23rd European Symposium on Poultry Nutrition

ESPN 2023

RIMINI/ITALY JUNE 21 - 24

INSECTS IN POULTRY FEEDING: TRANSLATING RESEARCH OUTCOMES INTO PRACTICE

Achille SCHIAVONE & Annelisse CASTILLO– University of Turin (Italy)

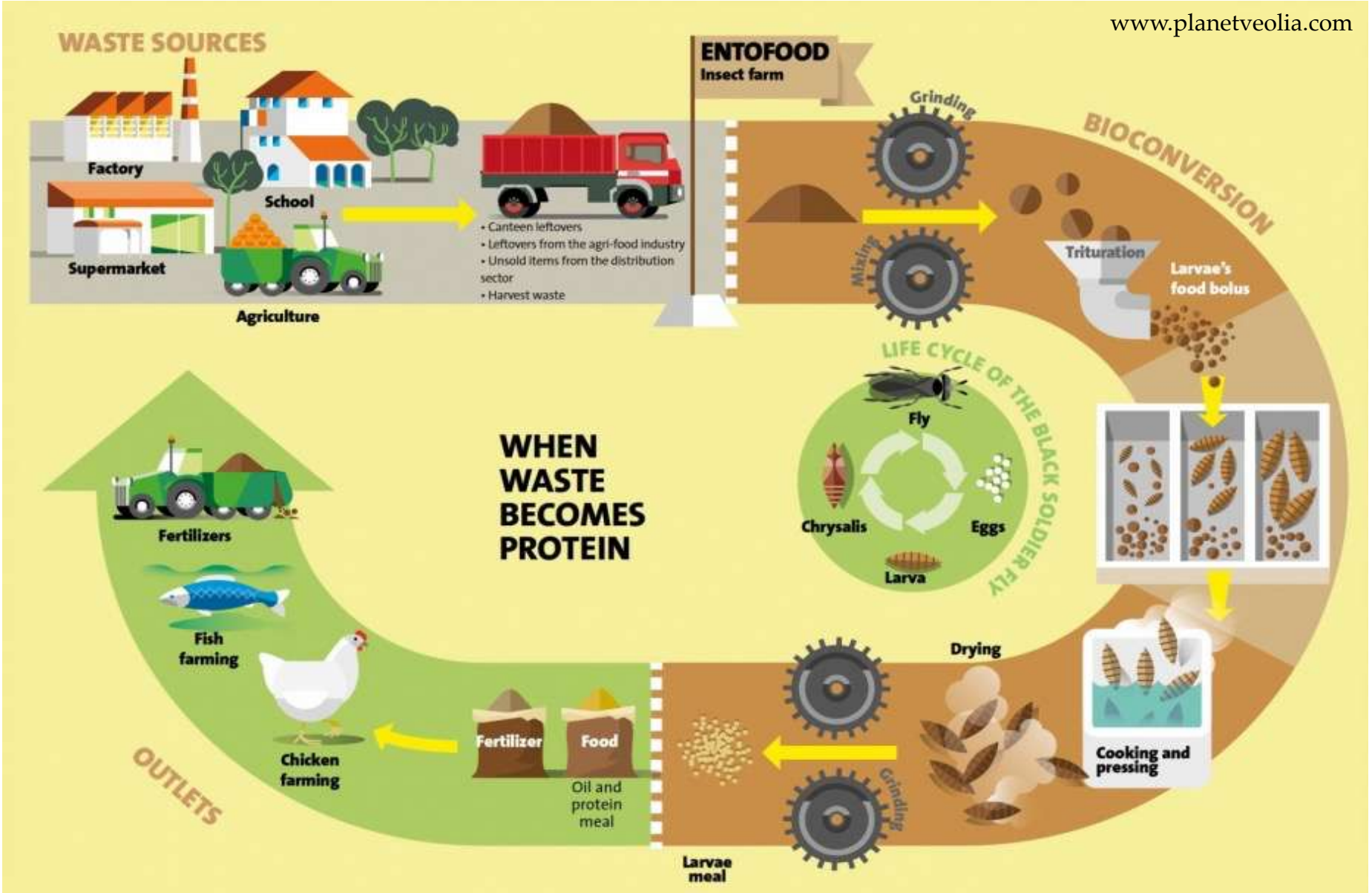
SUSTAvianFEED

POULTRYNSECT

CONTENTS

1. INTRODUCTION

Insects are proficient in converting agricultural and biological residues in high qualitative nutrients, reducing drastically gas emissions and waste mass



Avendaño et al. 2020 ; Veldkamp et al. 2022

COMMISSION REGULATION (EU) 2017/893

of 24 May 2017

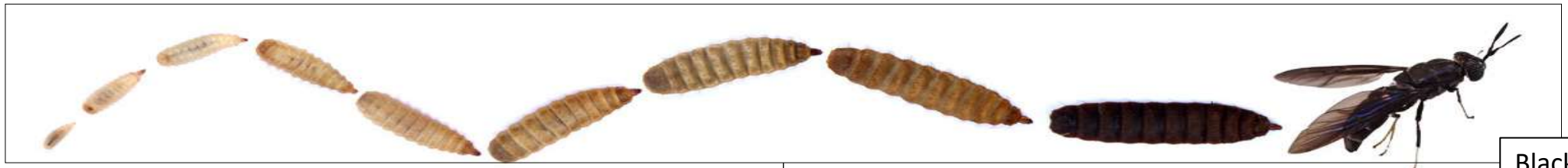
amending Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council and Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011 as regards the provisions on processed animal protein

APPROVED

COMMISSION REGULATION (EU) 2021/1372

of 17 August 2021

amending Annex IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council as regards the prohibition to feed non-ruminant farmed animals, other than fur animals, with protein derived from animals



Black soldier fly

Mealworm

Housefly

INSECT LARVAE

FULL FAT MEAL

FATS

DEFATTED MEAL

NUTRACEUTICALS

CHITIN

ANTIM. PEPTIDES

FEED ADDITIVES

WHOLE LARVAE

LIVE

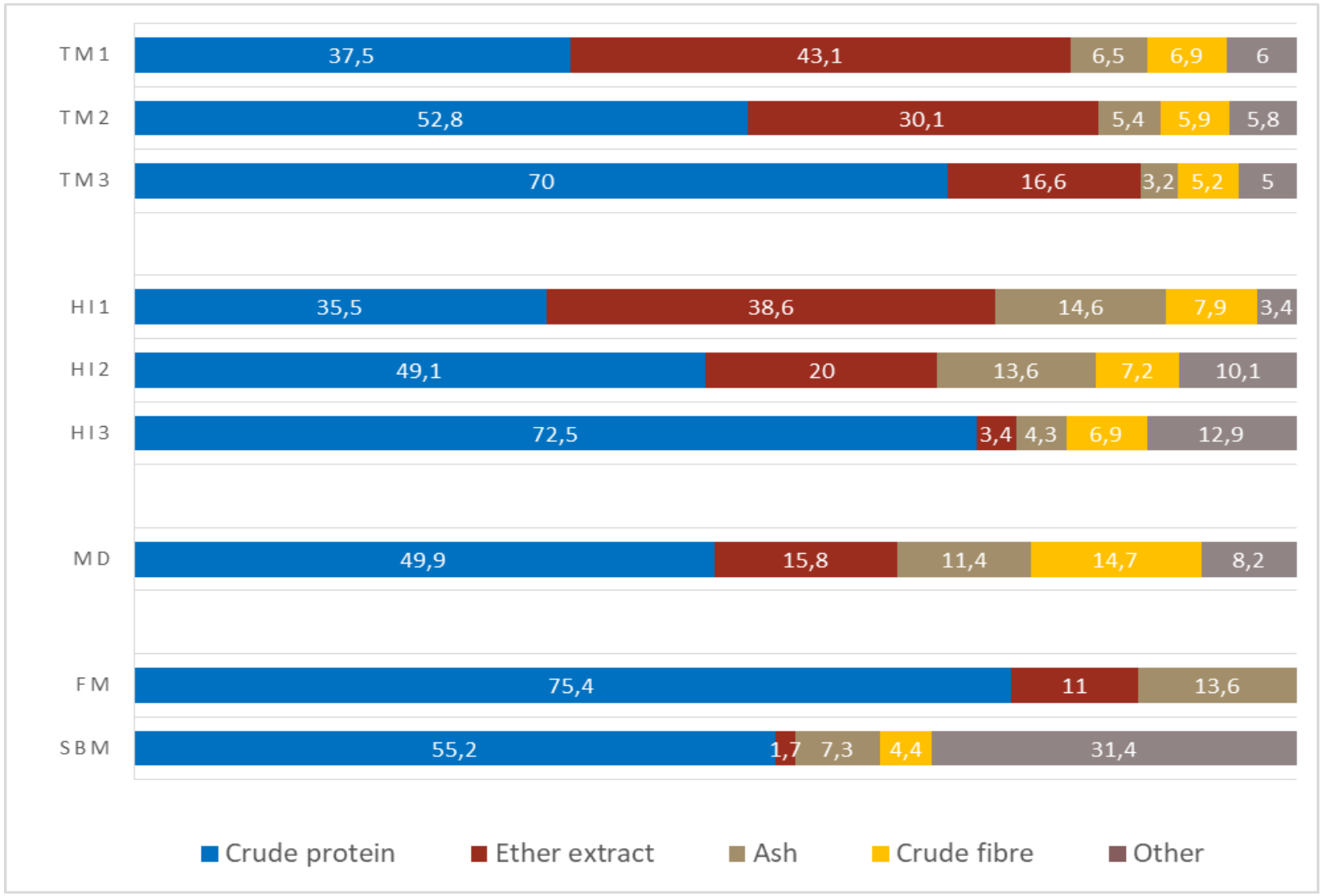
FROZEN

DRIED

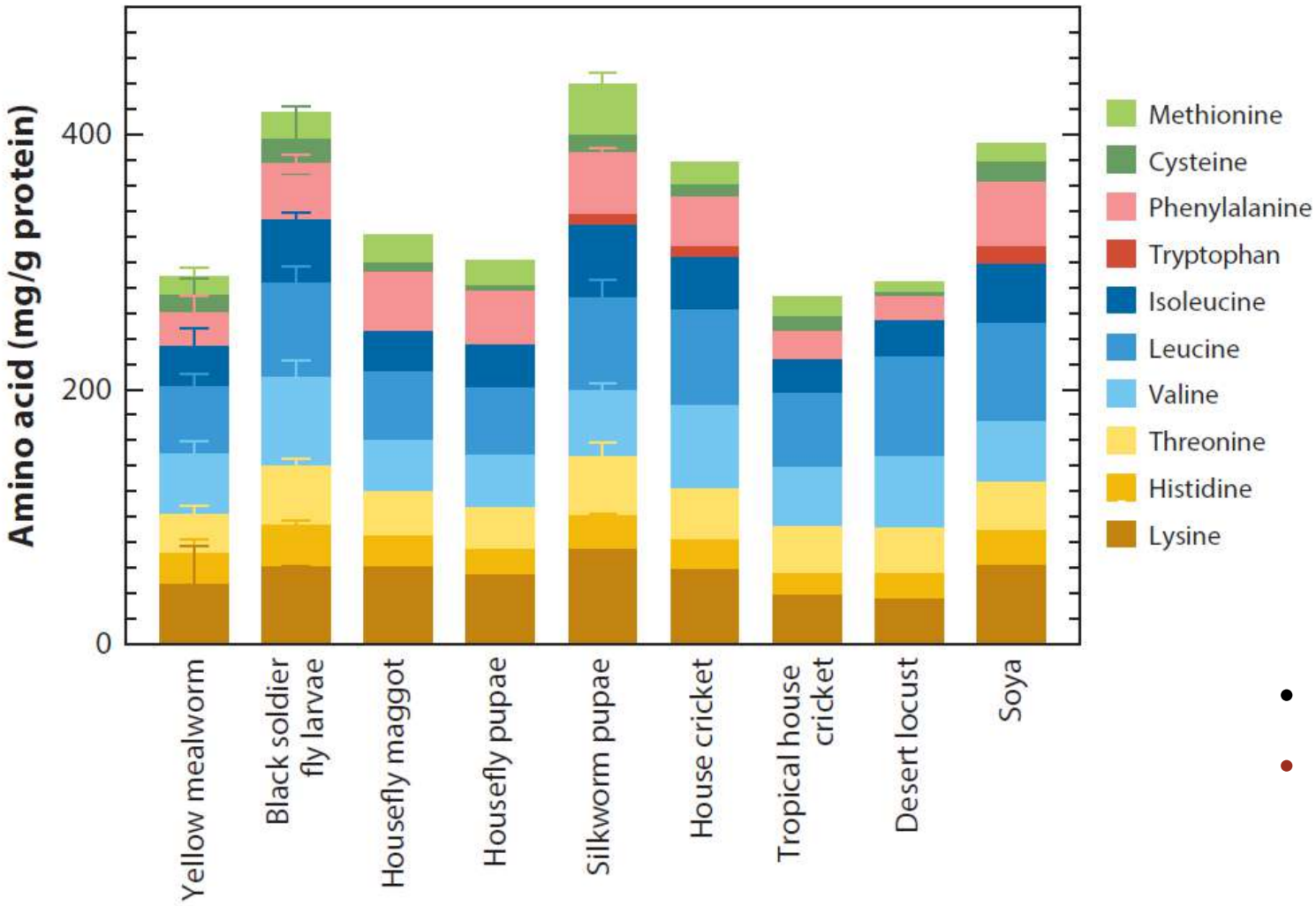
ENV. ENRICHMENT

ANIMAL NUTRITION

Insect meals chemical composition *vs* FM & SBM (% DM)



