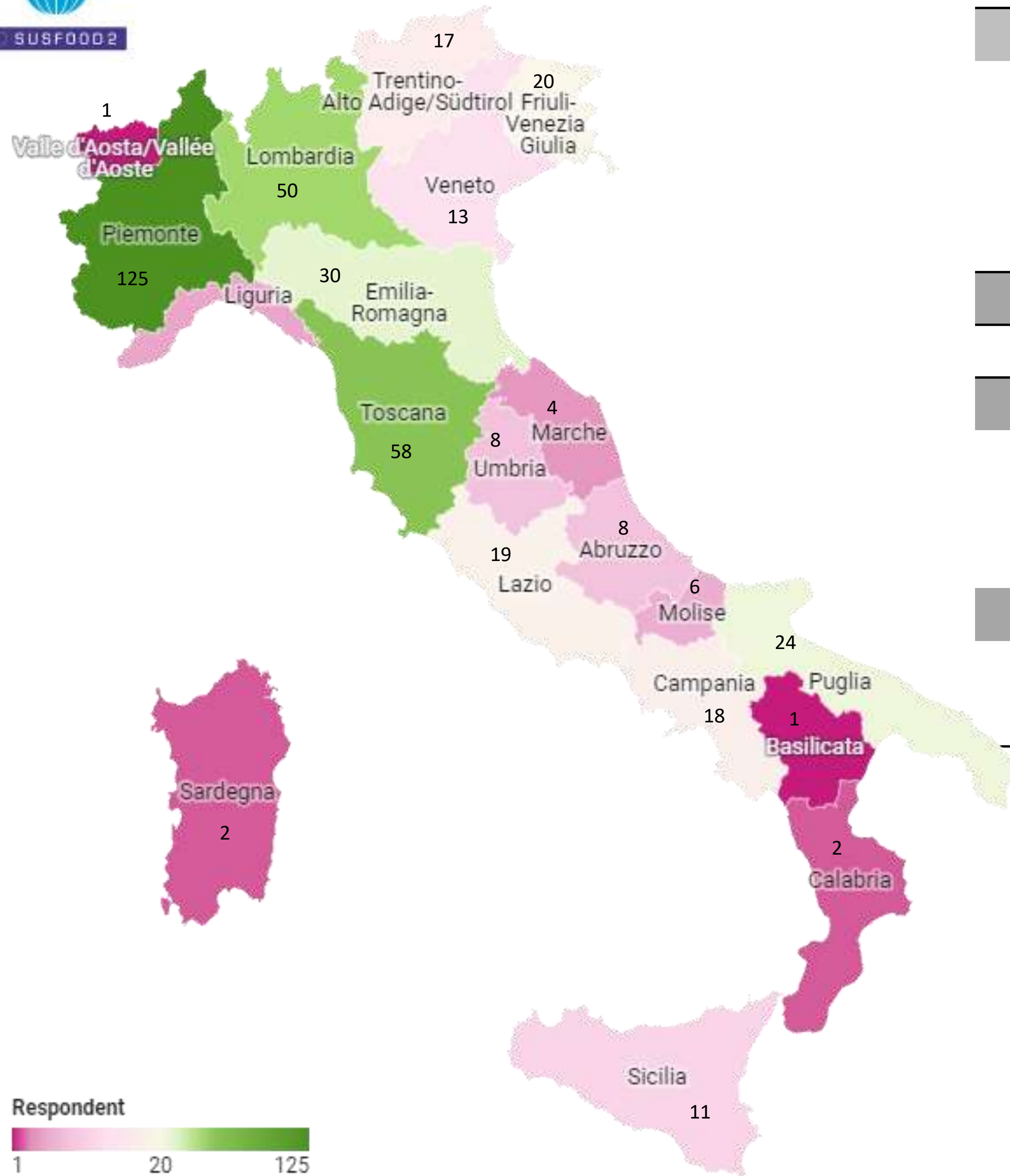
AWARENESS

TARGETING

Questionnaire design



RESULTS
(Demographic features)

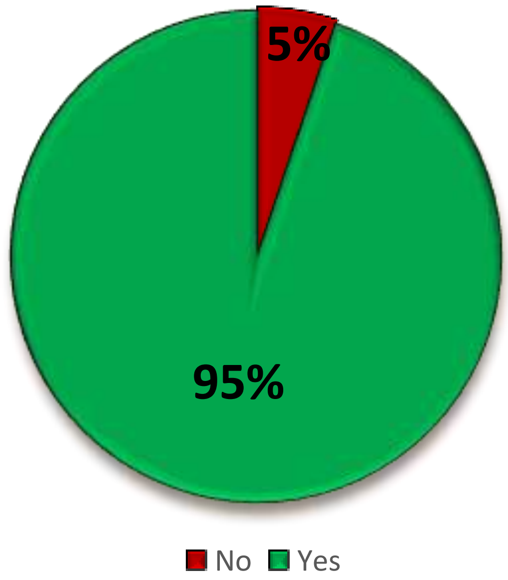


Gender	n
Female	258
Male	161
No answer	2
Non binary	1
TOTAL	**422**
Age average	44.87
Level of instruction	
Bachelor/Master/PhD	312
High School	95
Primary school	15
DIET	
Omnivorous	403
Vegetarian	19

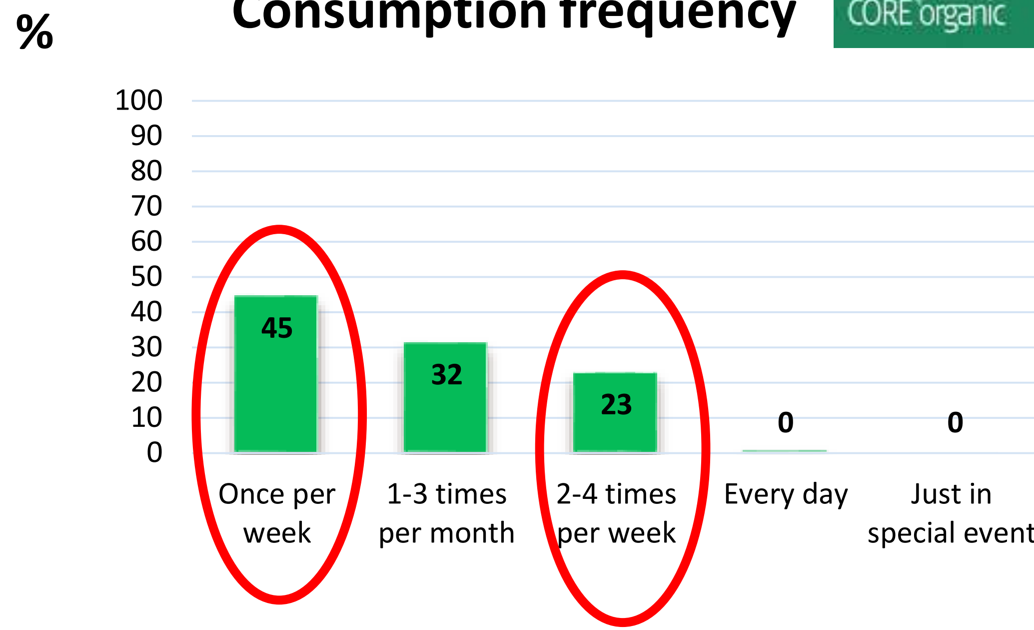
RESULTS

(Poultry consumption)

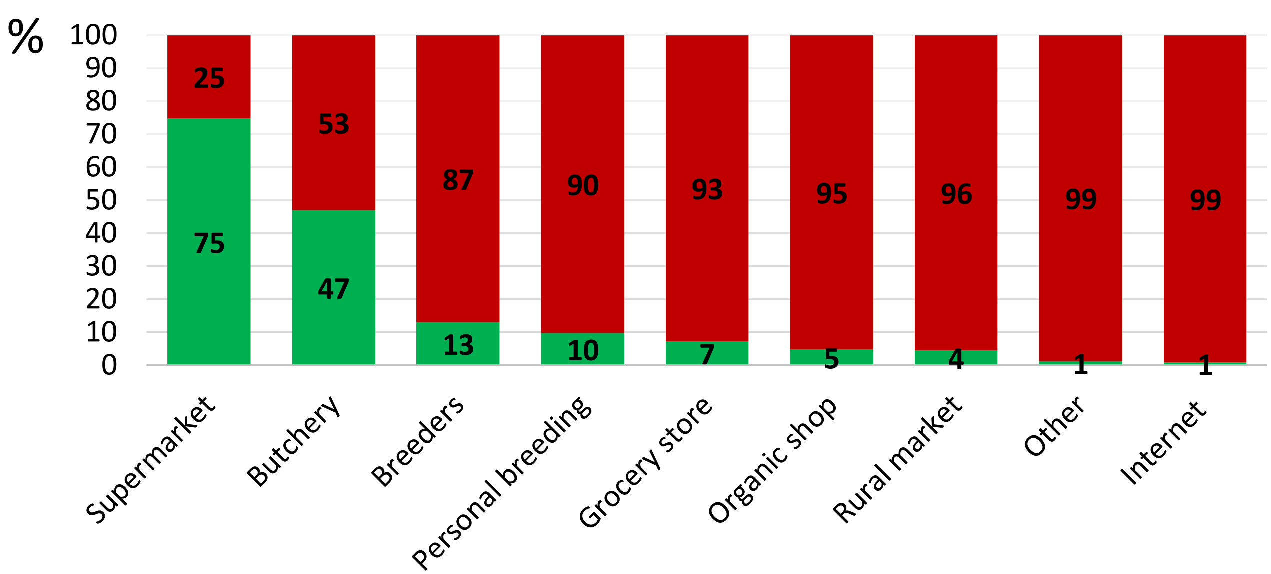
Poultry Consumption

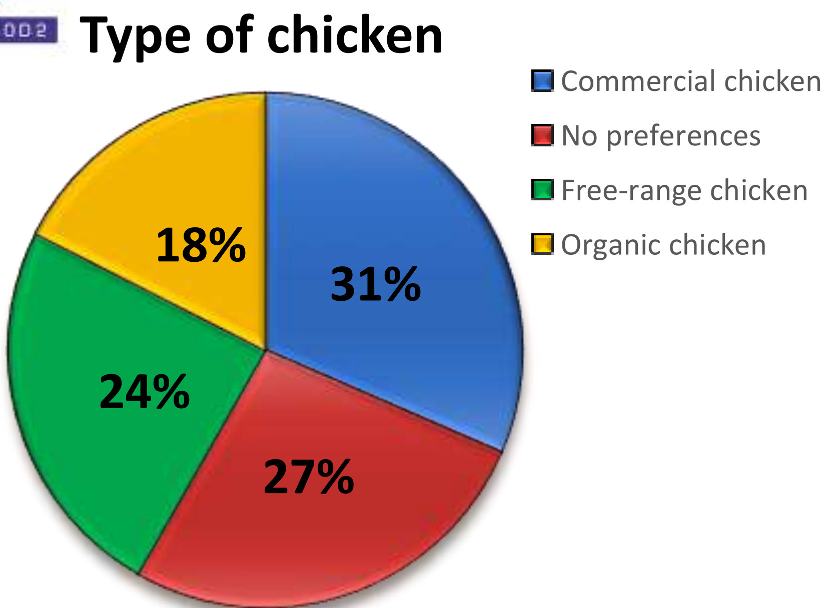


Consumption frequency

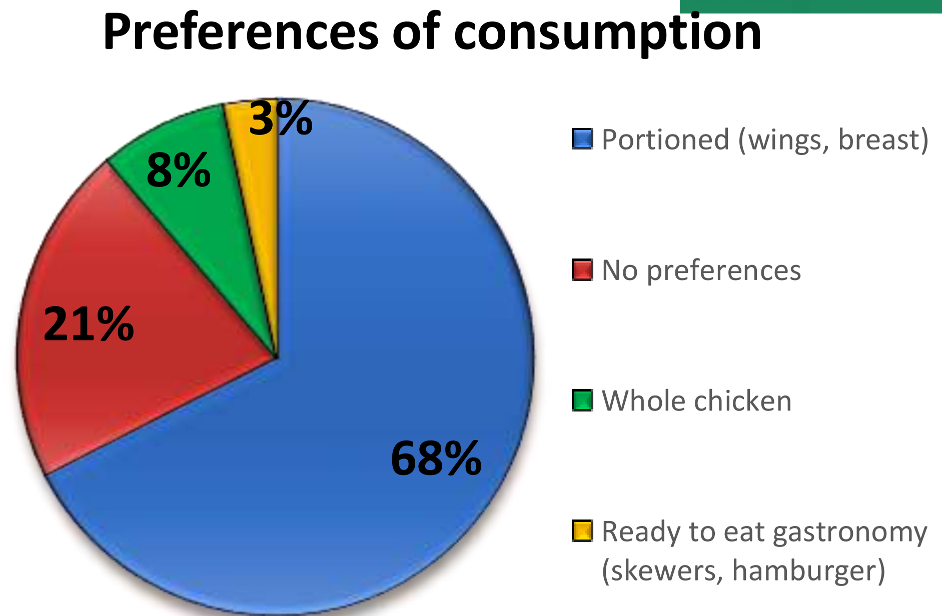


PURCHASE CHANNEL

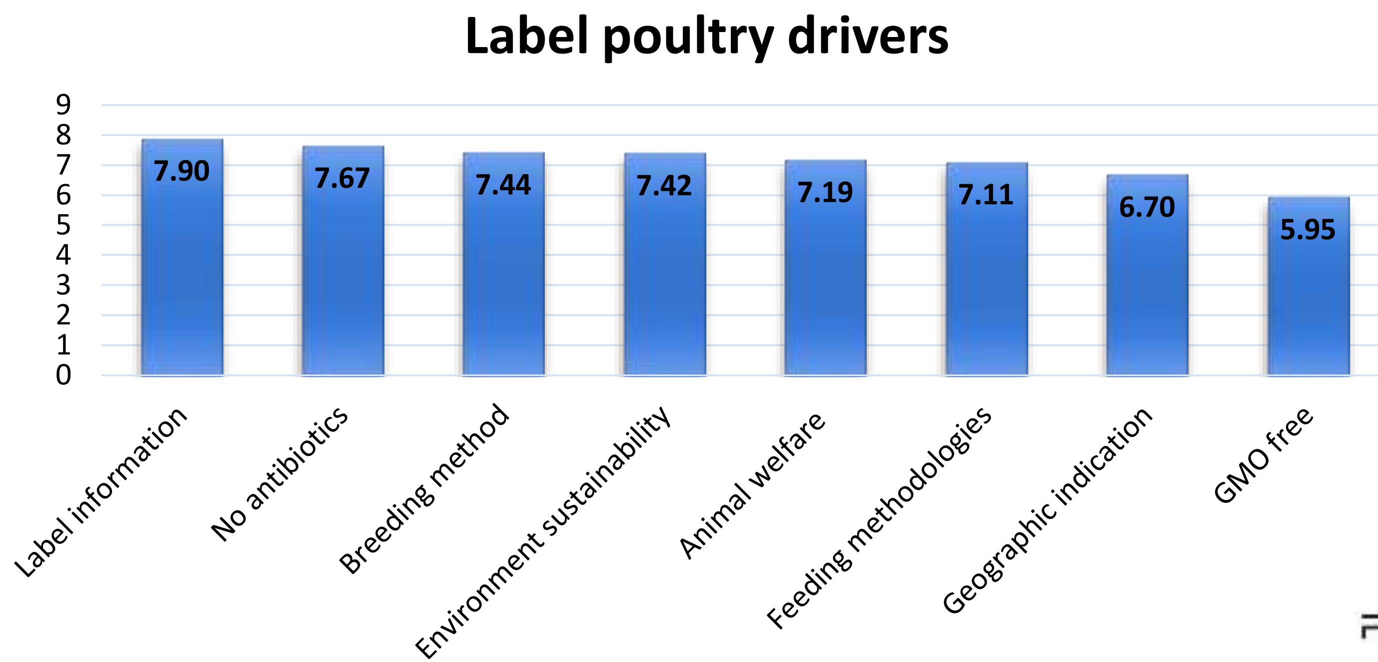




Type of chicken
Commercial chicken
No preferences
Free-range chicken
Organic chicken
31%
27%
24%
18%