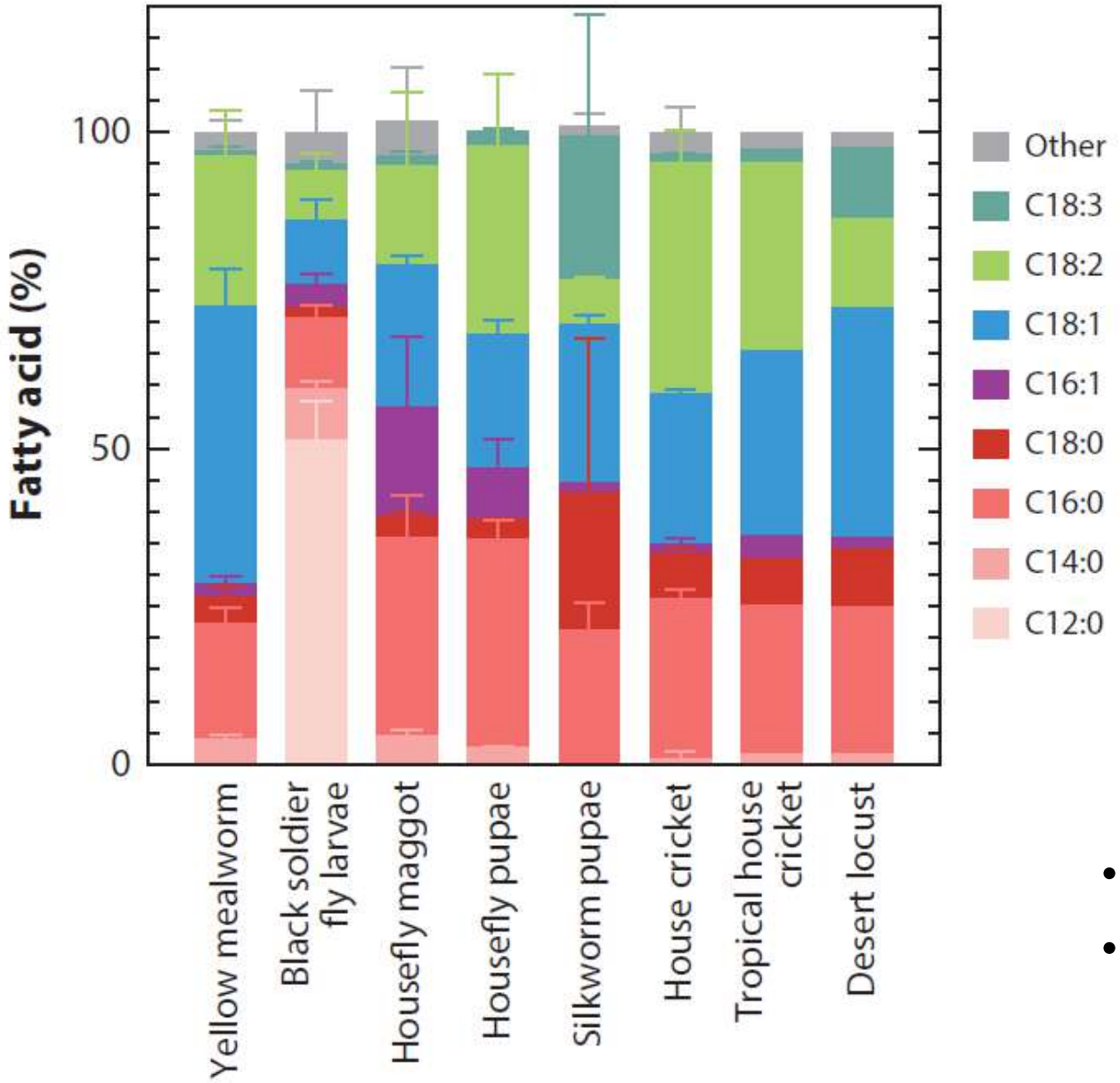
Gasco et al., 2020



- good sources of EAAs
- **affected** by insect specie & stage

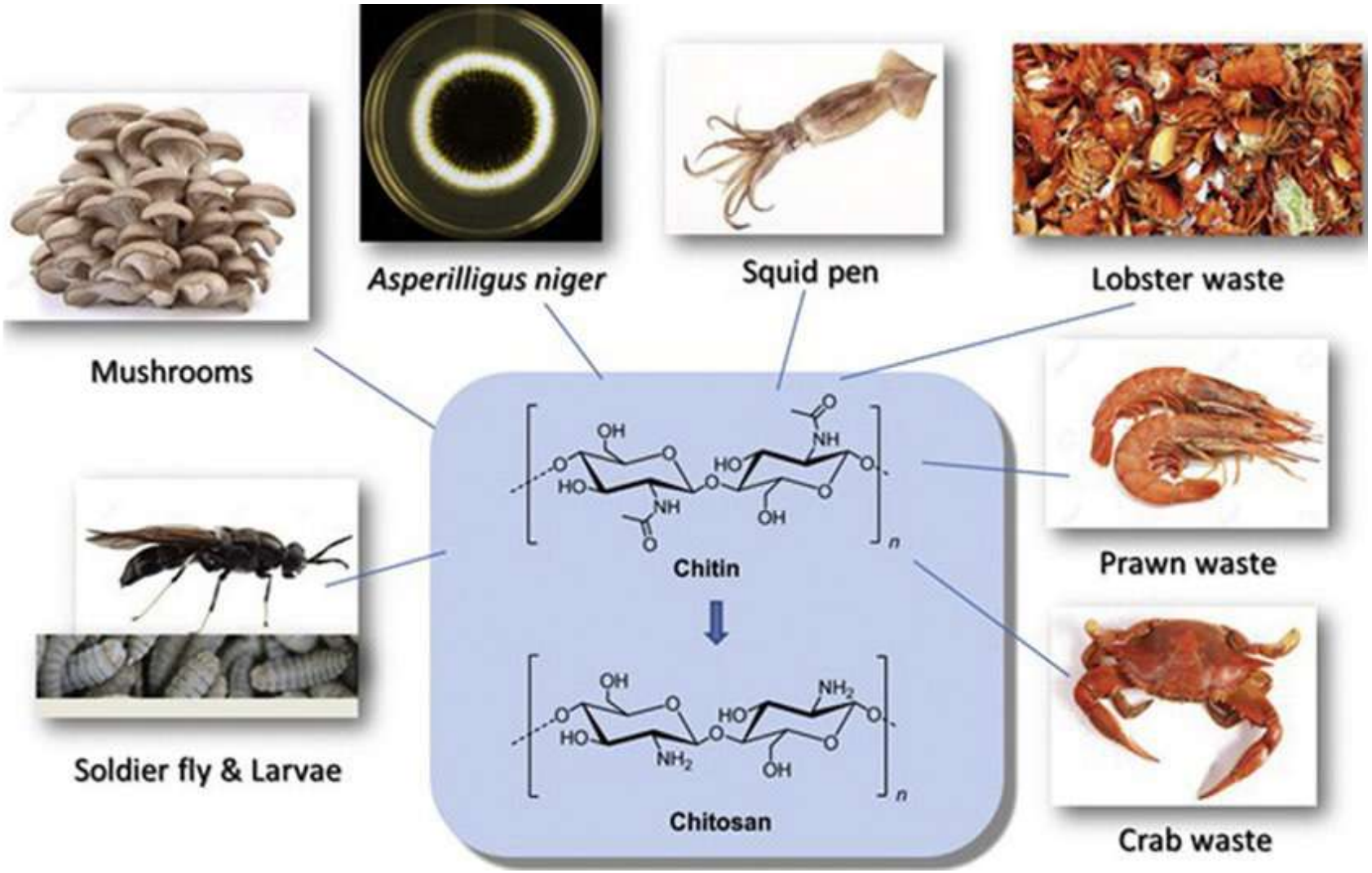
Hawkey et al., 2021

Hawkey et al., 2021



- Fat content & FA profile **affected** by **substrate**
- FA profile **affected** by **specie**

Hawkey et al., 2021.

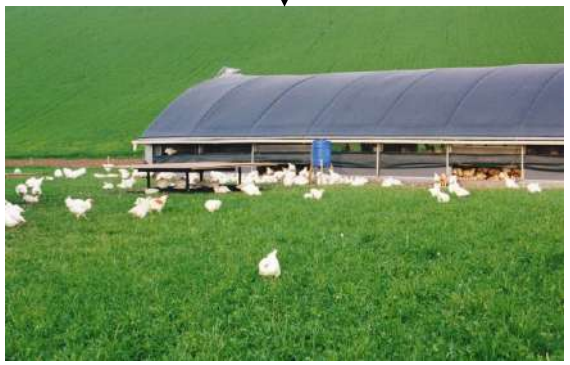


CHITIN

- antioxidant effects
- immune system stimulation
- microbiota modulation

Hawkey et al., 2021; Gasco et al., 2019

ENVIRONMENTAL ENRICHMENTS



?

Riber et al., 2018

In free-range farming systems insects are part of the spontaneousl diet of poultry

Great part of the day is spent by the bird foraging for feed. During this natural behavior, the bird pecks and scratches the ground, and eats.

Moreby et al., 2006; Mench 2009

2. WHOLE INSECT LARVAE in BROILER CHICKENS

SUPPLEMENT ARTICLE

Journal of Animal Physiology and Animal Nutrition WILEY J Anim Physiol Anim Nutr. 2021;105(Suppl. 1):10–18.

Black soldier fly and yellow mealworm live larvae for broiler chickens: Effects on bird performance and health status

Sara Bellezza Oddon[1] | Ilaria Biasato[1] | Arianna Imarisio[2] | Miha Pipan[3] | Dominik Dekleva[3] | Elena Colombino[2] | Maria Teresa Capucchio[2] | Marco Meneguz[1] | Bergagna Stefania[4] | Raffaella Barbero[4] | Marta Gariglio[2] | Sihem Dabbou[5,6] | Edoardo Fiorilla[2] | Laura Gasco[1] | Achille Schiavone[2]

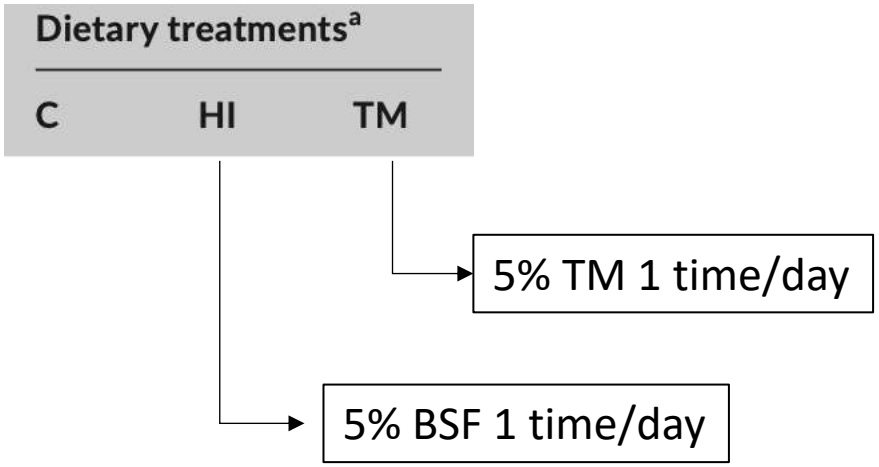


TABLE: chemical composition of live HI and TM larvae at two stages

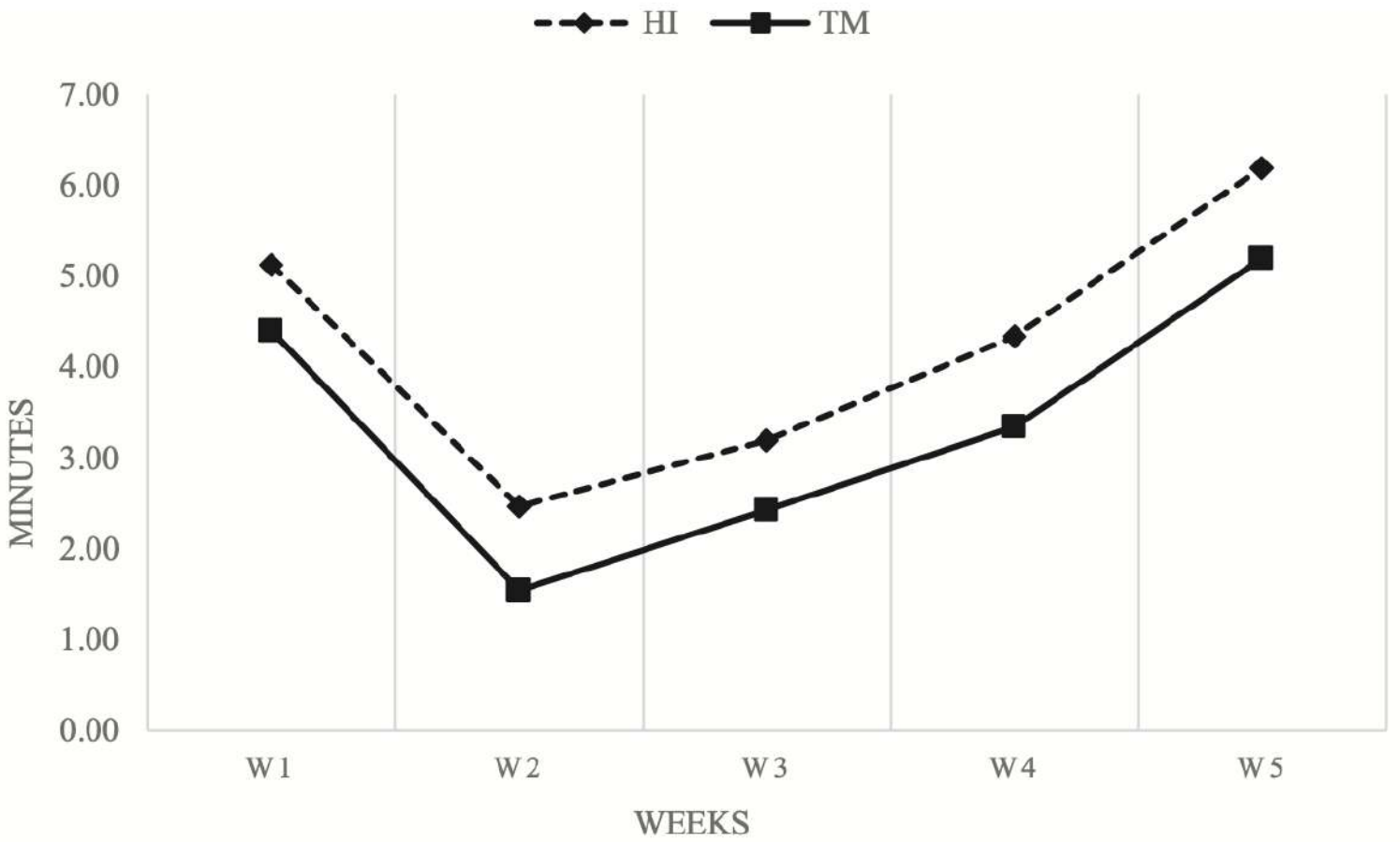
Chemical composition[a] (as fed basis, %)	HI early instar larvae	HI late instar larvae	TM early instar larvae	TM late instar larvae
DM	25.32	25.32	27.54	27.54
CP	12.01	8.07	16.78	10.82
Ash	3.05	2.00	1.69	0.90
EE	0.42	1.93	0.59	5.50
GE (MJ/kg)	5.03	6.76	5.90	7.65

Abbreviations: CP, crude protein; DM, dry matter; EE, ether extract; GE, gross energy.

[a]Values are reported as mean of duplicate analyses.

Bellezza Oddon et al., 2021

time spent for eating 5% supplemented HI or TM live larvae



Bellezza Oddon et al., 2021

TABLE 2 Effects of the dietary treatments on the growth performance of the broiler chickens (n = 6)

Items	Age (days)	Dietary treatments[a] C	HI	TM	SEM	p Value[b]
LW, g	4	87	87	88	0.38	0.796
	11	220	216	225	3.60	0.603
	38	2488	2527	2452	22.28	0.619
ADG, g/d	4–11	19	18	20	0.49	0.610
	12–38	76	72	80	1.98	0.348
DFI, g/d	4–11	24	22	22	0.67	0.679
	12–38	110	108	103	3.45	0.753
FCR, g/G	4–11	1.25	1.23	1.16	0.02	0.223
	12–38	1.36^{ab}	1.39^{a}	1.32^{b}	0.01	**
	4–38	1.37^{a}	1.38^{a}	1.31^{b}	0.01	**

Dietary treatments[a]		
C	HI	TM

5% TM 1 time/day

5% BSF 1 time/day

Welfare implications for broiler chickens reared in an insect larvae-enriched environment: Focus on bird behaviour, plumage status, leg health, and excreta corticosterone

Ilaria Biasato[1]*, Sara Bellezza Oddon[1], Giulia Chemello[2], Marta Gariglio[3], Edoardo Fiorilla[3], Sihem Dabbou[4], Miha Pipan[5], Dominik Dekleva[5], Elisabetta Macchi[3], Laura Gasco[1] and Achille Schiavone[3]

frontiers | Frontiers in Veterinary Science

PUBLISHED 25 August 2022
DOI 10.3389/fphys.2022.930158


HI and TM live larvae as environmental enrichments

Behaviour analysis

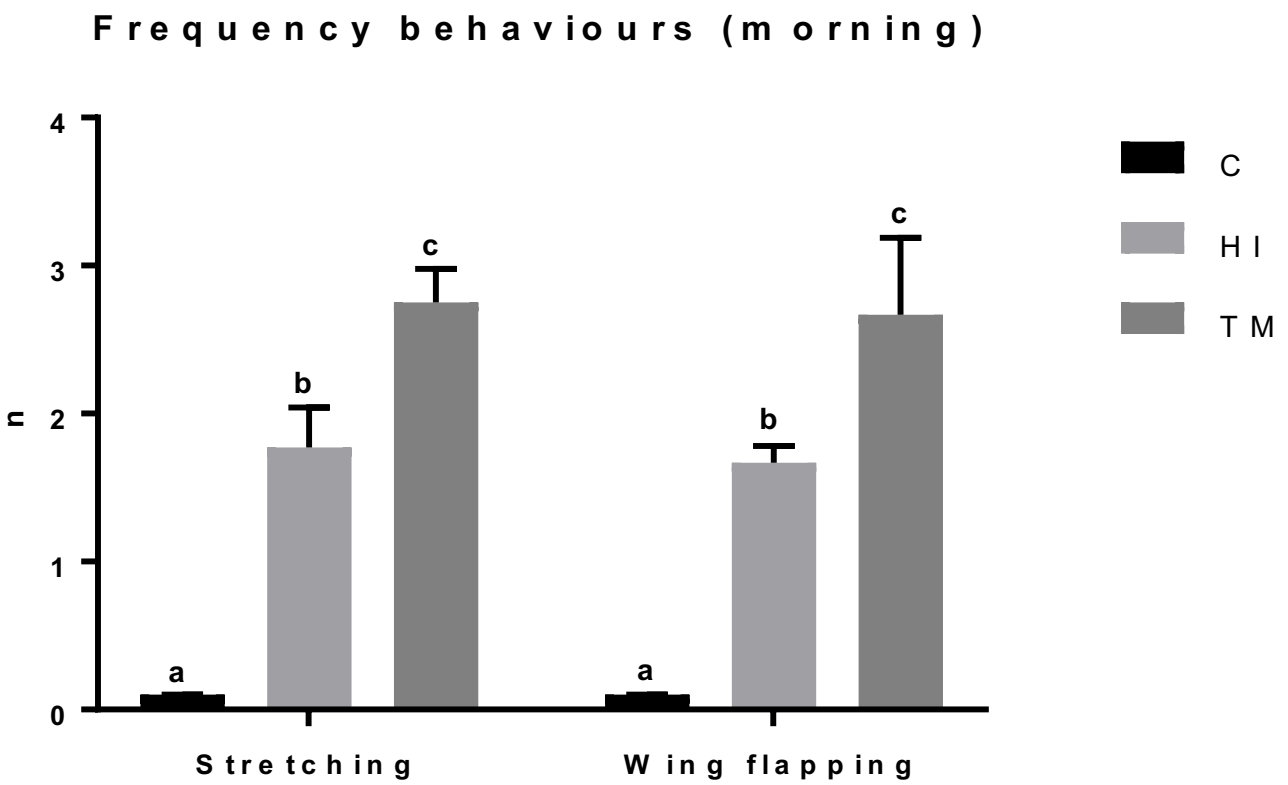
Welfare of broiler chickens

Faecal corticosterone assessment

Dietary treatments[a]		
C	HI	TM

5% TM 1 time/day

5% BSF 1 time/day



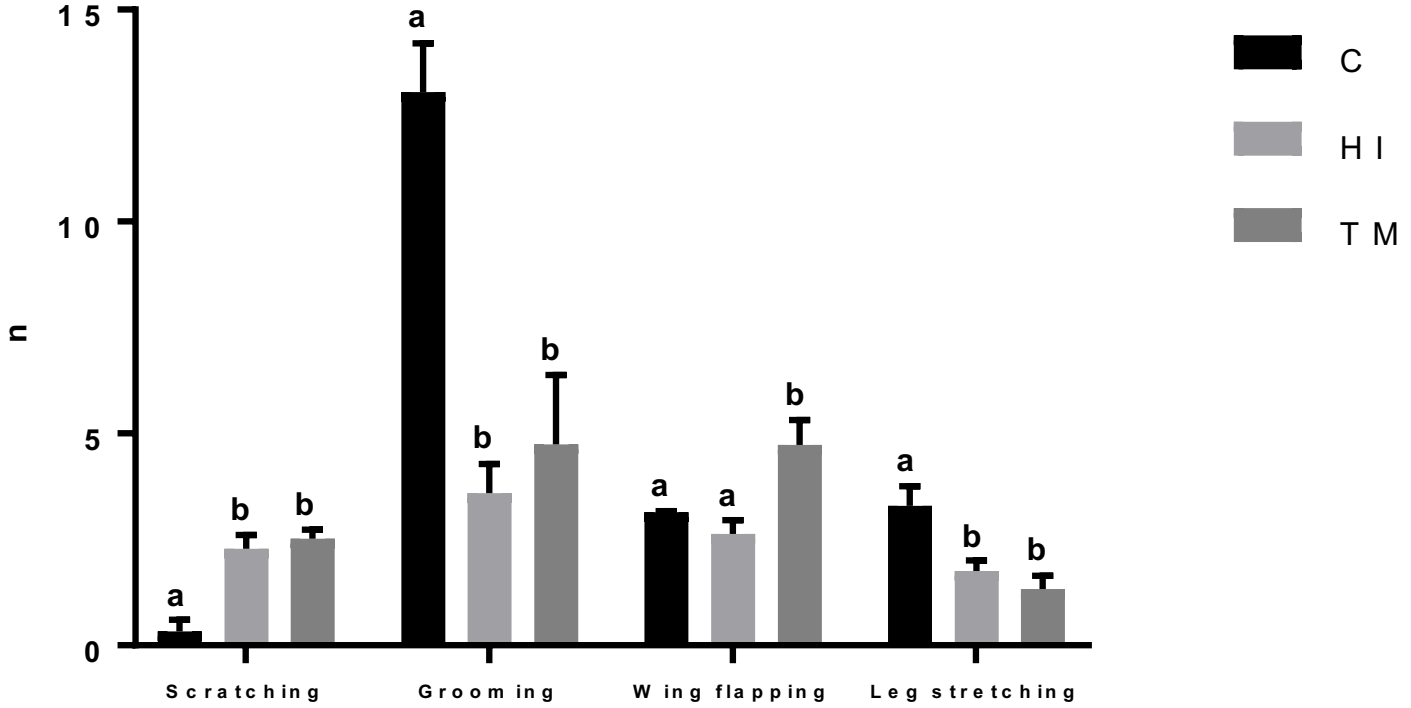
Biasato et al., 2022

Dietary treatments[a]		
C	HI	TM

5% TM 1 time/day

5% BSF 1 time/day

Frequency behaviours (larvae intake)