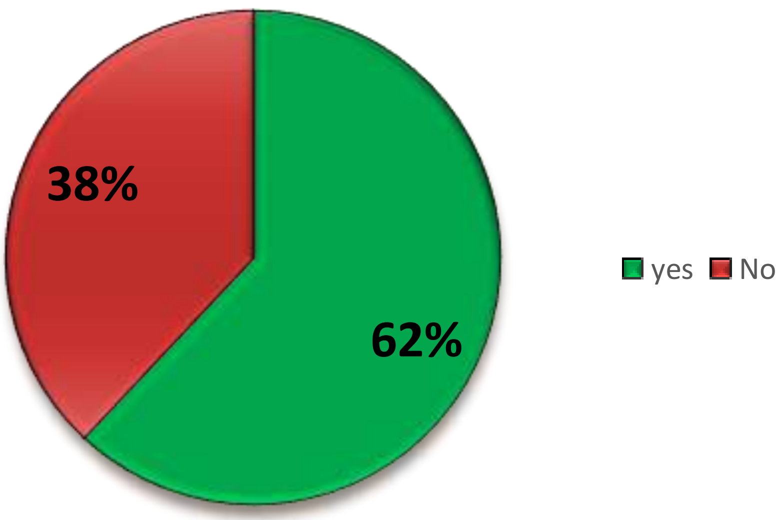
Preferences of consumption
Portioned (wings, breast)
No preferences
Whole chicken
Ready to eat gastronomy (skewers, hamburger)
68%
21%
8%
3%



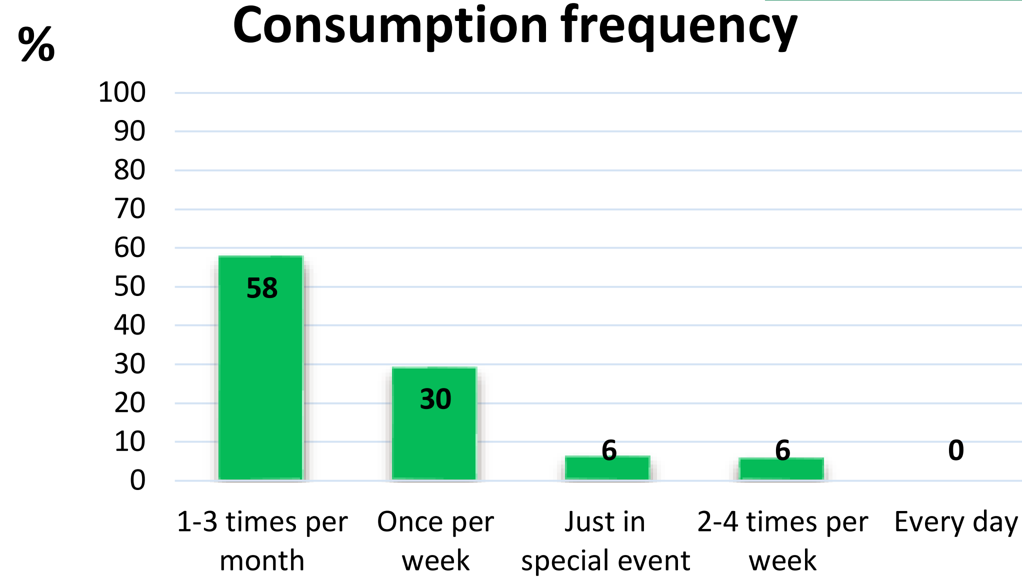
Label poultry drivers
9
8
7
6
5
4
3
2
1
0
7.90
7.67
7.44
7.42
7.19
7.11
6.70
5.95
Label information
No antibiotics
Breeding method
Environment sustainability
Animal welfare
Feeding methodologies
Geographic indication
GMO free

RESULTS
(Organic poultry consumption)

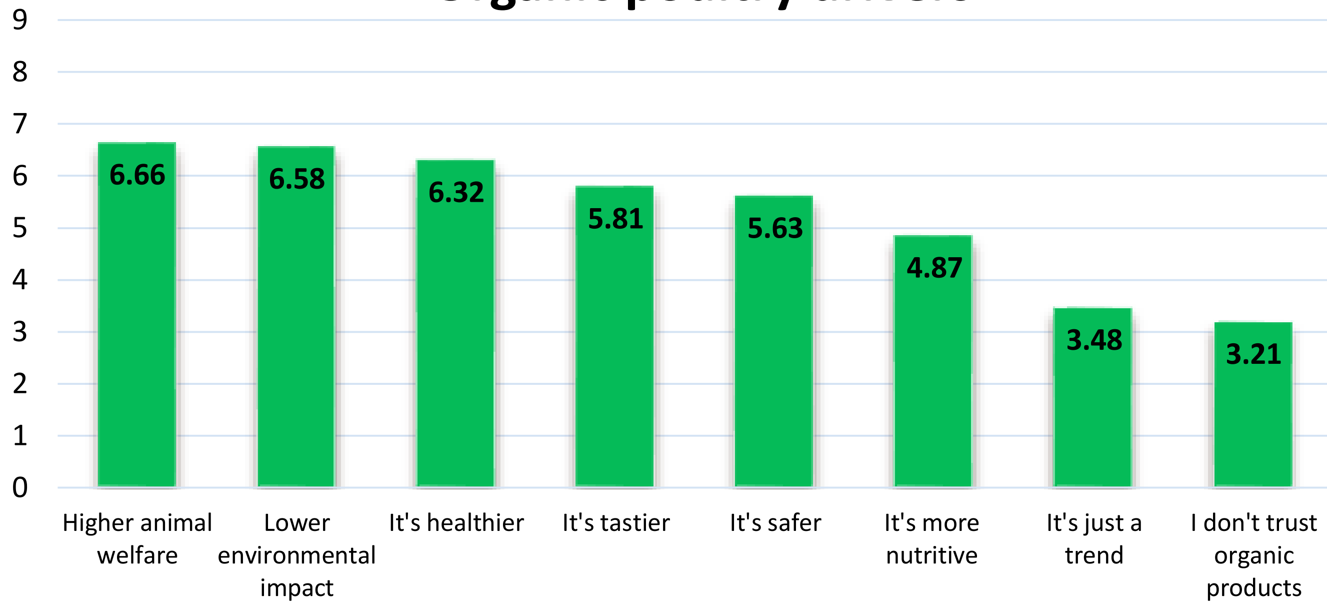
Organic poultry consumption

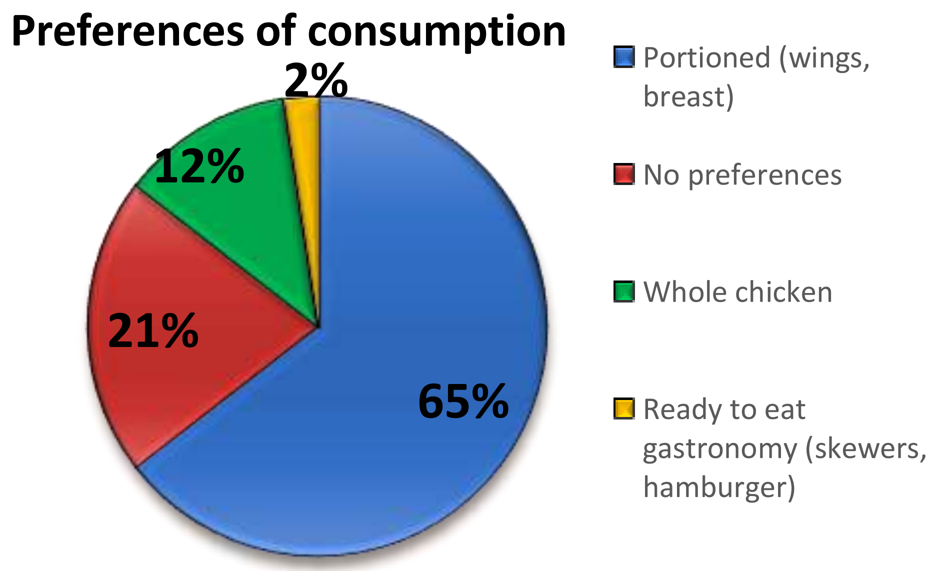


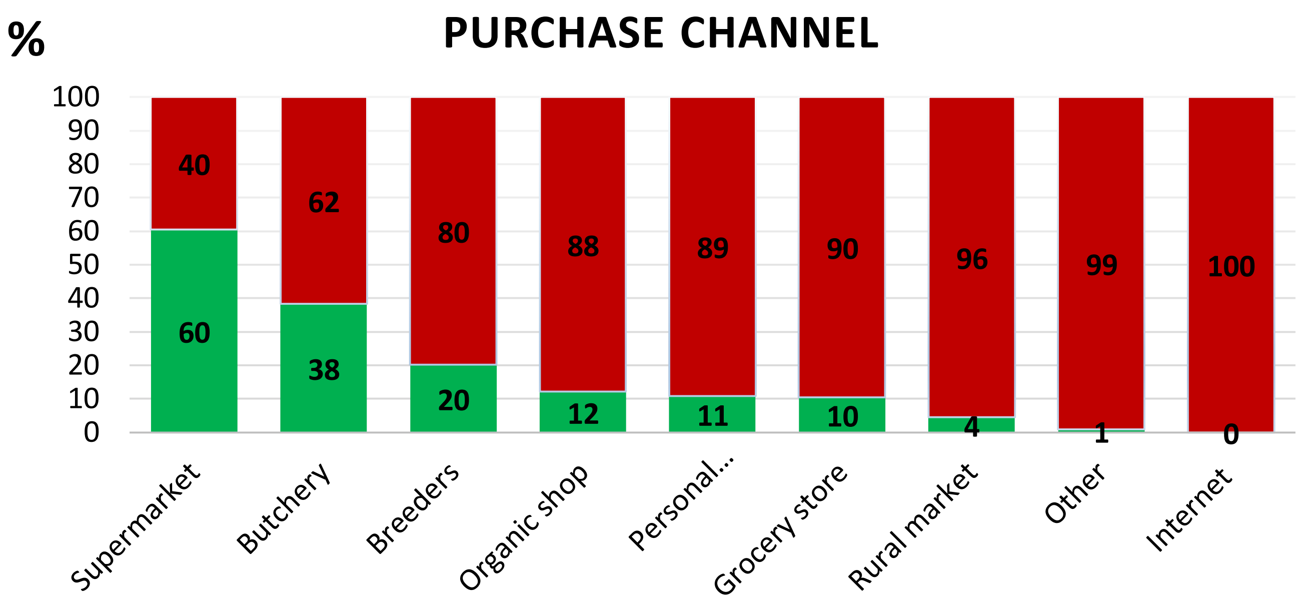
Consumption frequency



Organic poultry drivers



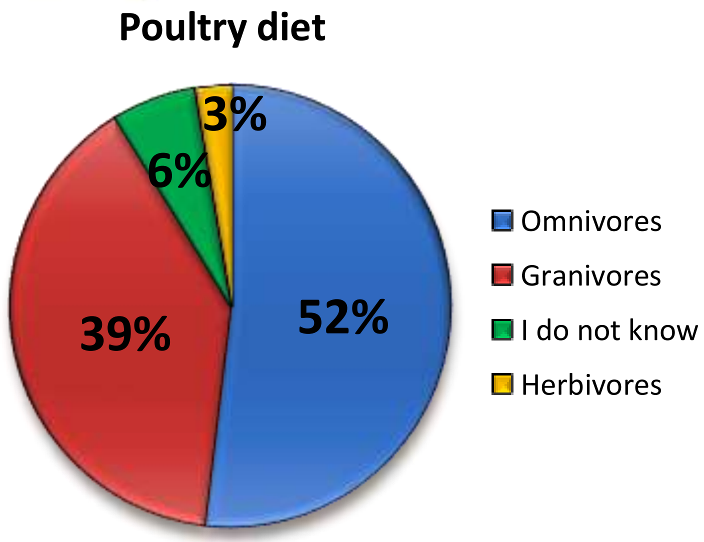

Preferences of consumption
2%
12%
21%
65%
Portioned (wings, breast)
No preferences
Whole chicken
Ready to eat gastronomy (skewers, hamburger)

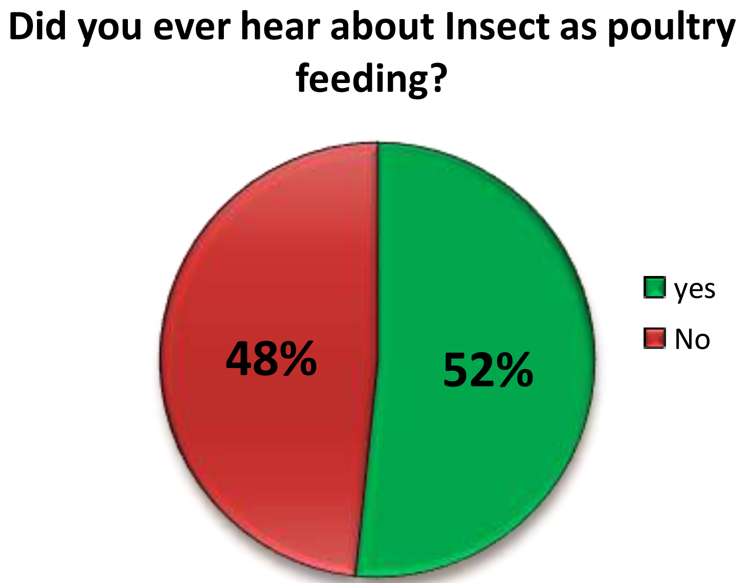

%
PURCHASE CHANNEL
100
90
80
70
60
50
40
30
20
10
0
40
60
62
38
80
20
88
12
89
11
90
10
96
4
99
1
100
0
Supermarket
Butchery
Breeders
Organic shop
Personal...
Grocery store
Rural market
Other
Internet