Biasato et al., 2022

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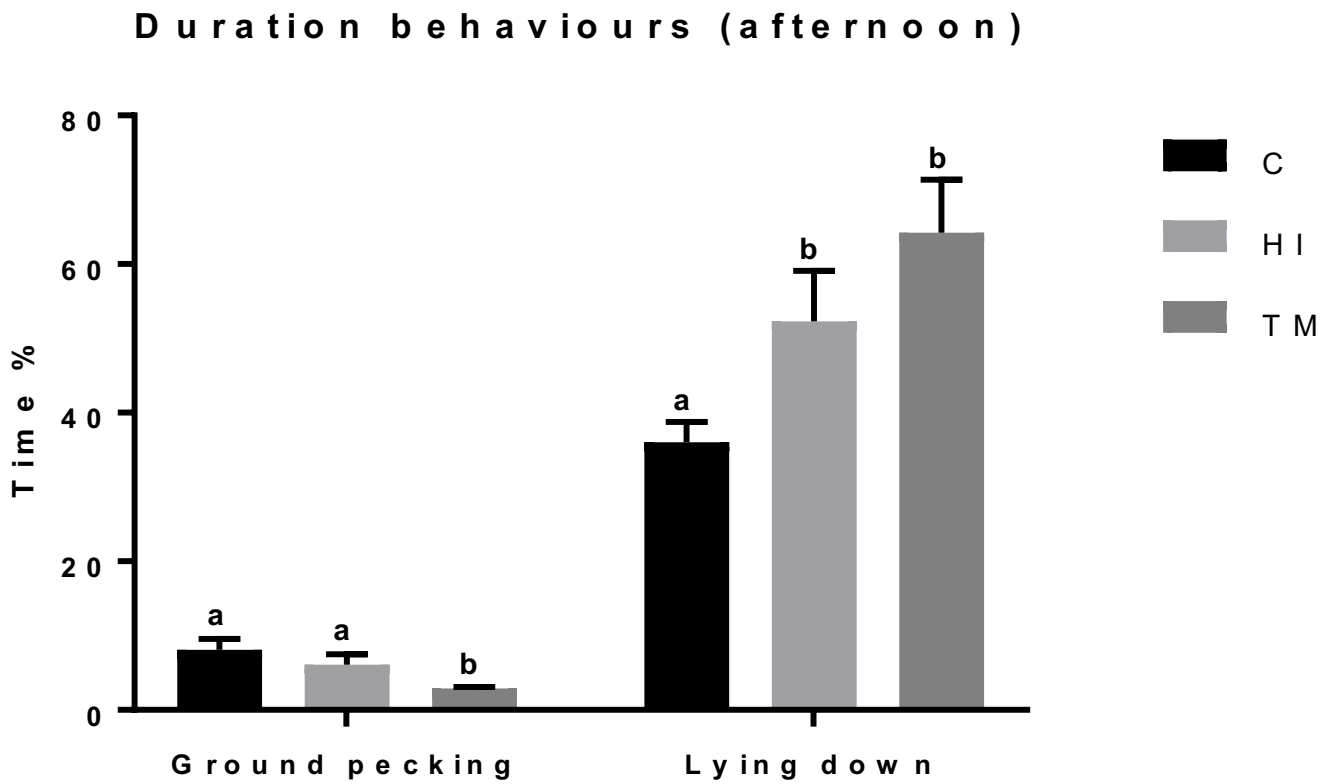

Biasato et al., 2022

Dietary treatments[a]		
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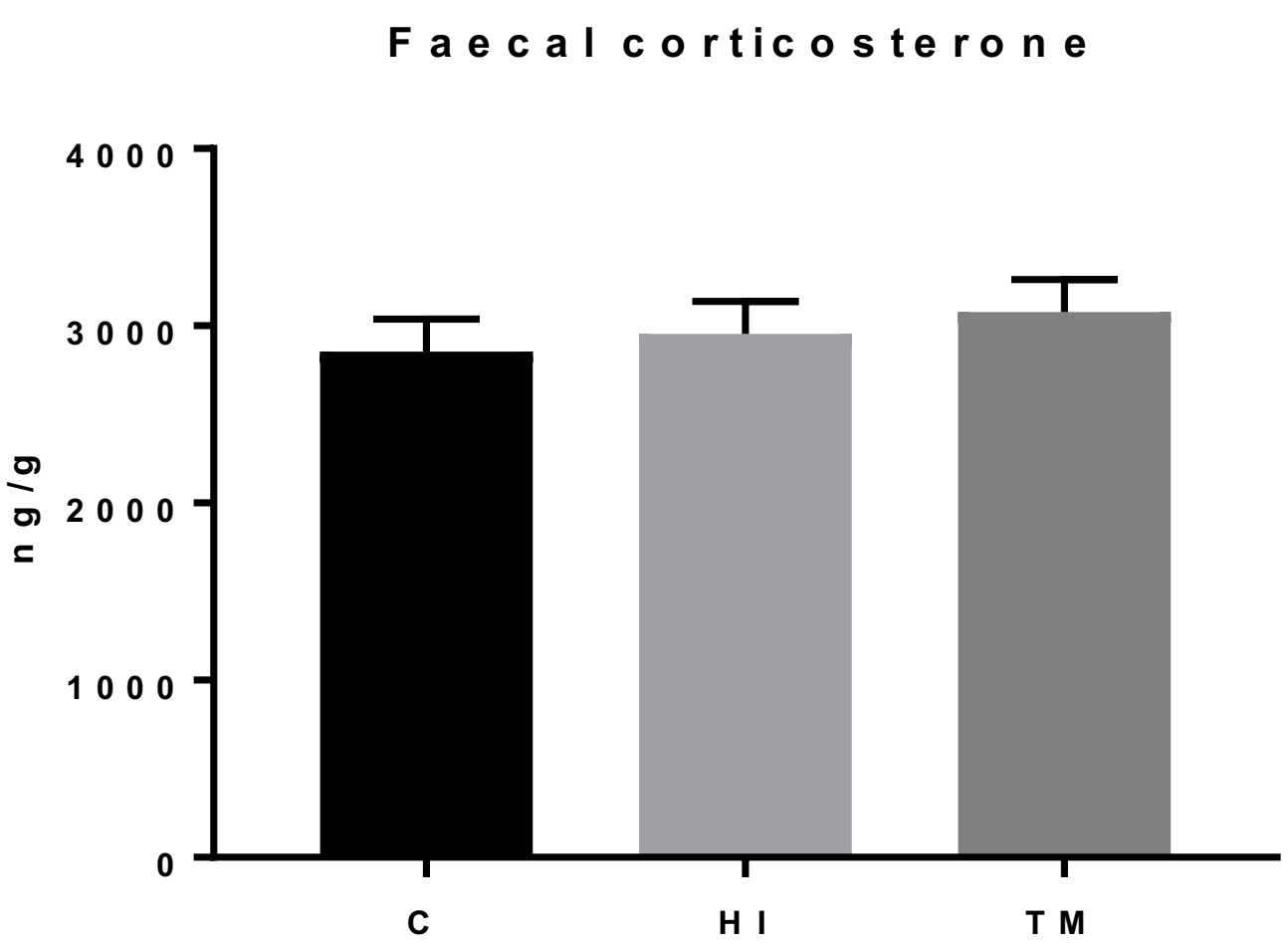


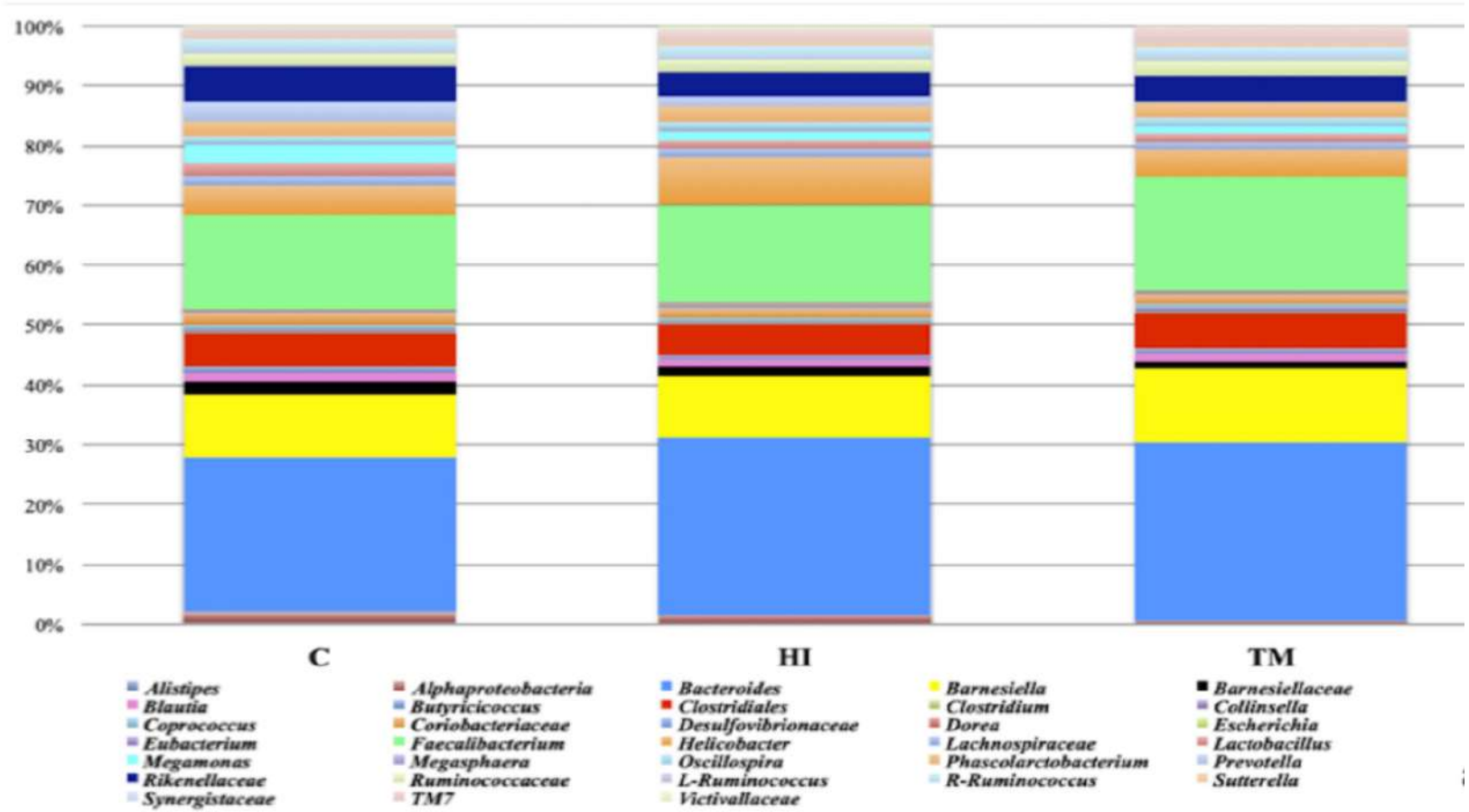
Biasato et al., 2022

Composition of the caeca microbiota

Dietary treatments[a]		
C	HI	TM

5% TM 1 time/day

5% BSF 1 time/day



Colombino et al., 2022

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

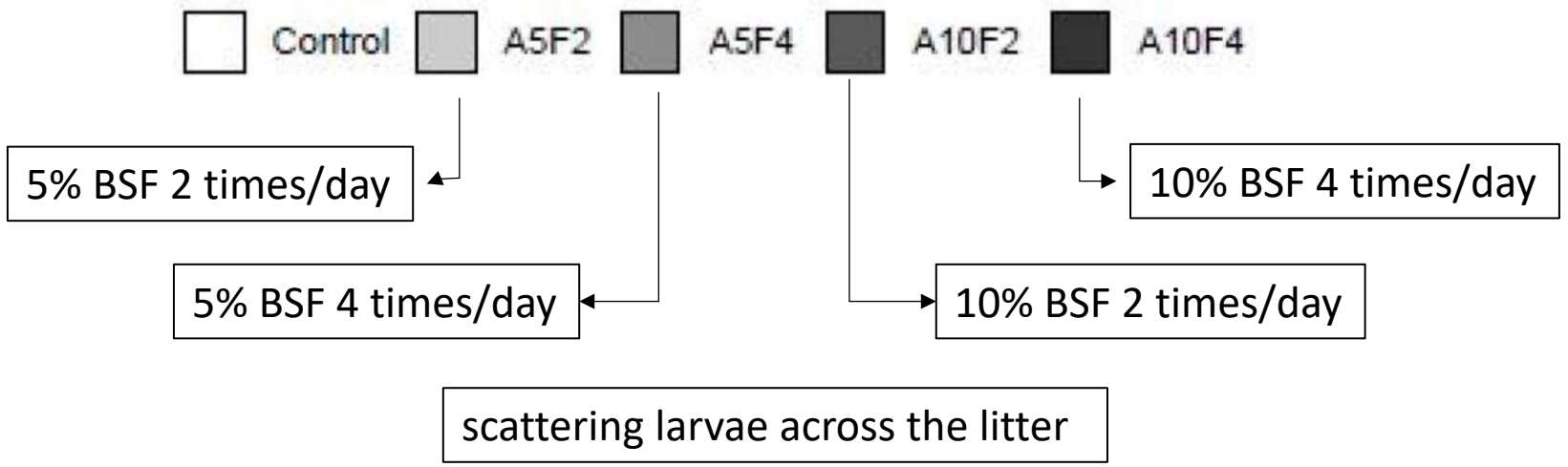
journal homepage: www.elsevier.com/locate/applanim

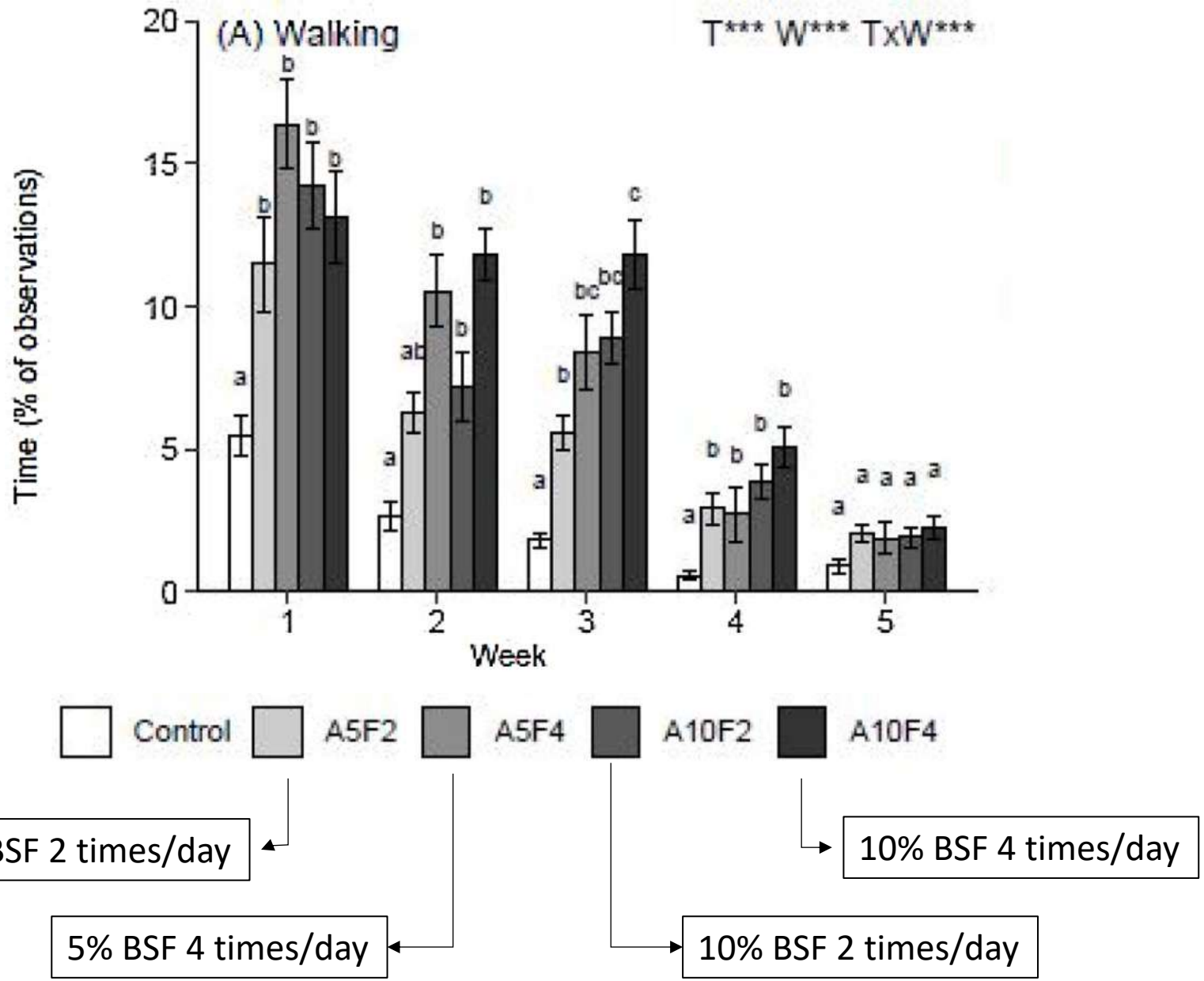
Applied Animal Behaviour Science 230 (2020) 105082

Provisioning of live black soldier fly larvae *(Hermetia illucens)* benefits broiler activity and leg health in a frequency- and dose-dependent manner

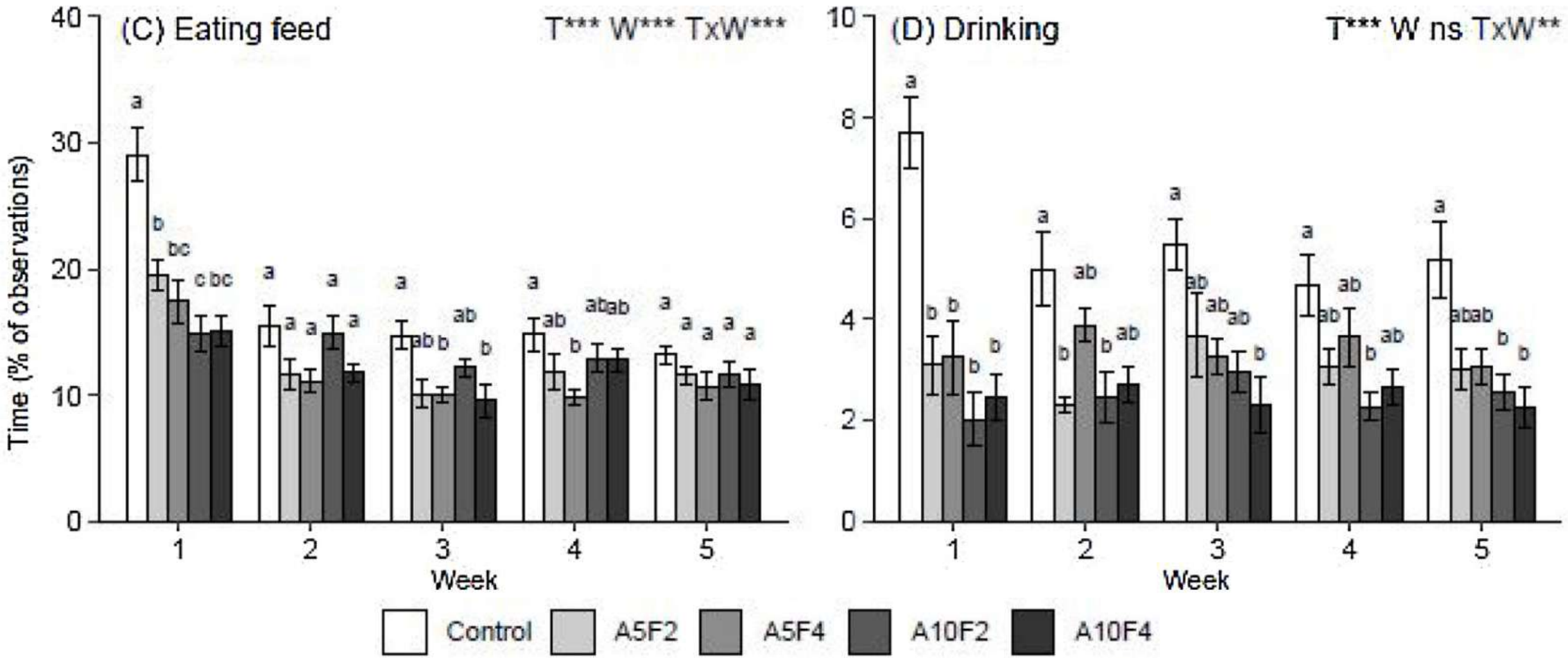
Allyson F. Ipema[a,*], Walter J.J. Gerrits[b], Eddie A.M. Bokkers[c], Bas Kemp[a], J. Elizabeth Bolhuis[a]

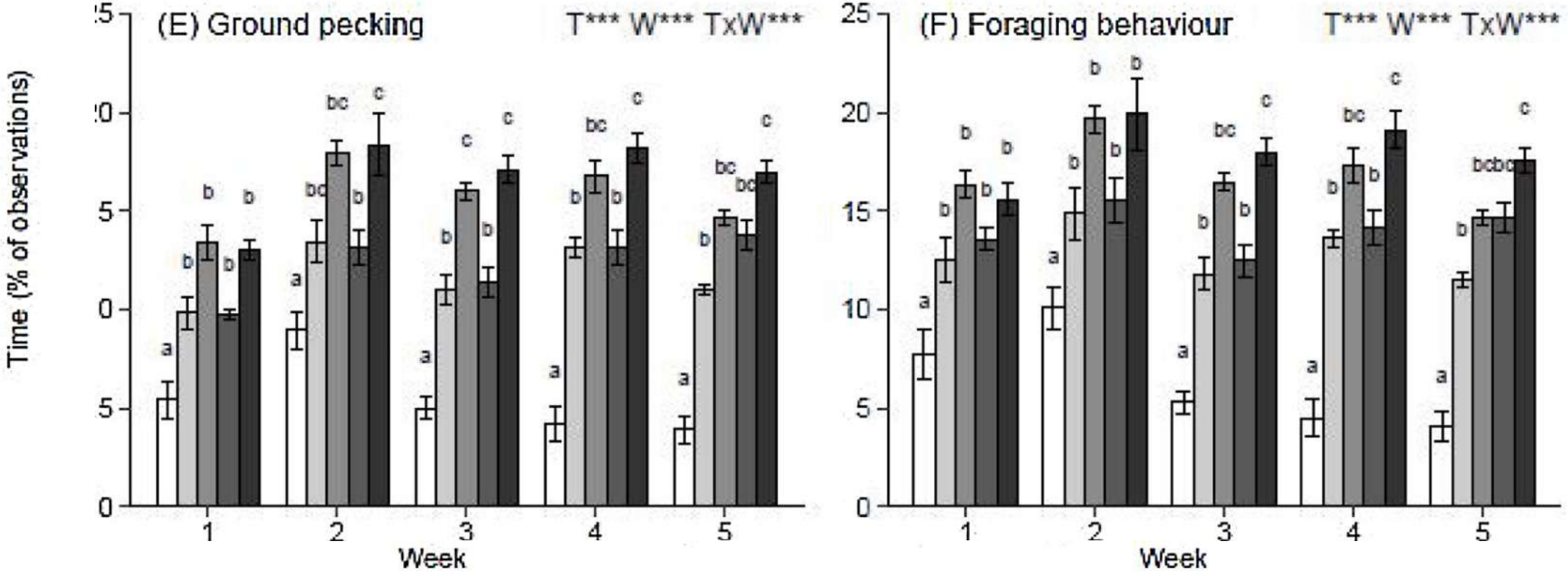
[a] *Adaptation Physiology Group, Department of Animal Sciences, Wageningen University & Research, P.O. Box 338, 6700 AH, Wageningen, the Netherlands*
[b] *Animal Nutrition Group, Department of Animal Sciences, Wageningen University & Research, P.O. Box 338, 6700 AH, Wageningen, the Netherlands*
[c] *Animal Production Systems Group, Department of Animal Sciences, Wageningen University & Research, P.O. Box 338, 6700 AH, Wageningen, the Netherlands*