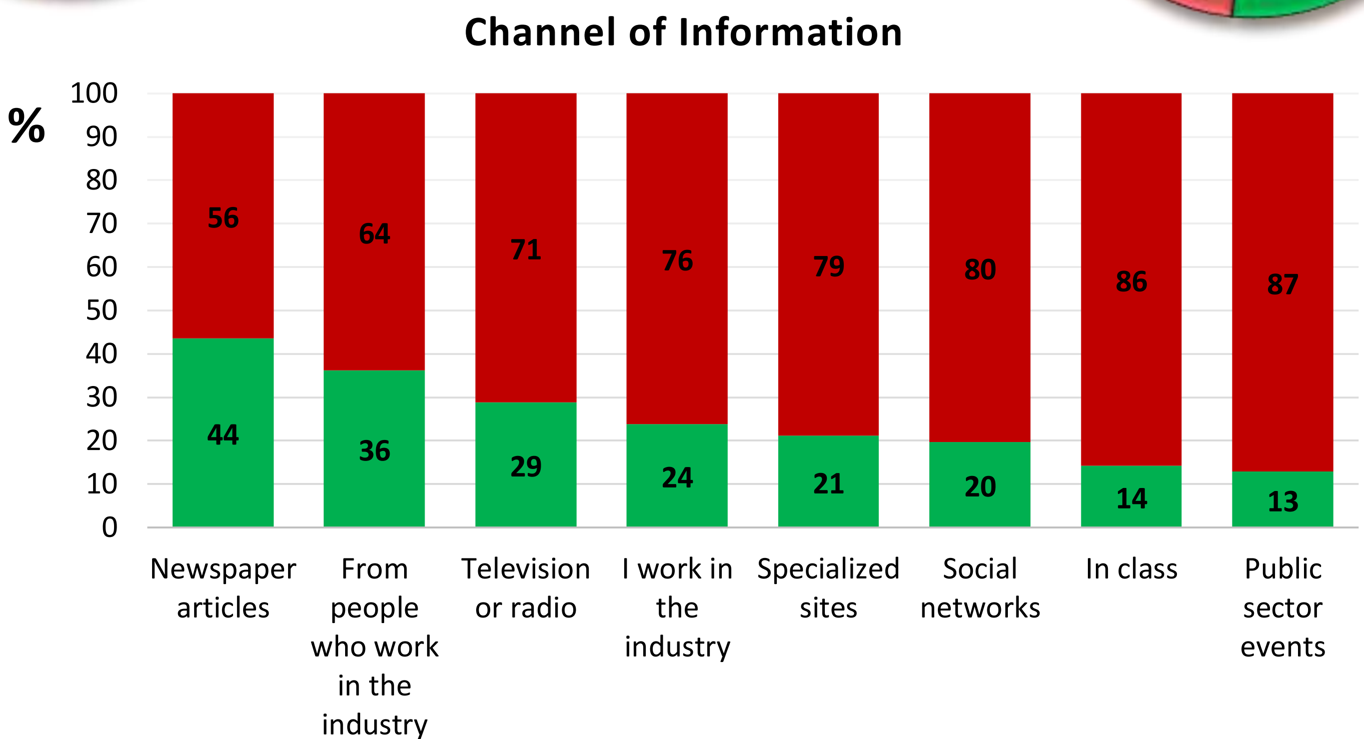
RESULTS

(Insect as poultry feeding)

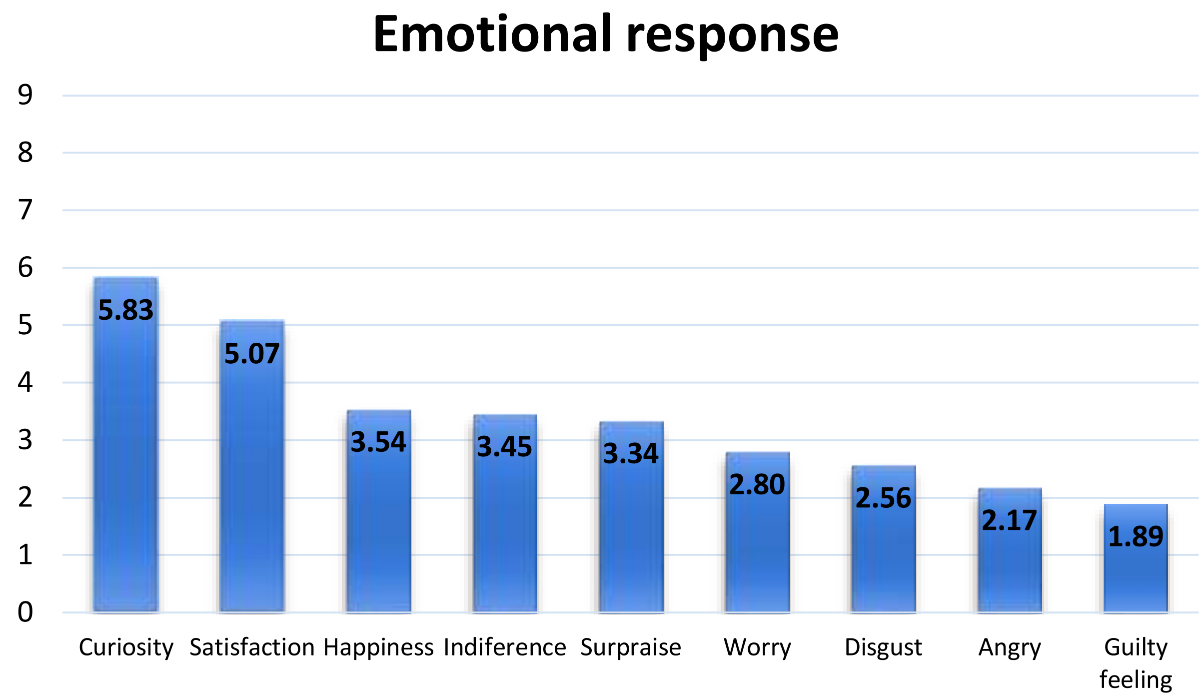
Awareness

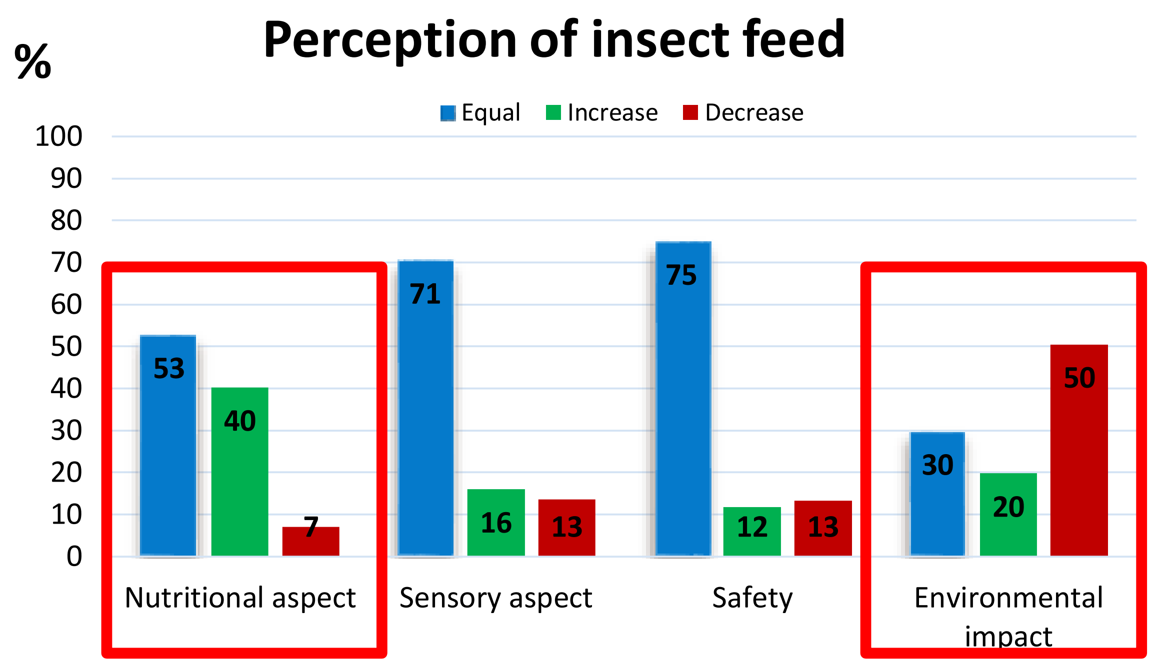


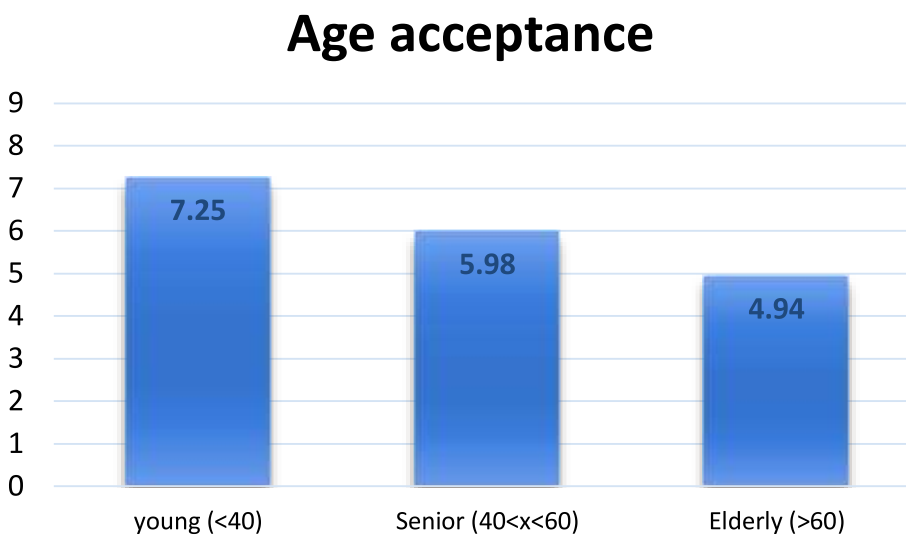


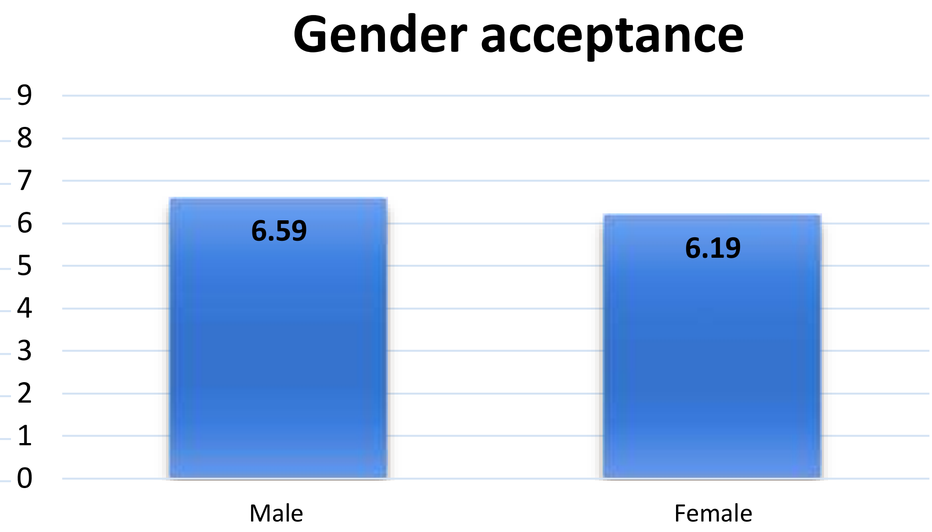


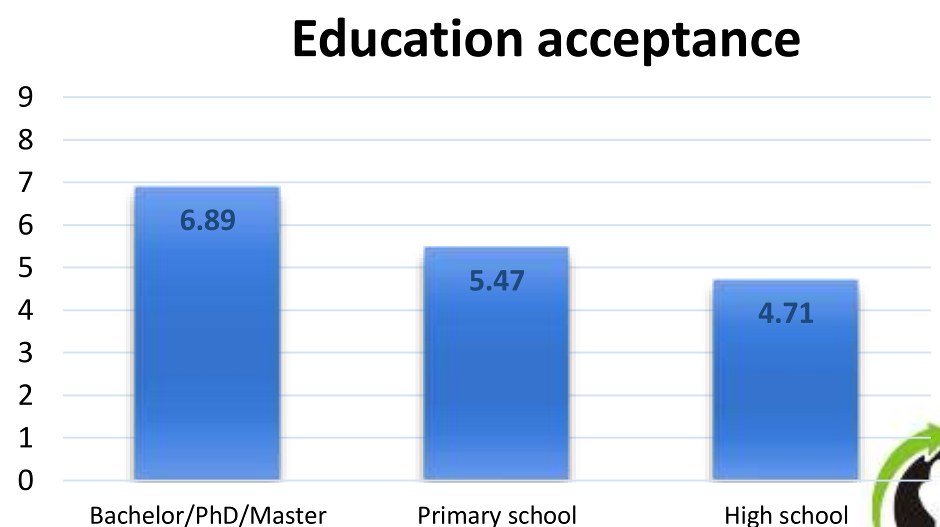
POULTRYNSECT


Emotional response
9
8
7
6
5
4
3
2
1
0
5.83
5.07
3.54
3.45
3.34
2.80
2.56
2.17
1.89
Curiosity
Satisfaction
Happiness
Indiference
Surpraise
Worry
Disgust
Angry
Guilty feeling


Perception of insect feed
%
Equal
Increase
Decrease
100
90
80
70
60
50
40
30
20
10
0
53
40
7
71
16
13
75
12
13
30
20
50
Nutritional aspect
Sensory aspect
Safety
Environmental impact