Ipema et al., 2020a


(C) Eating feed
T*** W*** TxW***
Time (% of observations)
Week
(D) Drinking
T*** W ns TxW**
Week
Control
A5F2
A5F4
A10F2
A10F4
5% BSF 2 times/day
5% BSF 4 times/day
10% BSF 4 times/day
10% BSF 2 times/day



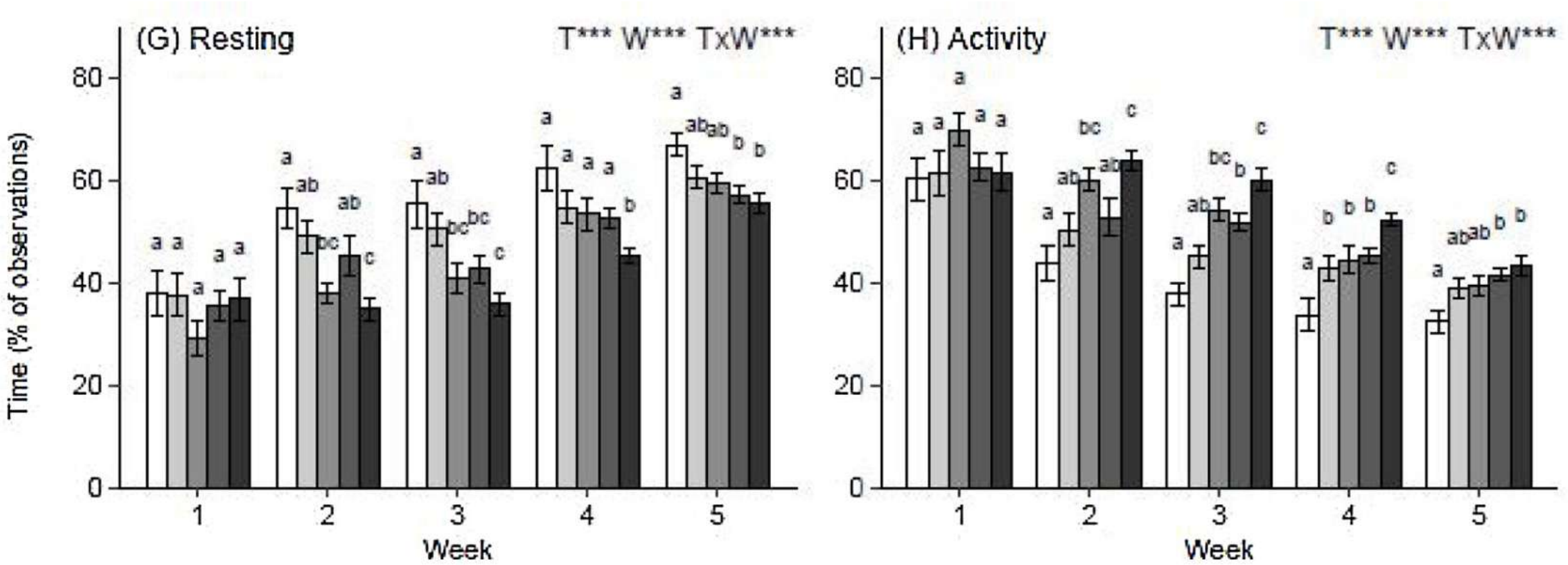
5% BSF 2 times/day

5% BSF 4 times/day

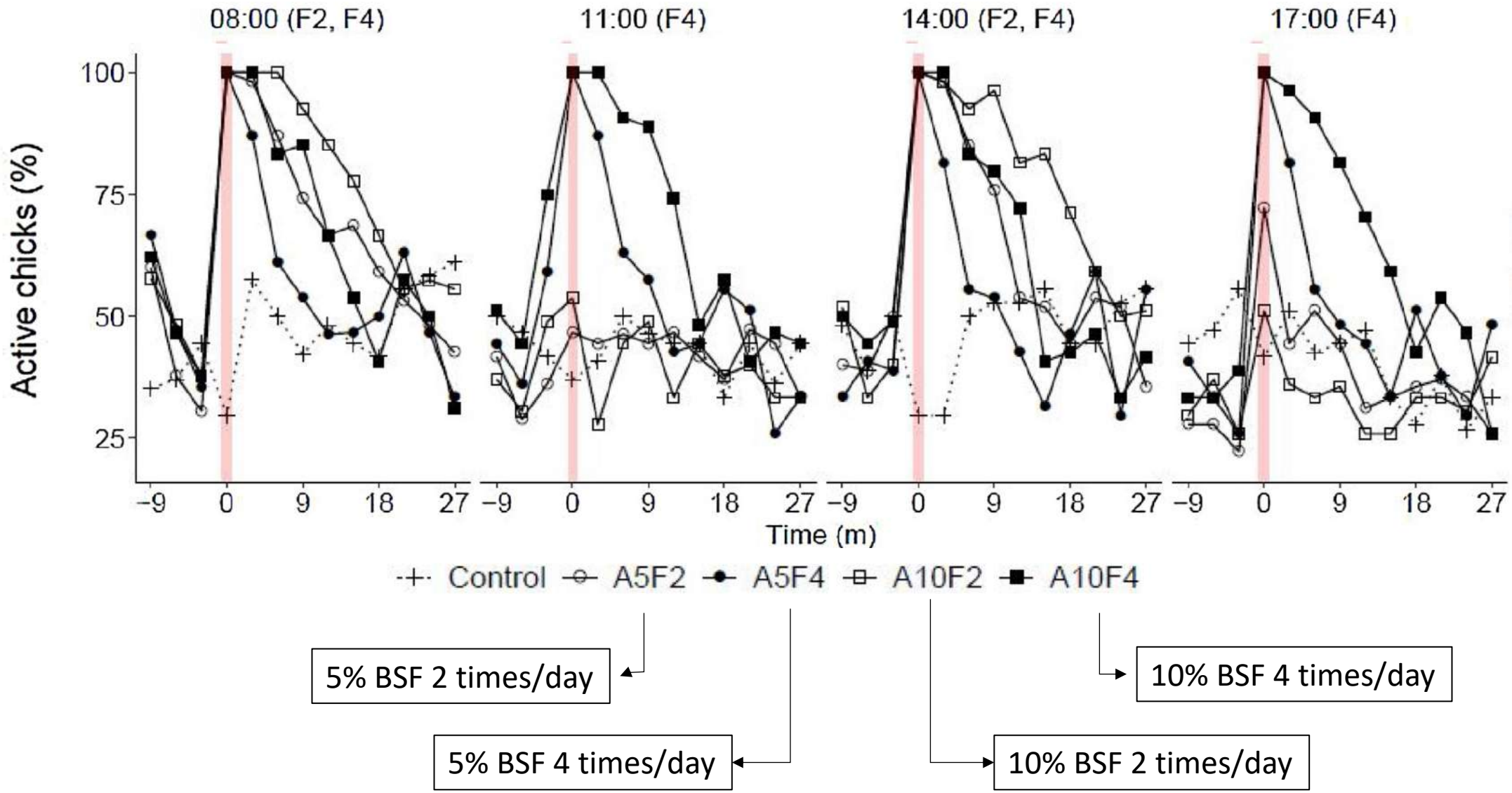
10% BSF 2 times/day

10% BSF 4 times/day

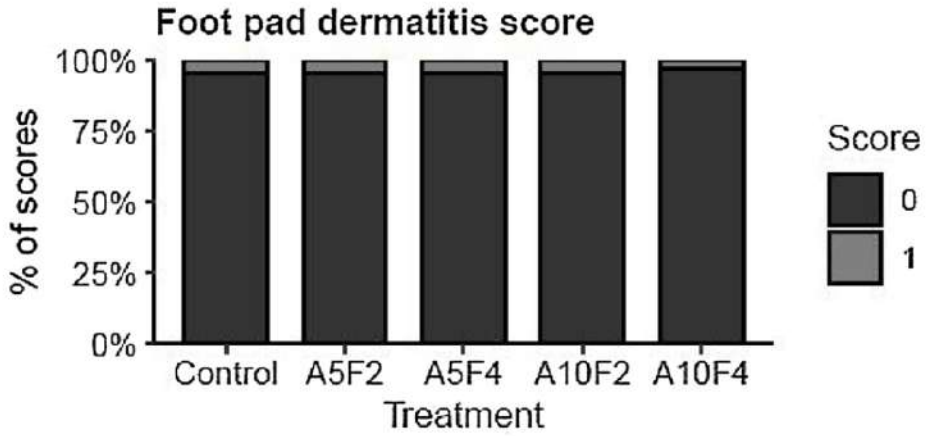
Ipema et al., 2020a

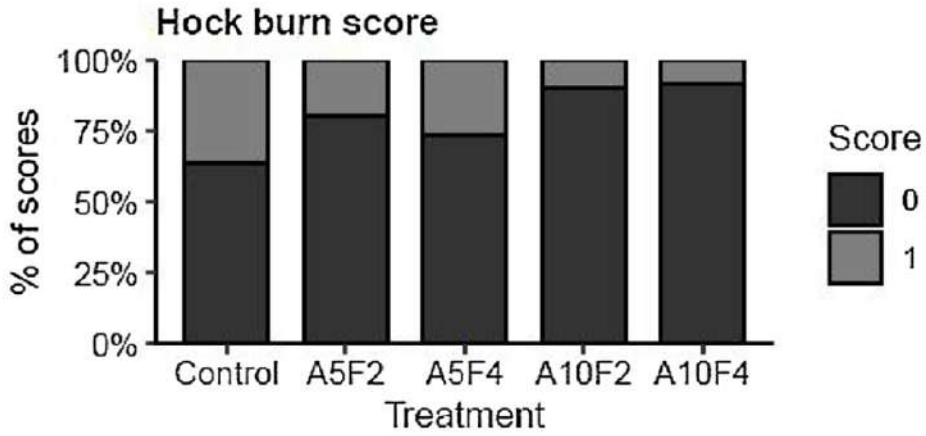


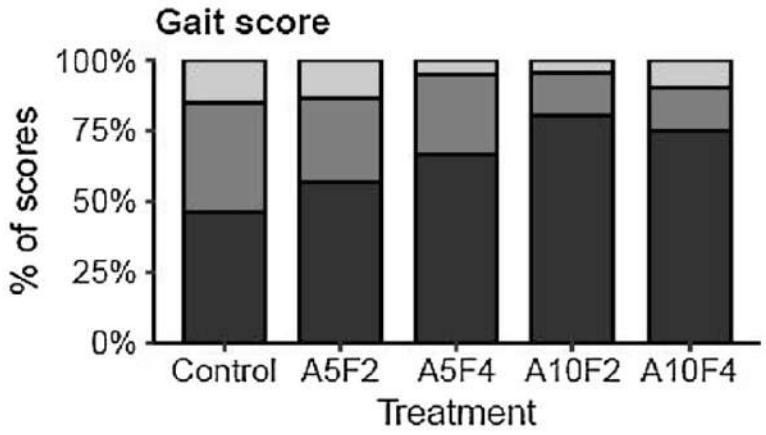
Ipema et al., 2020a



Ipema et al., 2020a







Control A5F2 A5F4 A10F2 A10F4

5% BSF 2 times/day

5% BSF 4 times/day

10% BSF 2 times/day

10% BSF 4 times/day

Ipema et al., 2020a

Contents lists available at ScienceDirect

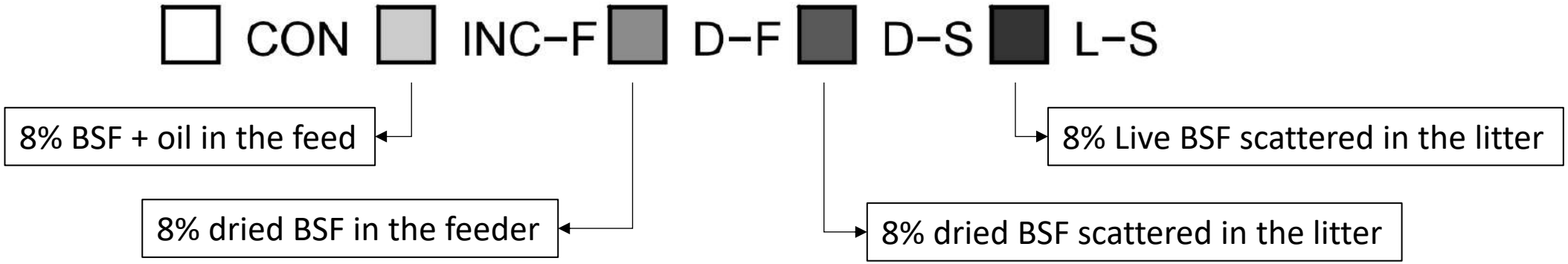
Physiology & Behavior

journal homepage: www.elsevier.com/locate/physbeh

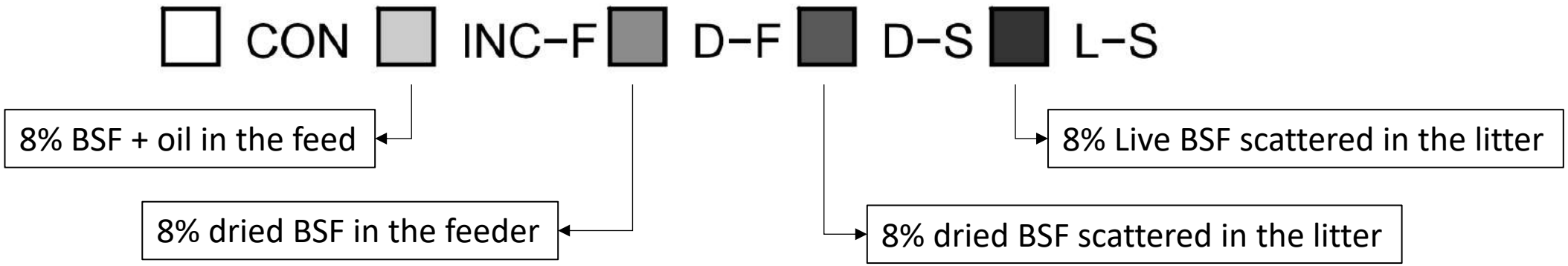
Physiology & Behavior 257 (2022) 113999

Provision of black soldier fly larvae (Hermetia illucens) in different ways benefits broiler welfare and performance, with largest effects of scattering live larvae

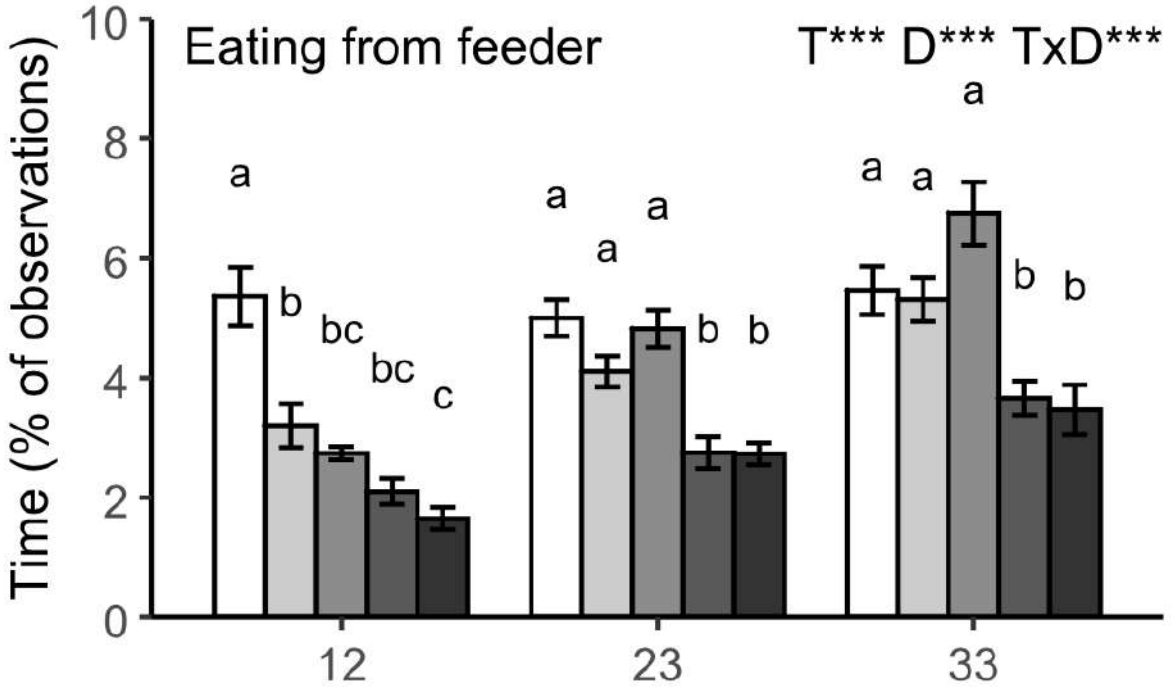
Allyson F. Ipema [a,*], Eddie A.M. Bokkers [b], Walter J.J. Gerrits [c], Bas Kemp [a], J. Elizabeth Bolhuis [a]

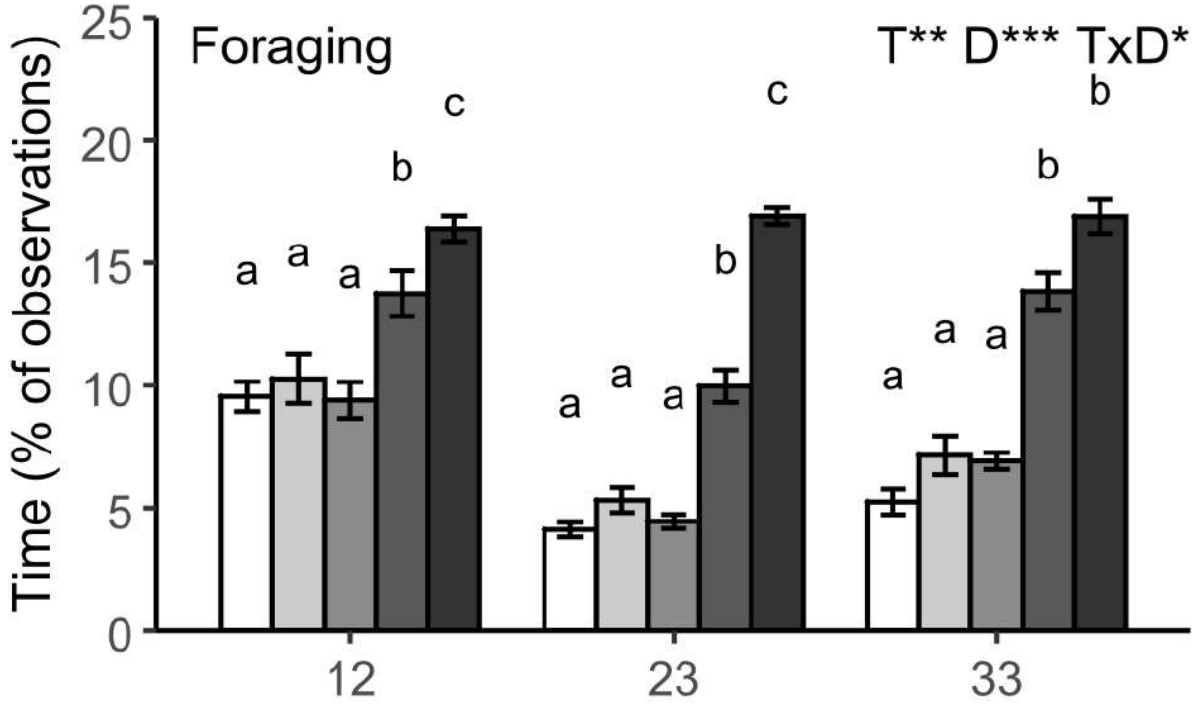


Measure	Period	CON	INC-F	D-F	D-S	L-S	Test-statistic and df	P-value
Average daily gain (g/d)	d1–9	22.6 ± 0.3^{a}	230±0.1^{ab}	23.7 ± 0.2^{b}	23.4 ± 0.3^{ab}	23.8 ± 0.3^{b}	$F_{(4,44)} = 4.50$	**0.004**
	d9–19	61.3 ± 0.6^{a}	61.6 ± 0.3^{a}	64.8 ± 0.4^{b}	64.2 ± 0.4^{b}	65.8 ± 0.7^{b}	$F_{(4,44)} = 17.15$	**<0.001**
	d19–27	102.4 ± 1.3^{a}	103.1 ± 0.9^{ab}	107.0 ± 1.3^{b}	107.6 ± 1.3^{b}	104.0 ± 1.4^{ab}	$F_{(4,44)} = 4.16$	**0.004**
	d27–35	122.4 ± 1.2	124.4 ± 1.2	123.6 ± 1.5	125.5 ± 1.5	124.6 ± 2.5	$F_{(4,44)} = 0.57$	0.688
Final weight (g)	d35	2660 ± 19.7^{a}	2694 ± 11.4^{ab}	2758 ± 9.8^{bc}	2772 ± 18.9^{c}	2747 ± 16.1^{bc}	$F_{(4,43)} = 9.88$	**<0.001**
Average daily dry matter intake of pellets (g/d)	d1–35	93.4 ± 0.7^{a}	92.4 ± 0.3^{a}	86.9 ± 0.6^{b}	85.8 ± 0.6^{b}	81.3 ± 0.6^{c}	$F_{(4,44)} = 73.48$	**<0.001**
Estimated average daily dry matter intake of pellets and larvae (g/d)*	d1–35	93.4 ± 0.7^{ab}	92.4 ± 0.3^{b}	95.0 ± 0.6^{a}	94.0 ± 0.6^{ab}	89.4 ± 0.5^{c}	$F_{(4,44)} = 13.73$	**<0.001**
Dry matter conversion ratio (g/g)	d1–35	1.25 ± 0.002^{a}	1.23 ± 0.003^{b}	1.24 ± 0.008^{ab}	1.22 ± 0.004^{b}	1.16 ± 0.004^{c}	$F_{(4,44)} = 49.63$	**<0.001**