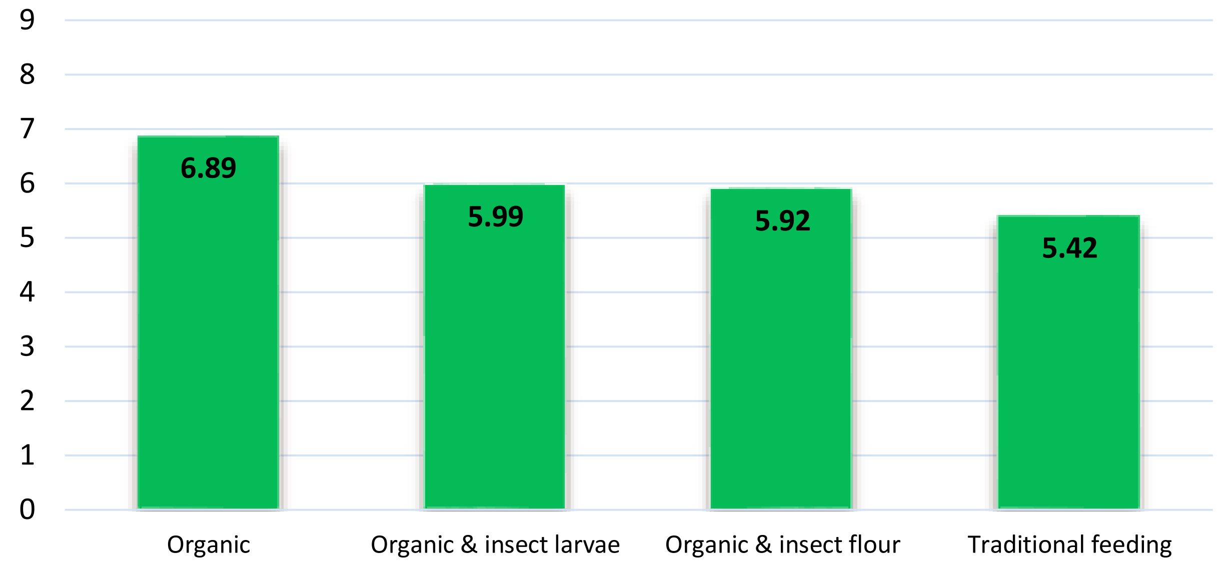




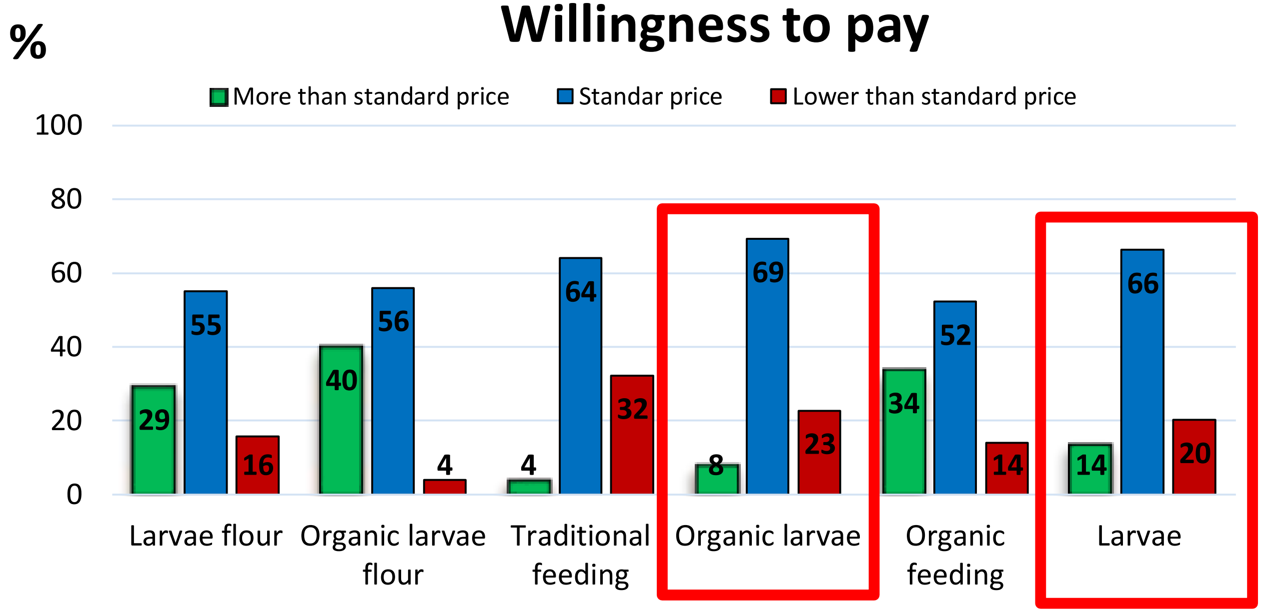


Total acceptance= 6.36

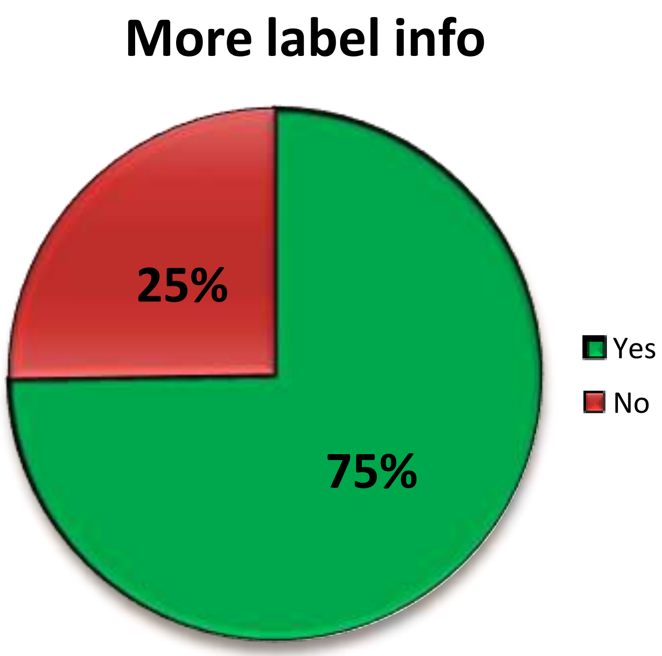
Willingness to buy

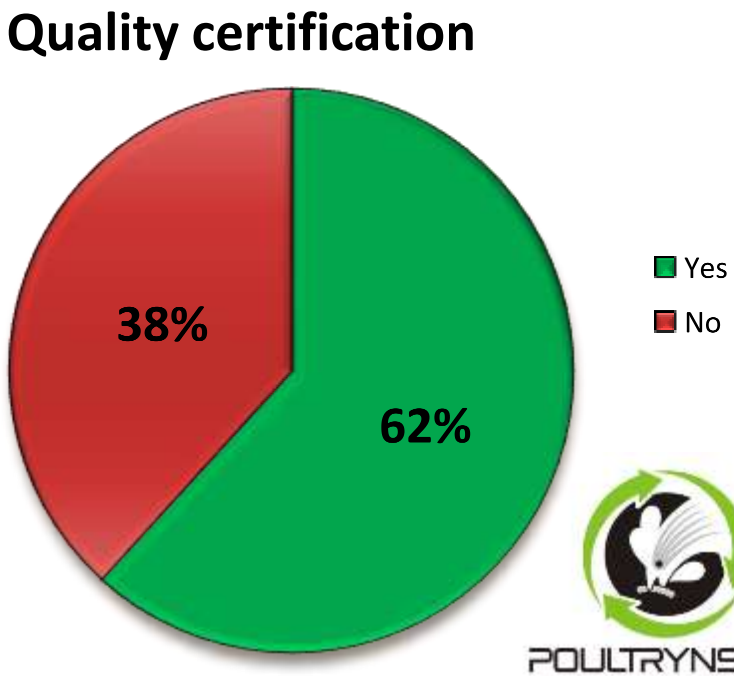


Willingness to pay



What could enhance the acceptance?





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POULTRYNSECT

CORE organic

The use of live insect larvae to improve sustainability and animal welfare of organic chickens production

inagro
ONDERZOEK & ADVIES IN LAND- & TUINBOUW

Consiglio Nazionale delle Ricerche
(Coordinator)

Nofima

DIL

Final Symposium
Rome 27 October 2023

POULTRYNSECT FINAL MEETING
ROME 2023

DIL overview

- Founded 1983
- Employees 200
- Locations Quakenbrück (GER), Brussels (BEL), Karlsruhe (GER), Berlin (GER),
- Legal status registered association

SUSFOOD2

Our members

CORE organic

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Sustainability

The quality of being able to continue over a period of time

3 pillars of sustainability:

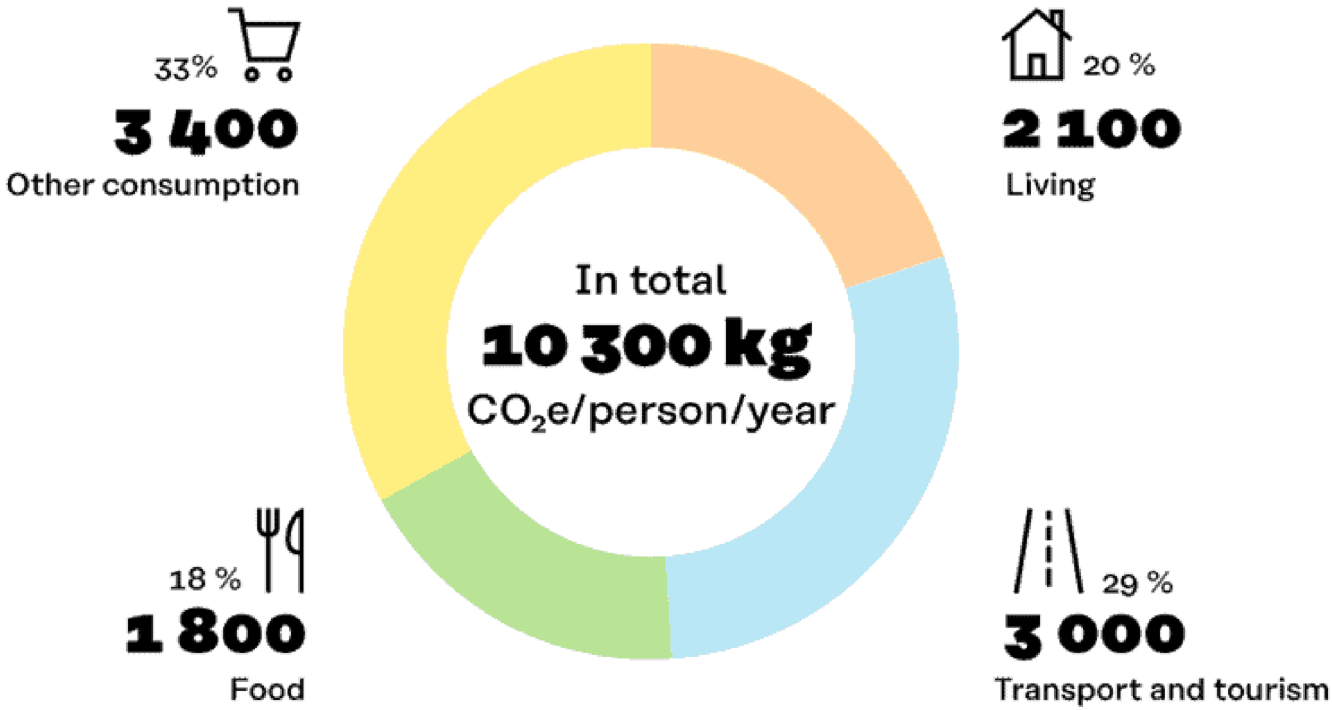
1. Environmental
2. Economical
3. Social

Footprint Analysis
Life cycle assessment

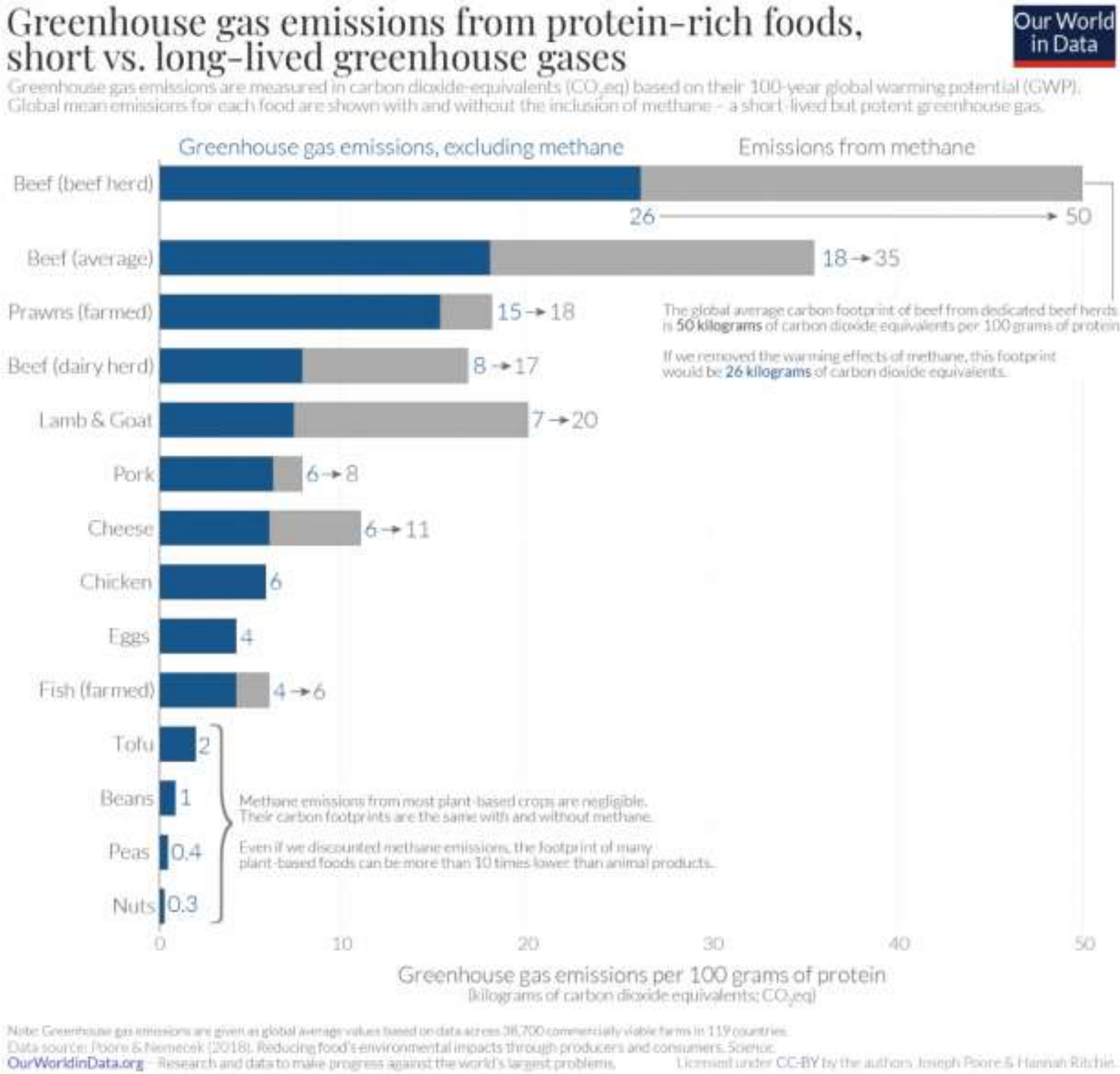
- Objective data about the sustainability of processes and products
- Identification of footprint hotspots within process chains
- Basis for process optimization and transparency

Sustainability of food

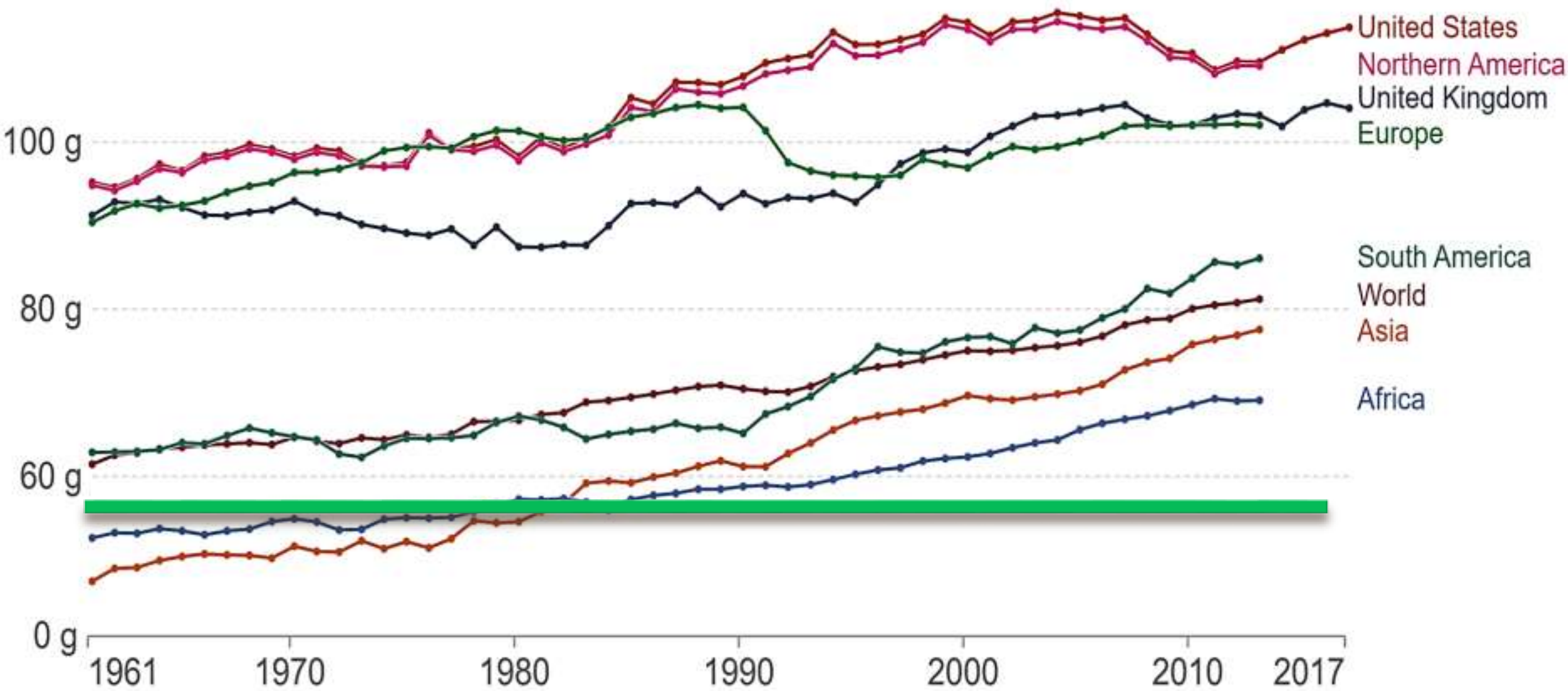
CARBON FOOTPRINT OF THE AVERAGE FINN



Sustainable protein



Daily protein supply



Requirements in proteins:

0.8 g kg^{-1} body weight = 45-46 g to 55-56 g daily for adult women and men respectively (WHO, 2007)

Real consumption: In 2013 globally 81.3 g daily per capita

What are we hoping for

Change that can be accepted

1. Local chicken breed
2. High-quality meat
3. More sustainable

Chicken or egg?
Goal and scope

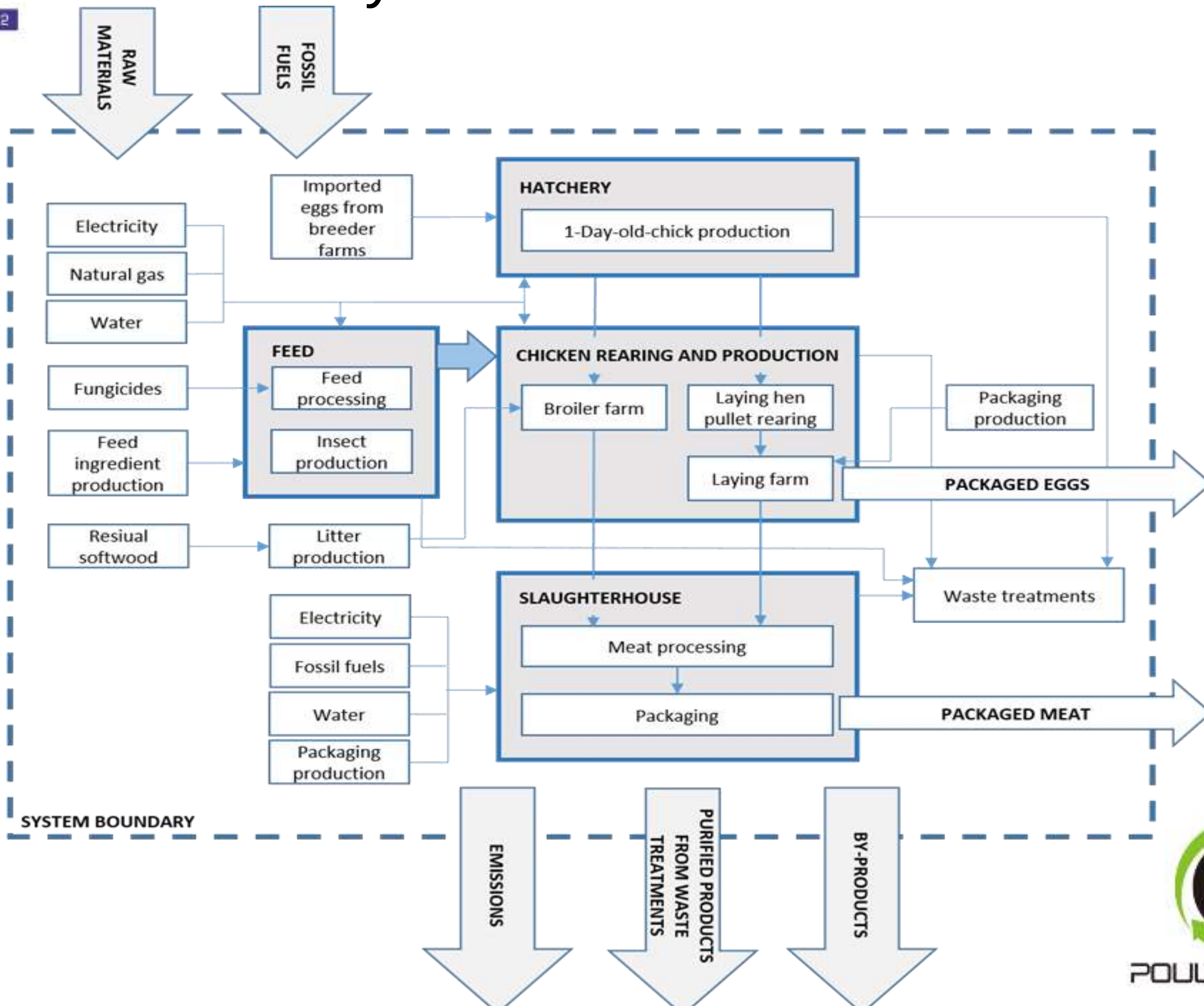
Environmental impact and efficiency of 2 types of chicken protein production

Estimate the amount of protein produced from feed providing 20t of protein

Further, it was hypothesized that environmental footprint of protein production can be lowered by inclusion of insects into the commercial feed

Insects were considered to be fed on 2 different diets

System boundaries



Inventory analysis

The data were collected from the literature, mostly:

1) Dekker et al. (2011) (Netherlands) for laying hen production and
2) González-García et al. (2014) (Portugal) for broiler production

Calculations were done in SimaPro 8.5.2.0 (PRé Consultants, Netherlands)

Background data were taken from the ecoinvent 3 (ecoinvent, Switzerland) and Agri-footprint (Agri-footprint, Netherlands) database.

Adapted to the DIN EN ISO 14044:2006

Inventory analysis

Methodology - IMPACT 2002+

Two functional units:

1) Protein conversion ratio, FU1 – amount of chicken protein that can be produced with 20t of feed protein.

2) FU2 – estimation of production of 1 kg of chicken protein.

Protein produced

Scenarios		Commercial feed protein (t)	BSFL protein, fed with Gainesville diet (t)	BSFL protein, fed with fruit and vegetable waste (t)	Protein produced (kg)
A	Egg production	20			8,335.75
B	Egg production	18	2		
C	Egg production	18		2	
D	Broiler production	20			9,135.456
E	Broiler production	18	2		
F	Broiler production	18		2	

Protein conversion efficiency: 2.4 for laying hens and 2.24 for broilers.

But not all protein is same…

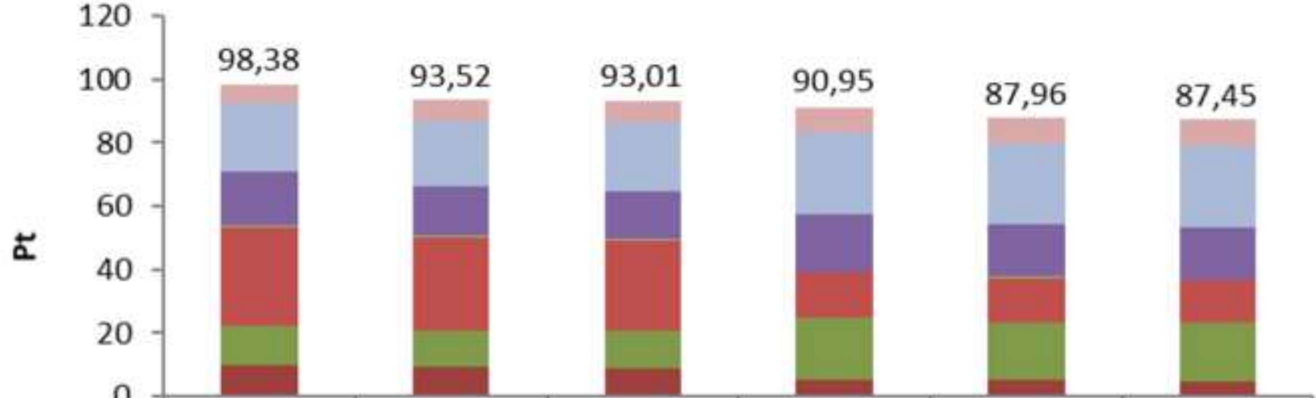
- The quality of protein can be measured by Digestible Indispensable Amino Acid Score (DIAAS)

- Protein quality is determined by amino acid sequence and digestibility

- A DIAAS of 116.4% is given for the whole chicken egg and 108.2% for chicken meat and skin

- Protein conversion efficiency is therefore corrected to 2.06
- in laying hen production and to 2.07 in broiler chicken production.

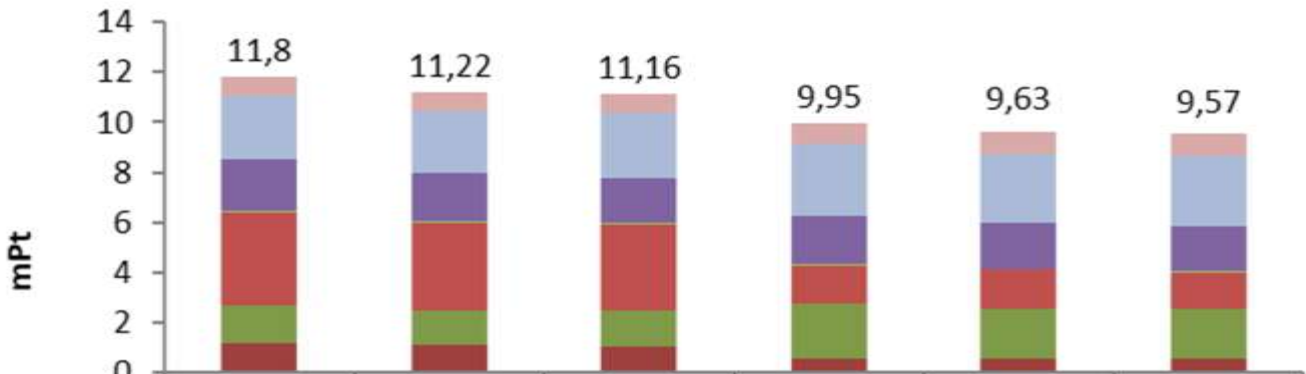
LCA results



	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Scenario F
Non-renewable energy	5.9358	6.325	6.7158	7.6382	8.117	8.5077
Global warming	21.6267	21.022	21.5076	26.0406	25.248	25.7337
Land occupation	16.804	15.6618	15.1724	17.7097	16.7596	16.2703
Terrestrial acid/nutri	0.5376	0.5084	0.4934	0.4345	0.4221	0.4071
Terrestrial ecotoxicity	31.2559	29.2303	28.6297	14.26	14.0222	13.4216
Respiratory inorganics	12.4206	11.6928	11.5668	19.6196	18.3642	18.2382
Non-carcinogens	9.4004	8.7037	8.5412	4.5695	4.3874	4.2249
Carcinogens	0.3966	0.3762	0.3853	0.6763	0.6412	0.6502

Comparing processes; FU1: use of 20 t of feed protein
Method: IMPACT 2002+ V2.14 / IMPACT 2002+ / Single score

LCA results



	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Scenario F
Non-renewable energy	0.712	0.7588	0.8057	0.8361	0.8885	0.9313
Global warming	2.5944	2.5219	2.5802	2.8505	2.7637	2.8169
Land occupation	2.0159	1.8789	1.8202	1.9386	1.8346	1.781
Terrestrial acid/nutri	0.0645	0.061	0.0592	0.0476	0.0462	0.0446
Terrestrial ecotoxicity	3.7496	3.5066	3.4346	1.5609	1.5349	1.4692
Respiratory inorganics	1.49	1.4027	1.3876	2.1476	2.0102	1.9964
Non-carcinogens	1.1277	1.0441	1.0246	0.5002	0.4803	0.4625
Carcinogens	0.0476	0.0451	0.0462	0.074	0.0702	0.0712

Comparing processes; FU2: 1 kg produced chicken protein
Method: IMPACT 2002+ V2.14 / IMPACT 2002+ / Single score

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Conclusions

- Laying hen production achieved higher single score results than broiler production
- The production of feed has by far the largest share of the environmental impact of the entire production
- Decrease of environmental impact due to the introduction of larvae:

Decrease in environmental impact achieved by introduction of HI larvae into the diet of:	Larvae fed on Gainesville diet	Larvae fed on fruit and vegetable waste
Laying hens	5%	5.50%
Broilers	3.30%	3.80%

16 (2022) 200121

Contents lists available at ScienceDirect

Resources, Conservation & Recycling Advances

journal homepage: www.sciencedirect.com/journal/Resources-Conservation-and-Recycling-Advances

Eggs or meat? Environmental impact and efficiency assessment of chicken protein production with potential of *Hermetia illucens* use in feed

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ARTICLE INFO

Keywords:
Broiler
Laying hen
BSF
Life cycle assessment
Protein conversion efficiency
Insects in feed

ABSTRACT

This study presents a life cycle assessment (LCA) comparing laying hen to broiler chicken production. Sustainability and protein conversion efficiency are considered. The protein-to-protein conversion was calculated per 1t of feed protein consumed by birds and per 1 kg of protein in end products for human consumption. Additionally, a part of the commercial feed was replaced by live black soldier fly larvae, reared on Gainesville diet, and fruit and vegetable waste (FVW). Results of the LCA showed significant differences in integrated impacts between different production systems and different chicken feeds but not between different insect feeds. The most environmentally friendly scenario is insect (FVW) fed broiler. In protein conversion efficiency (PCE) assessment, laying hen production achieved better PCE than broiler chicken when protein quality is considered. Main influencing factors on results were feed production, composition, and protein content. Due to many assumptions made, results should be viewed critically.

1. Introduction

The food sector is facing a challenging future. According to UN DESA (2019), the world's population is expected to rise from 7.7 billion people

In poultry farming, the feed production is especially climate-intensive. Above all feed processing requirements, the feed ingredient production has the most damaging effect on the environment (Bengtsson and Seddon, 2013; González-García et al., 2014; López-Andrés et al.,

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Experimental setup

- The slow-growing Label Naked Neck chicken variety

- 2 experimental groups based on feed:
  1) reared on commercial organic feed with the inclusion of 10% Hermetia Illucens larvae into feed (BSFL)

  2) reared only on commercial organic feed.

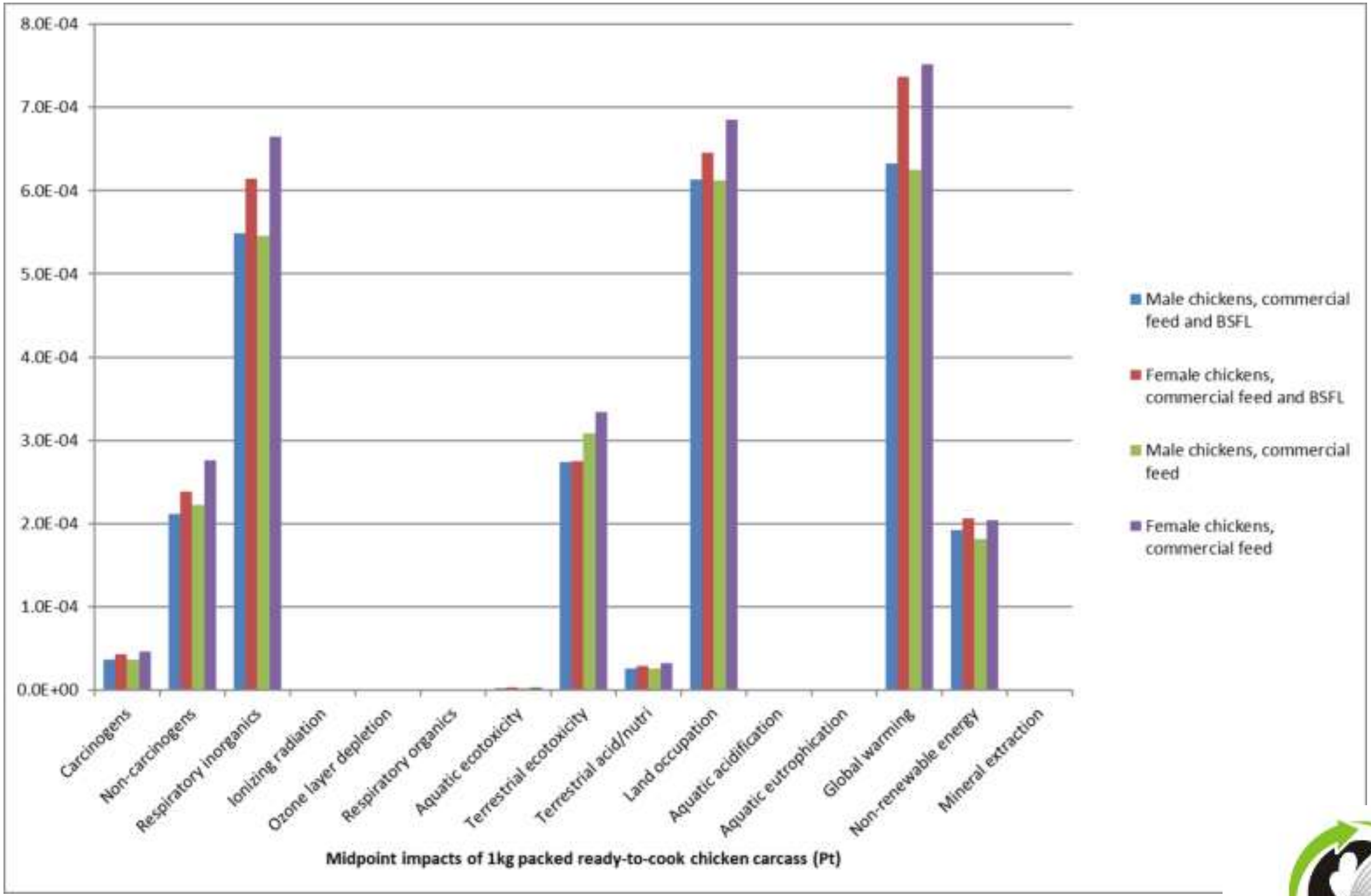
Goal and scope

- Modular and attributional life cycle assessment (LCA) was developed to assure a structured and quantitative approach
- Experimental data collected from the project partners, partly extended by the background data and data from the literature
- Cradle-to-slaughterhouse gate perspective with further extensions to waste treatments, thus including feed production, larvae production, hatchery, poultry production, and slaughterhouse

Inventory Analysis

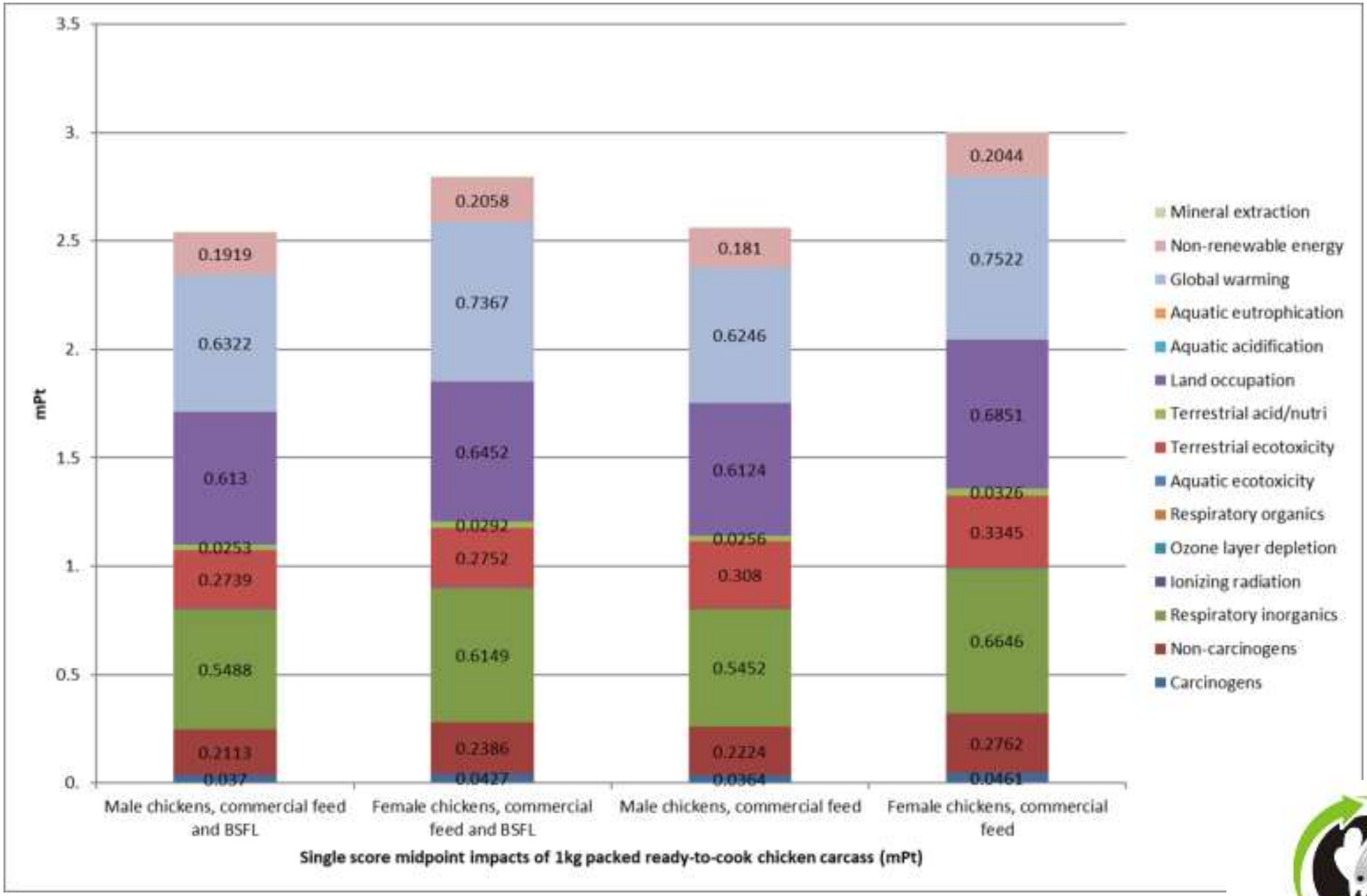
- The results are based on experimental data collected from the project partners, partly extended by the background data and data from the literature
- Calculations were done in SimaPro 8.5.2.0 (PRé Consultants, Netherlands)
- Background data were taken from the ecoinvent 3 (ecoinvent, Switzerland) and Agri-footprint (Agri-footprint, Netherlands) databases.
- Methodology - IMPACT 2002+
- 1kg of packed ready-to-cook chicken carcass was the functional unit

LCA results



8.0E-04
7.0E-04
6.0E-04
5.0E-04
4.0E-04
3.0E-04
2.0E-04
1.0E-04
0.0E+00
Carcinogens
Non-carcinogens
Respiratory inorganics
Ionizing radiation
Ozone layer depletion
Respiratory organics
Aquatic ecotoxicity
Terrestrial ecotoxicity
Terrestrial acid/nutri
Land occupation
Aquatic acidification
Aquatic eutrophication
Global warming
Non-renewable energy
Mineral extraction
Midpoint impacts of 1kg packed ready-to-cook chicken carcass (Pt)
Male chickens, commercial feed and BSFL
Female chickens, commercial feed and BSFL
Male chickens, commercial feed
Female chickens, commercial feed

LCA results



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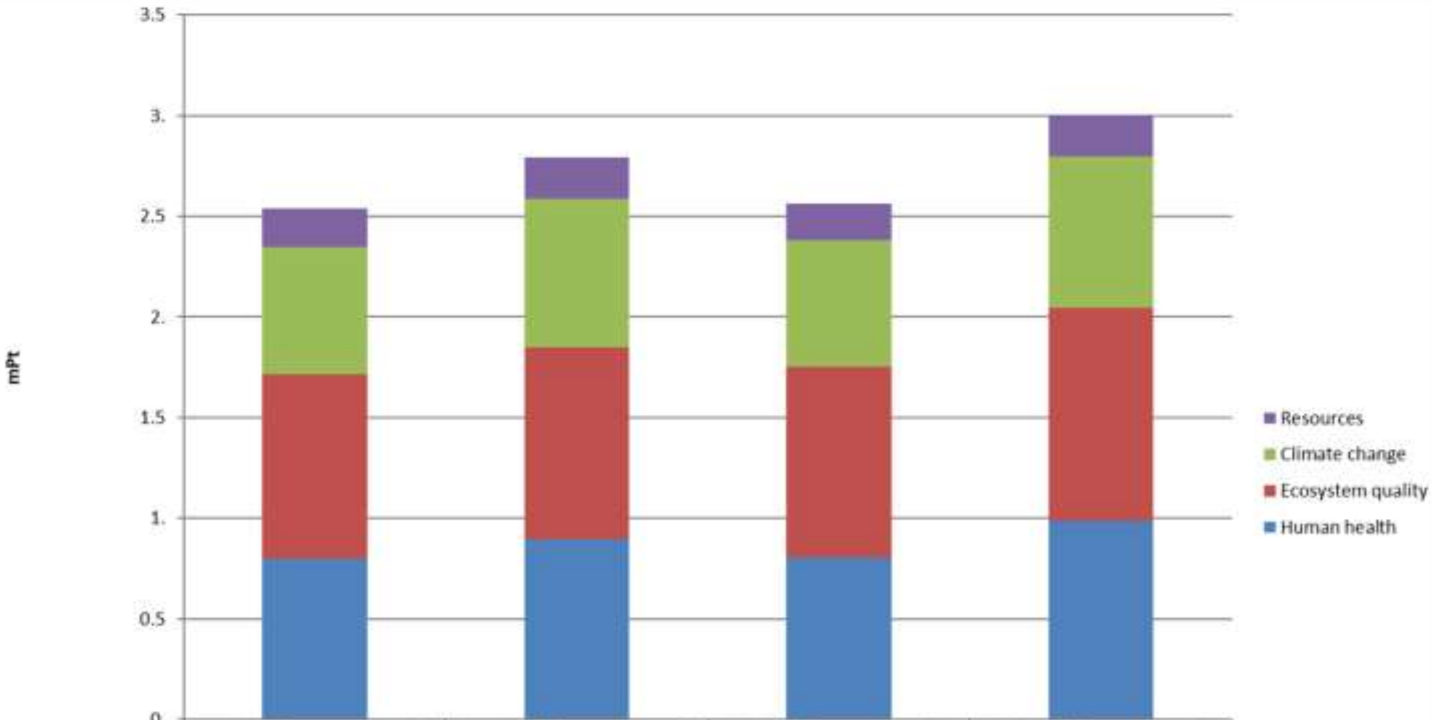
LCA results



	Male chickens, commercial feed and BSFL	Female chickens, commercial feed and BSFL	Male chickens, commercial feed	Female chickens, commercial feed
Resources	0.1925	0.2065	0.1817	0.2051
Climate change	0.6322	0.7367	0.6246	0.7522
Ecosystem quality	0.9147	0.9523	0.9486	1.0553
Human health	0.7983	0.8974	0.805	0.9882

Single score endpoint impacts of 1kg packed ready-to-cook chicken carcass (mPt)

POULTRYNSECT

Conclusions

- The inclusion of 10% of larvae into chicken feed did not lead to significant environmental gains
- The difference in impacts can be observed between the sexes
- Better results might be expected if insect feed were adjusted to overproduced fruits and vegetables, and if the portion of BSFL in broilers' diets were increased

Life Cycle Costing

- Life cycle costing is the process of compiling all costs incurred throughout a product's life cycle.
- Life Cycle Costing compares the economic efficiency and economic sustainability of products
- The system boundaries remained the same as for LCA

Life Cycle Costing

The modeled product was 1 kg of packed ready-to-cook chicken carcass

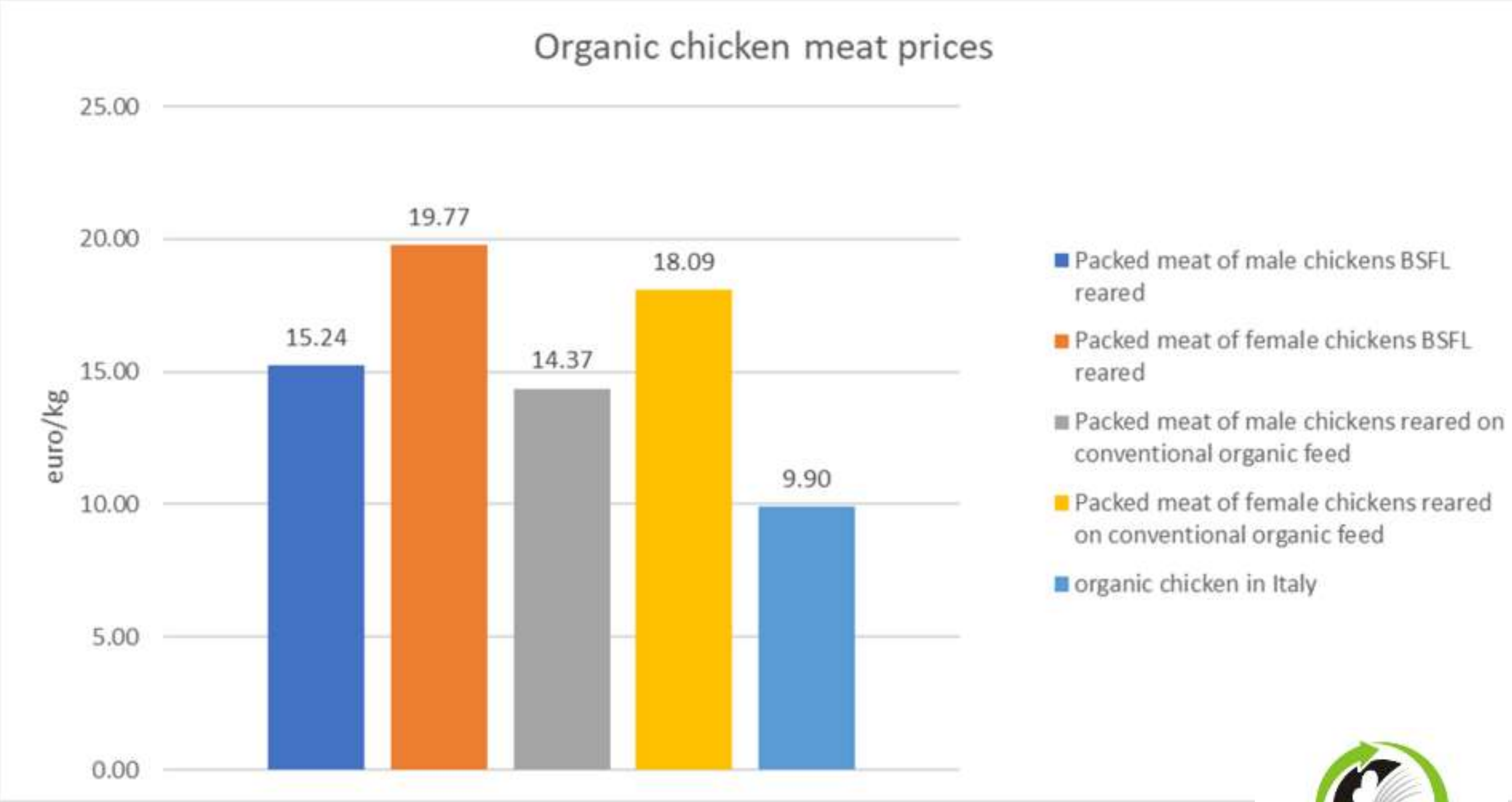
The profit of the bird-rearing company was not included in the analysis

Major changes in the market in the last two years

Availability and prices (particularly of feed and energy) kept changing

High inflation

Life Cycle Costing



Life Cycle Costing

20% cost difference between the sexes

Almost 10% cost increase with the addition of the BSFL

Highest contribution coming from labor (over 50%), followed by the feed

Increase in scale might help

SLCA What did we assess

Same modeled farm(s)

Due to the size of the farm, we focused on workers as the main stakeholders

Focus was on changes that can be expected with inclusion of insects (per example, slaughterhouse is excluded)

Social

The starting relevant themes as well as the grading system were taken from Pelletier, N. (2018). (https://www.mdpi.com/2071-1050/10/5/1601)

Fair wage potential was calculated per Neugebauer, S. et al. (2016). (https://www.sciencedirect.com/science/article/abs/pii/S0959652616320340?via%3Dihub)

Social Assessment Matrix - Grading system

5 – Not assessed (questionable sources)

4 – Risky

3 – Compliant

2 – Proactive

1 – Committed

Social Assessment Matrix

	insect farm		chicken farm			
	predominantly manual	automated	predominantly manual		automated	
			insects included	control	insects included	control
Health and Safety	3	2	3	2.5	2.5	2
Fair wage potential	2.42	2	2.42	2.42	2	2
Freedom of Association and Collective Bargaining	small, likely family farm, and therefore not relevant					
Child Labour						
Working Hours	3	1	3	3	2	2
Equal opportunities/Discrimination	3	2	3	3	2	2
Forced Labour	3	1	no difference introduced by insects expected			
Social Benefits/Social Security	3	3				
overall	2.90	1.83	2.85	2.73	2.13	2

Social LCA, conclusions

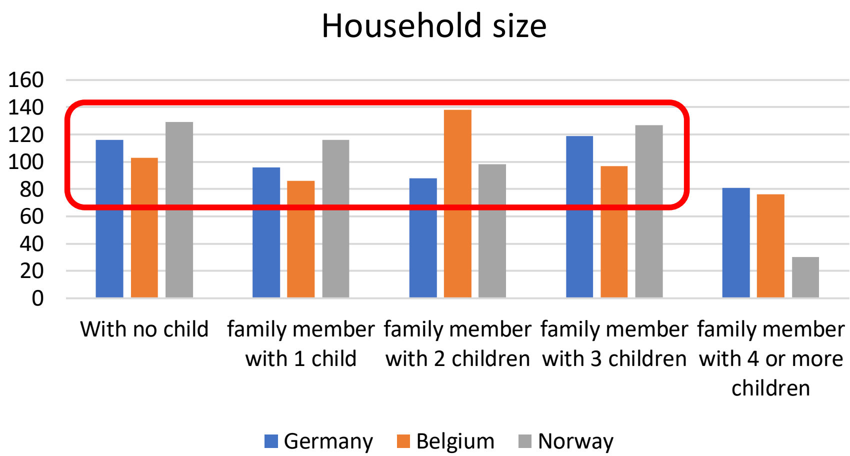
Automation can improve social sustainability scores of both insect and chicken farming

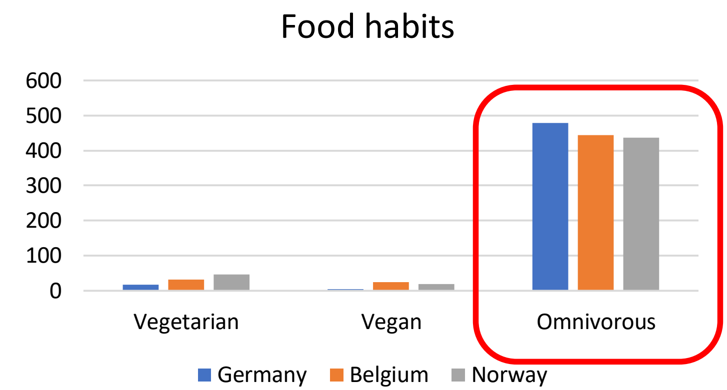
The inclusion of insects into chicken feed represents an allergenicity risk

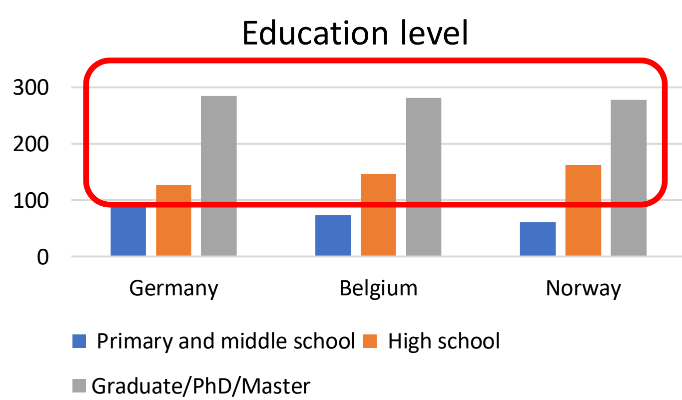
Consumer study

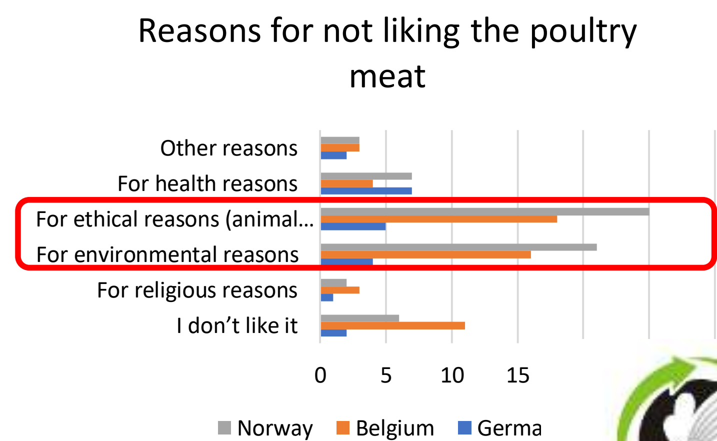
- In 2023 (July-September)
- Germany, Norway, Belgium (Italy)
- 500 respondents in each country
- Attitude to consuming poultry, organic poultry, organic poultry fed on insect larvae

General information

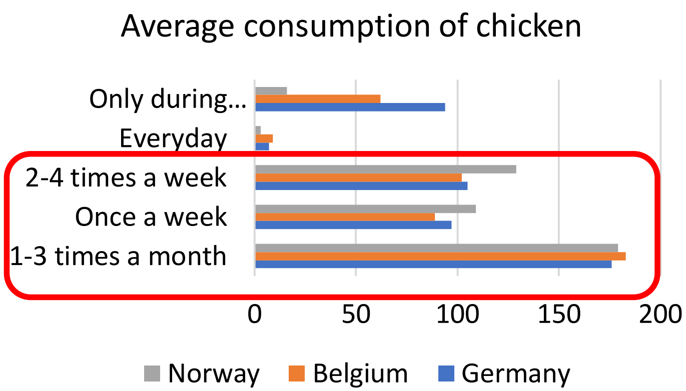


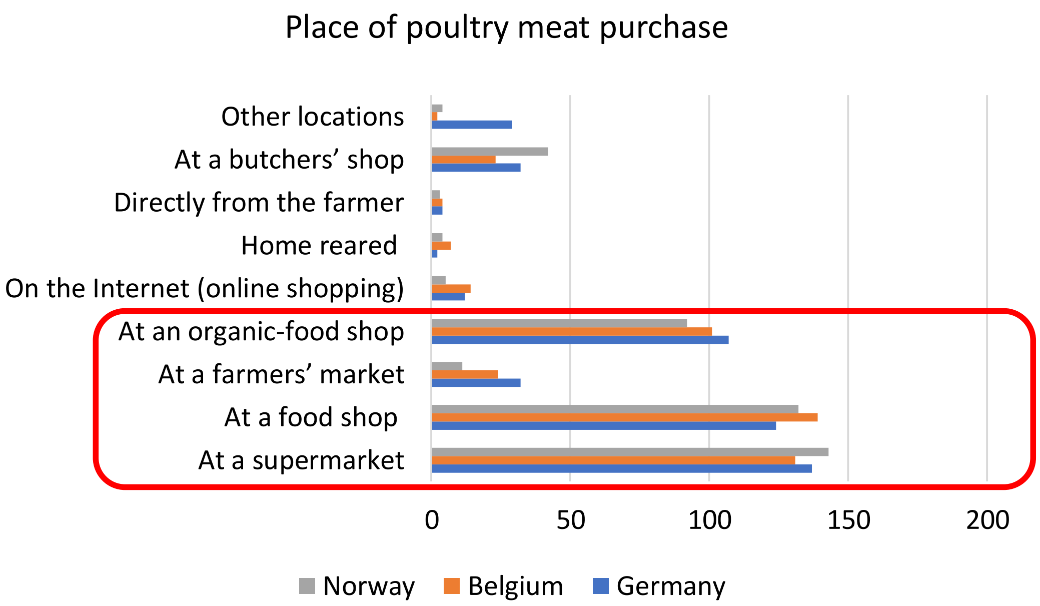


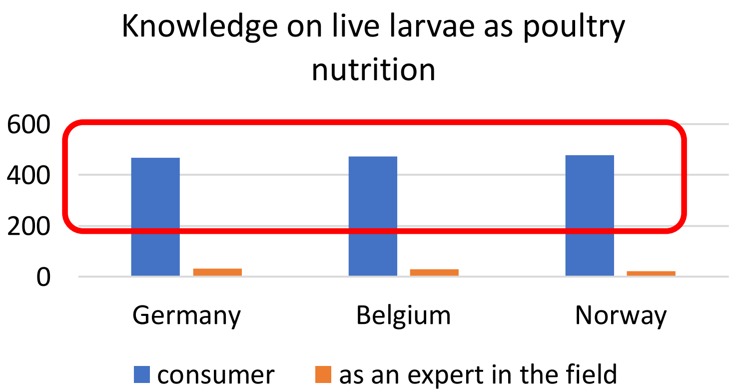




Relation to chicken meat and larvae

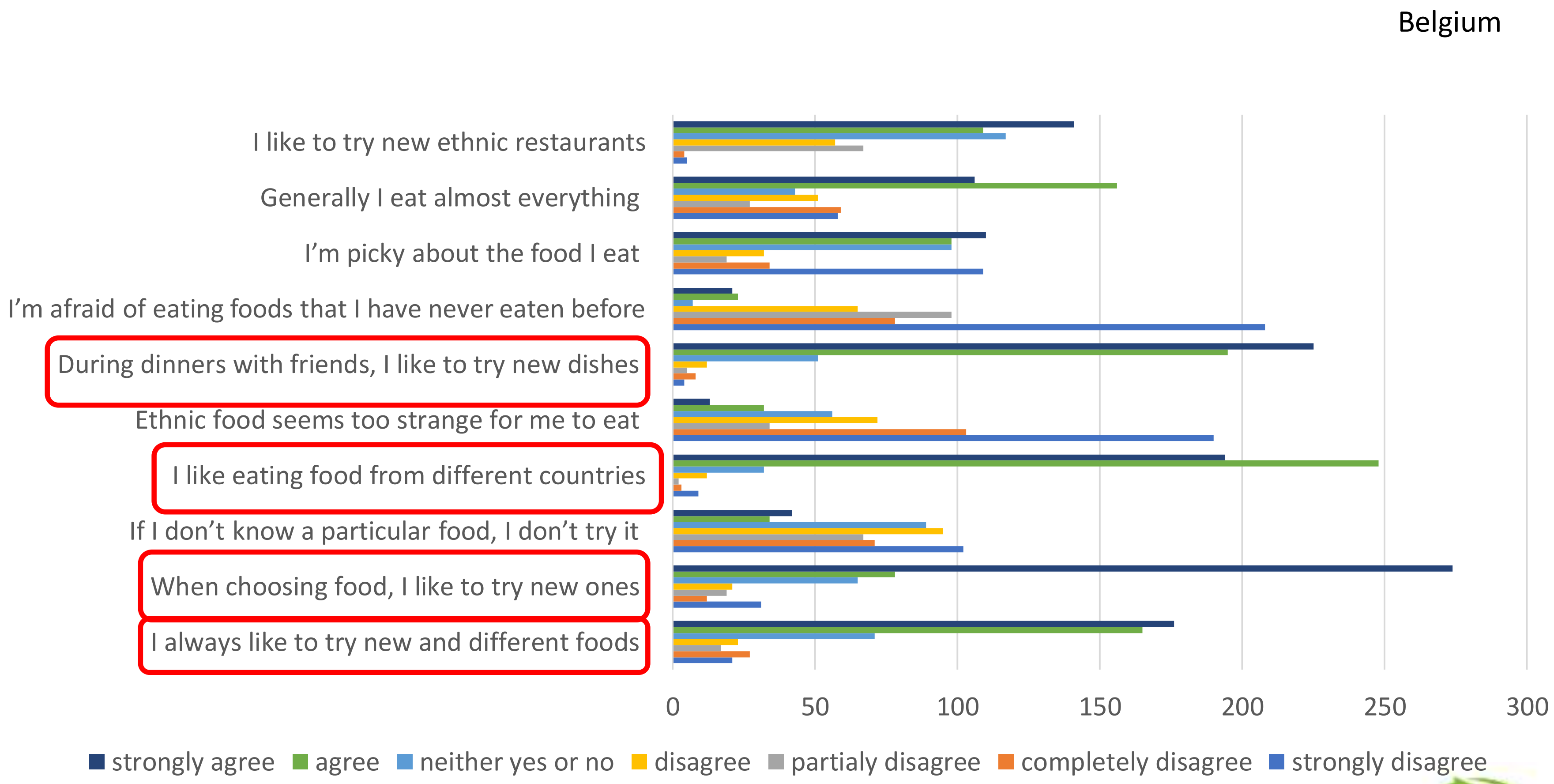






Consumers' consumption preference

Consumers' consumption preference

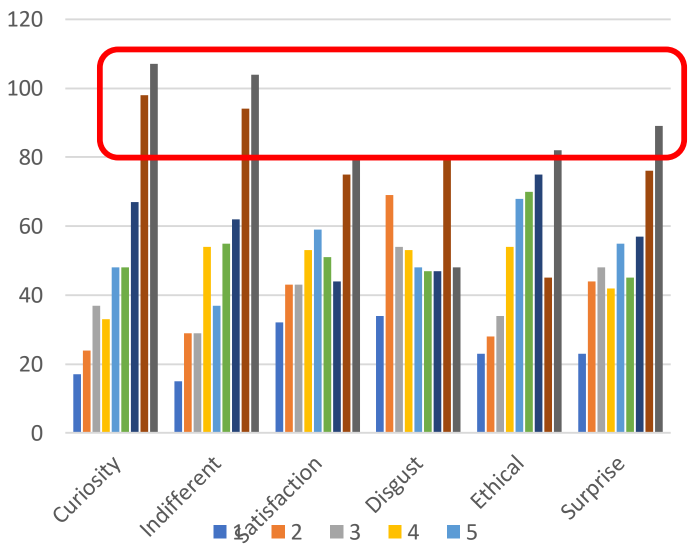


Consumers' consumption preference

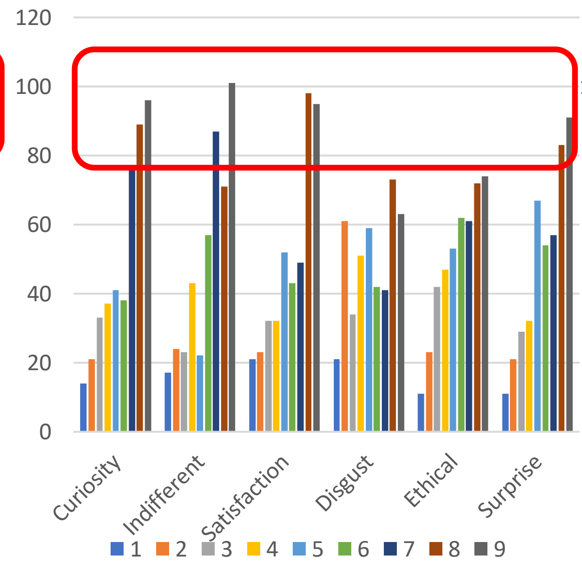
Reason for trying insect-fed poultry

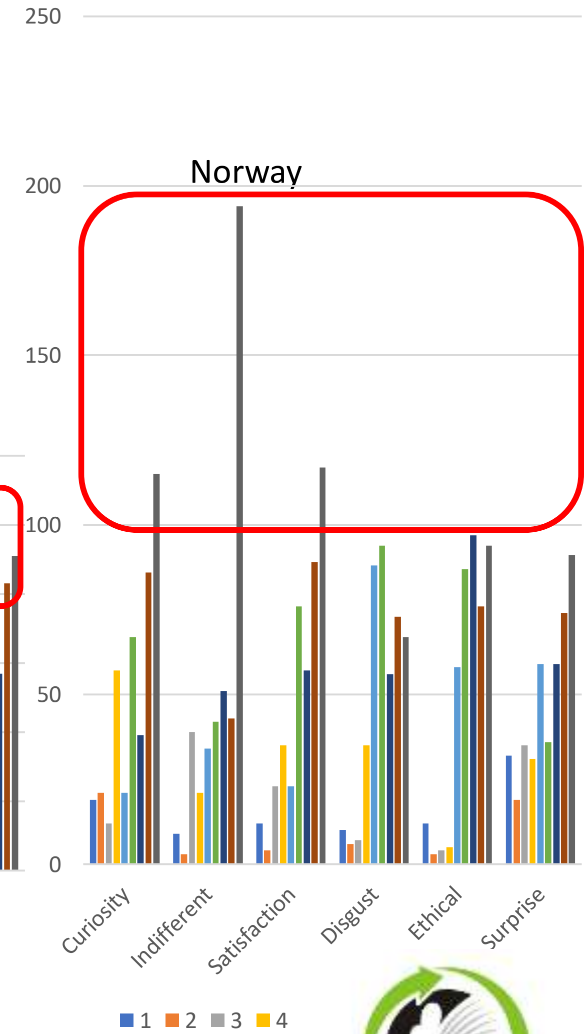
(1-highly disagree, 9-highly agree)

Germany

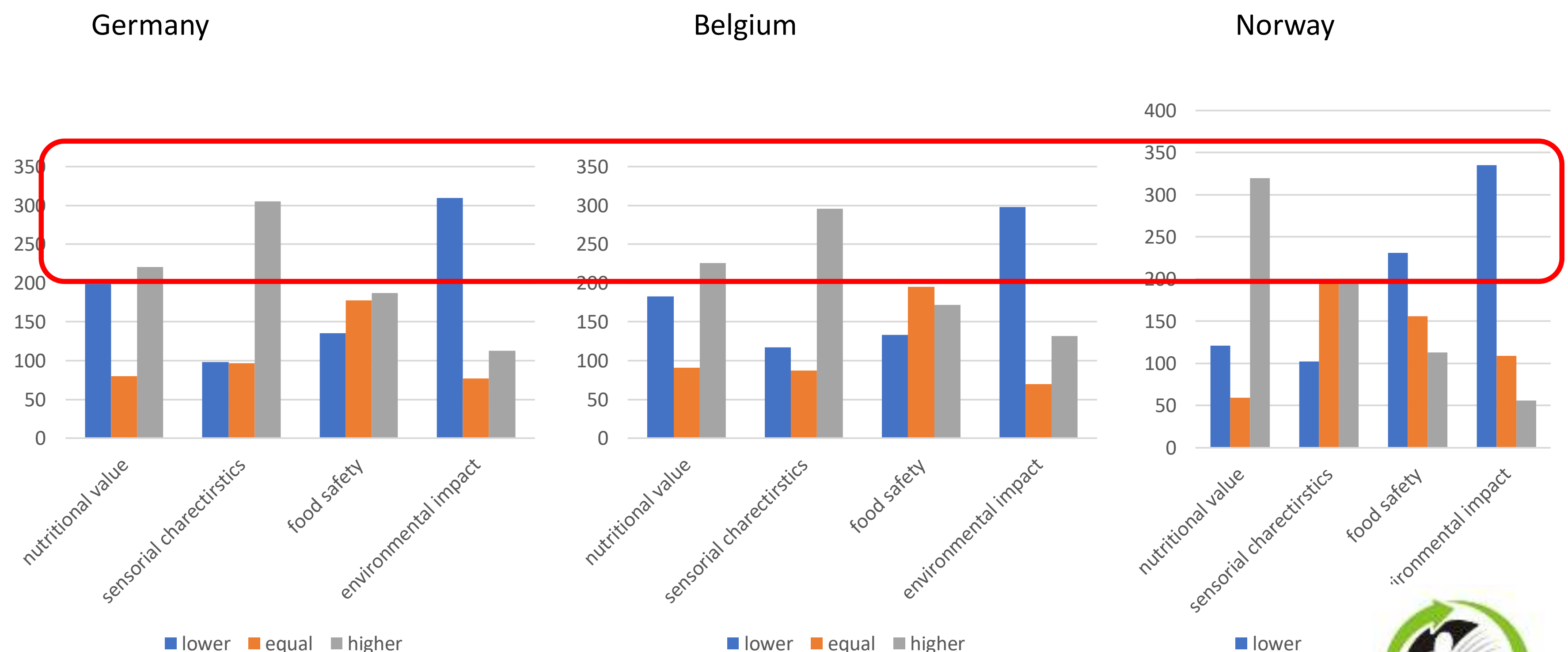


Belgium

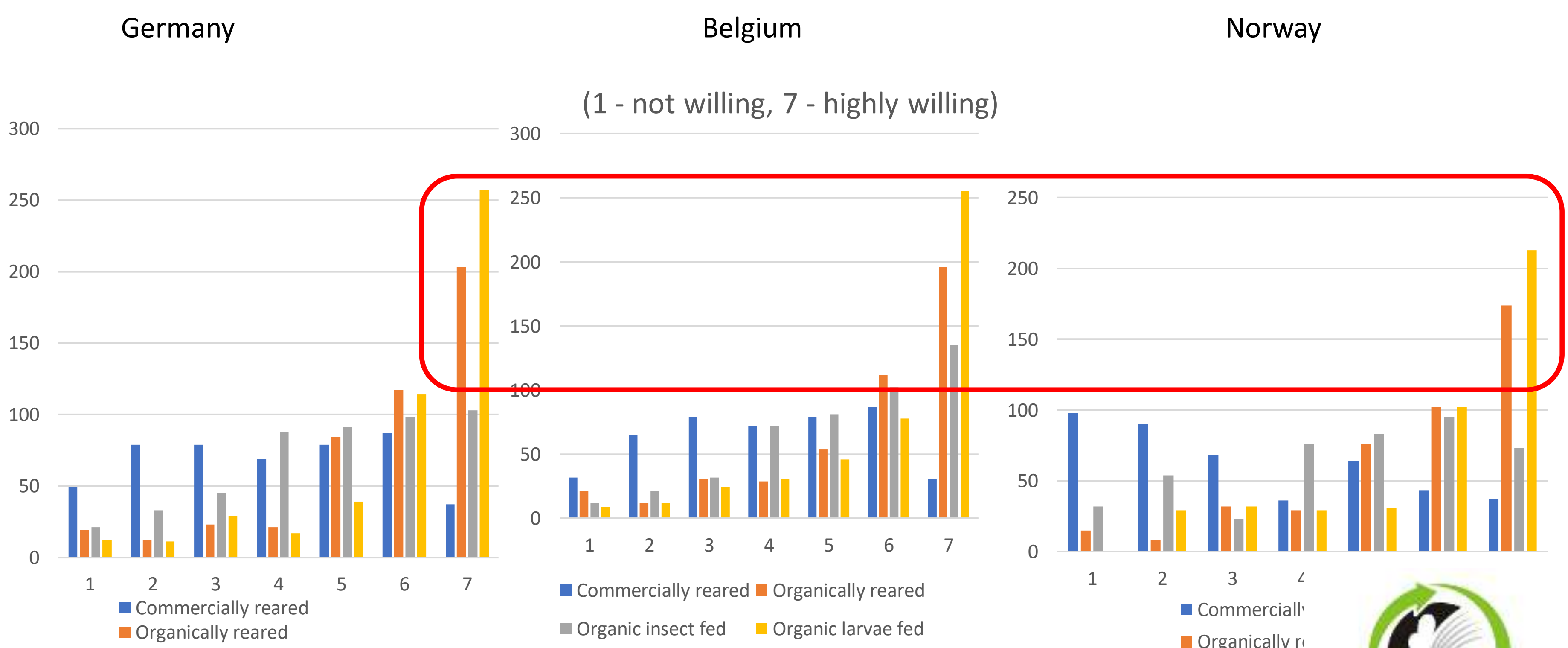




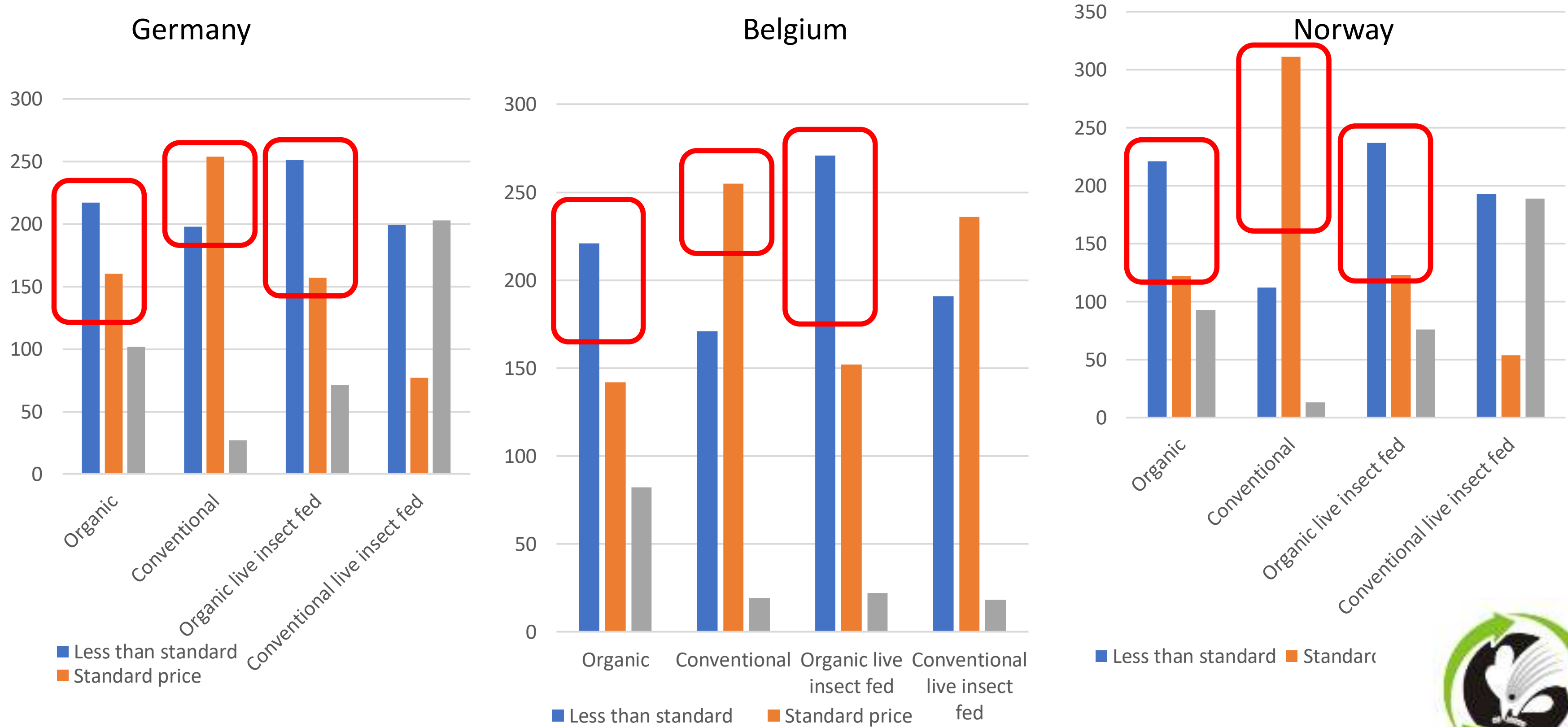
Opinion on impacts on nutrition, sensory, safety and environment due to larve-fed chickens



Willingness to purchase types of chicken



Willingness to pay for specific poultry meat



Conclusions

- There are 2 main drivers for trying insect-fed poultry in Germany, which divided the population into those being **curios or being indifferent** towards new food. Norwegian people expressed much higher level of indifference towards poultry fed on insects, however, certain aspects of **curiosity and satisfaction from food is expected**. Belgium population is curious, indifferent, searching satisfaction and surprise at the same time.

- Insect-fed chicken **are expected to taste better and have lower environmental** impact in Germany and Belgium. Norway adds also high **expectations for the higher nutritional value**.

- In all three countries people responded to be **willing to purchase more organically reared chicken grown on larvae and organically reared chicken**. But lower willingness to buy organic insect fed chicken. Words have different negative value (insect vs larvae**?). Organic chicken meat and organic chicken meat fed with insects is expected to cost less than standard price**, while the price for the conventional meat is considered to be at satisfactory levels.

Integrated sustainability assessment

Combines single score LCA results, LCC production price results and Social LCA results

	chicken meat production							
	predominantly manual				automated			
	insects included		control		insects included		control	
	males	females	males	females	males	females	males	females
LCA	4.23	4.65	4.27	5.00	4.23	4.65	4.27	5.00
LCC	3.85	5.00	3.63	4.58	3.85	5.00	3.63	4.58
SLCA	2.85	2.85	2.73	2.73	2.13	2.13	2.00	2.00
Sum	10.94	12.51	10.63	12.30	10.21	11.78	9.90	11.58
overall grade	3.65	4.17	3.54	4.10	3.40	3.93	3.30	3.86
	3.91		3.82		3.66		3.58	

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Integrated sustainability assessment

Combined LCA, LCC, and Social LCA results of the modeled farm indicate that the inclusion of insects did not increase overall sustainability

The influence of the sex of the chickens, or automation, proved to be greater than that of inclusion of insects

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