Ipema et al., 2022





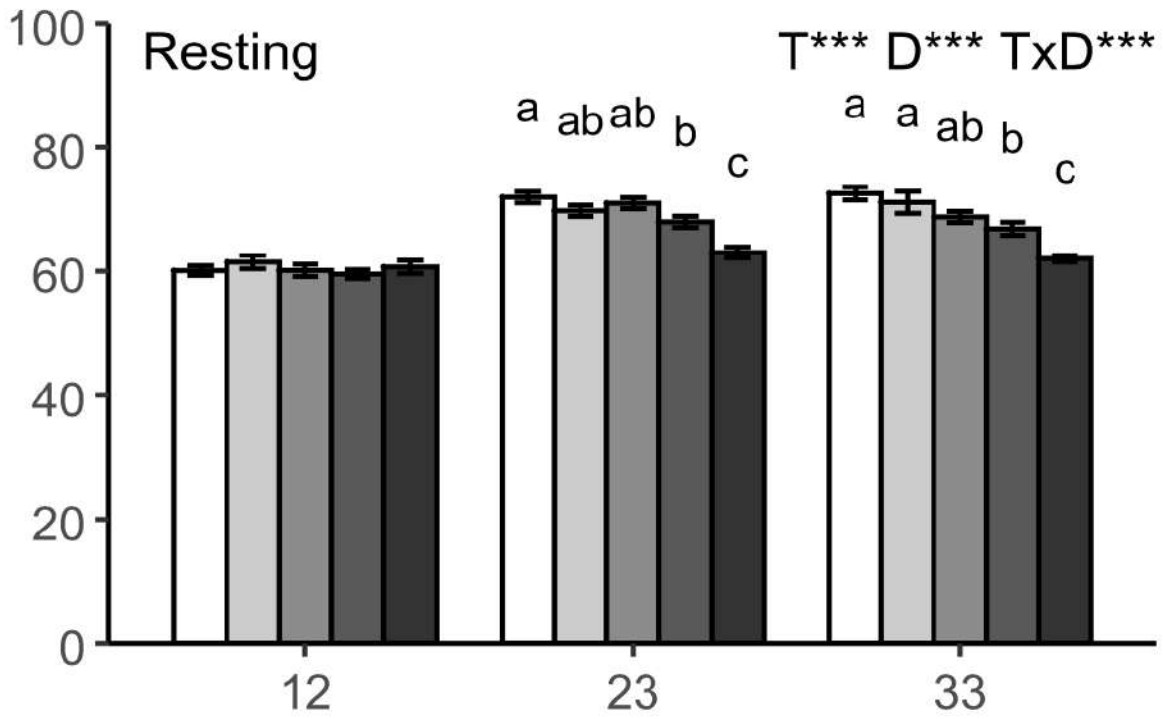
CON INC−F D−F D−S L−S

8% BSF + oil in the feed

8% dried BSF in the feeder

8% dried BSF scattered in the litter

8% Live BSF scattered in the litter



CON INC−F D−F D−S L−S

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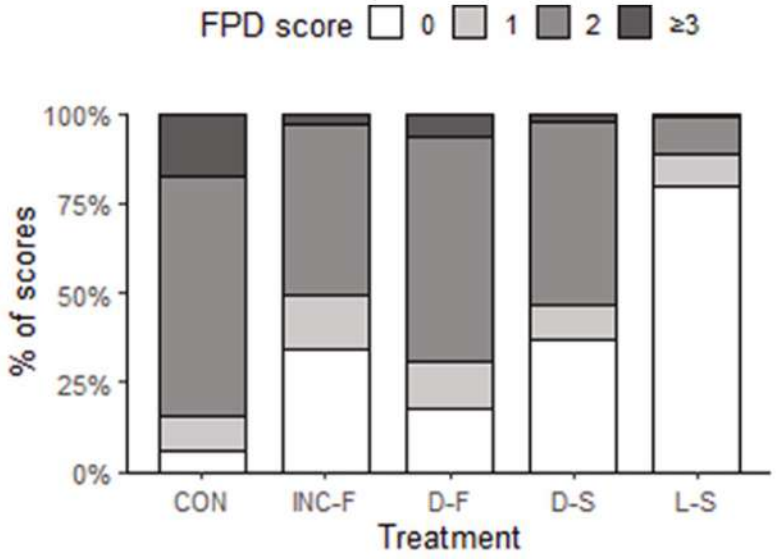
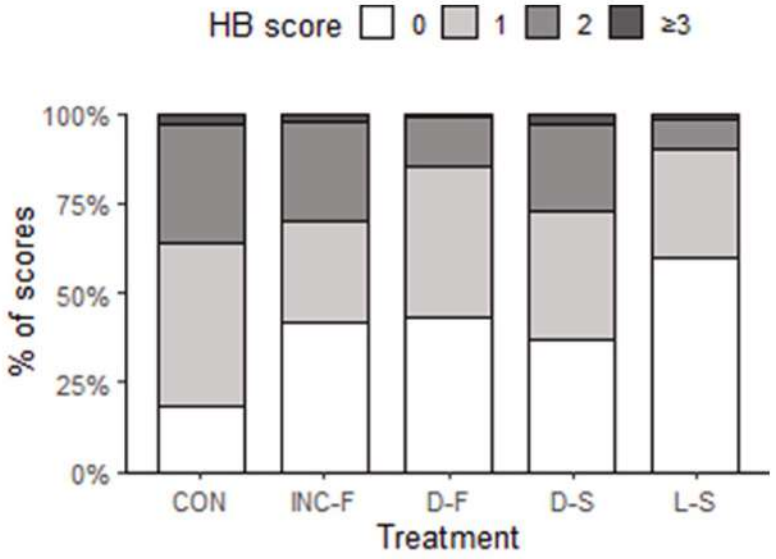
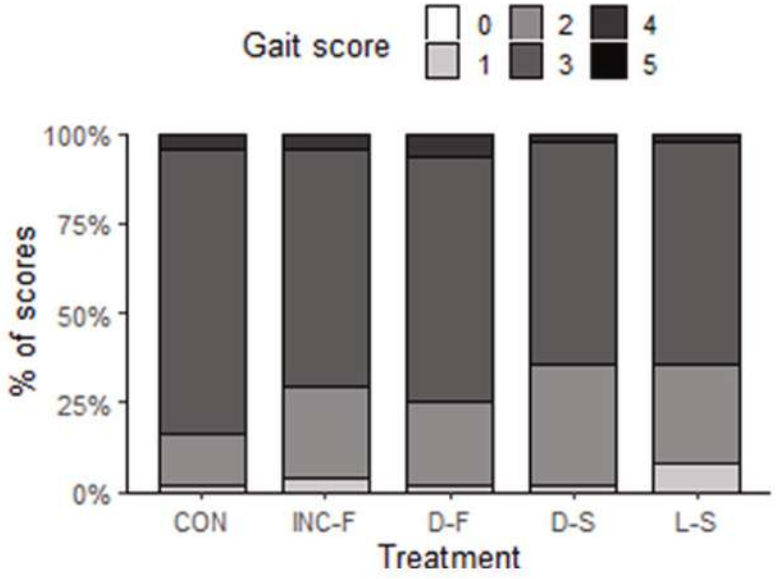
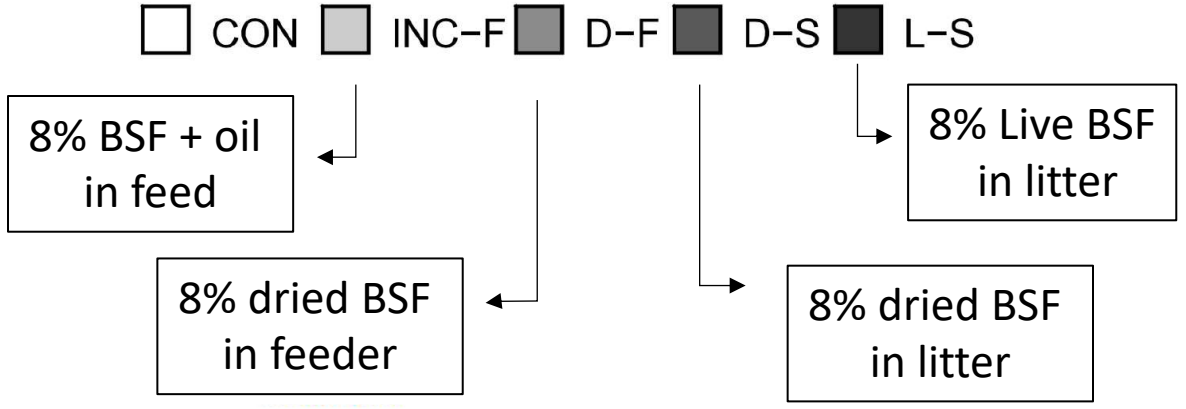


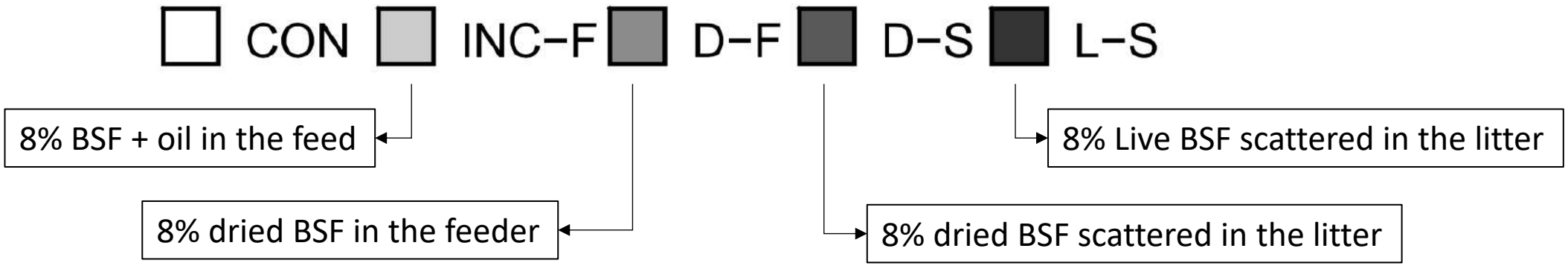






Ipema et al., 2022

Measure	CON	INC-F	D-F	D-S	L-S	Test-statistic and df	P-value
Feather CORT (pg/mm)	0.44 ± 0.13	0.24 ± 0.06	0.30 ± 0.11	0.41 ± 0.14	0.38 ± 0.12	$F_{(4,55)} = 2.76$	**0.037**

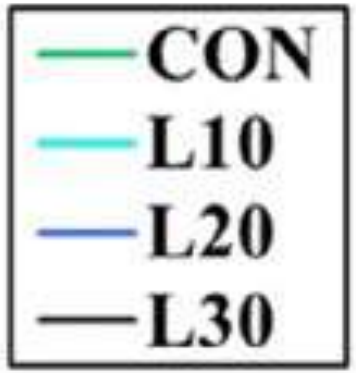


Ipema et al., 2022

Effects of increasing levels of whole Black Soldier Fly (*Hermetia illucens*) larvae in broiler rations on acceptance, nutrient and energy intakes and utilization, and growth performance of broilers

M. M. Seyedalmoosavi,* M. Mielenz ,* S. Görs,* P. Wolf,† G. Daş ,*,[1] and C. C. Metges *

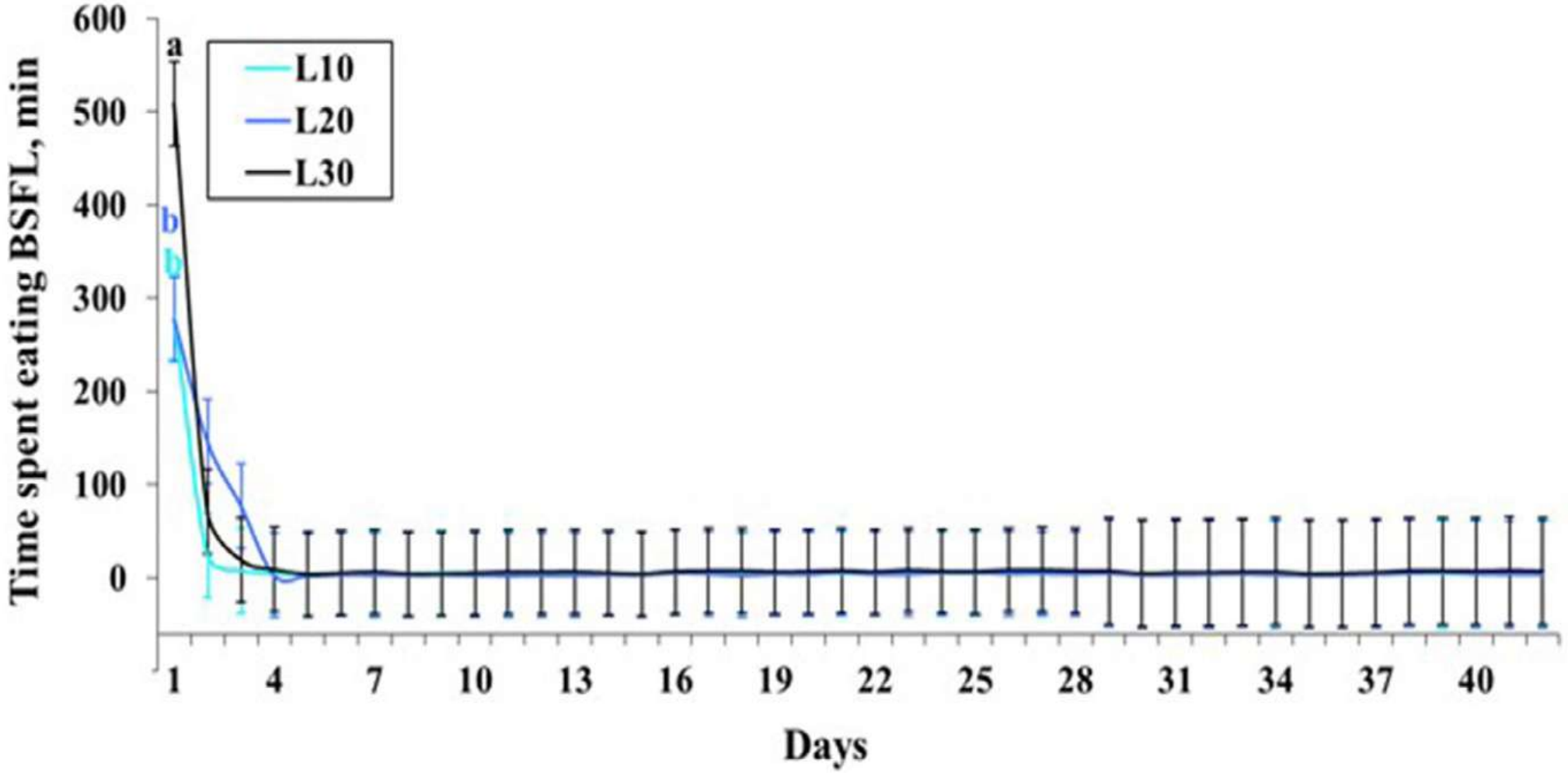
2022 Poultry Science 101:102202



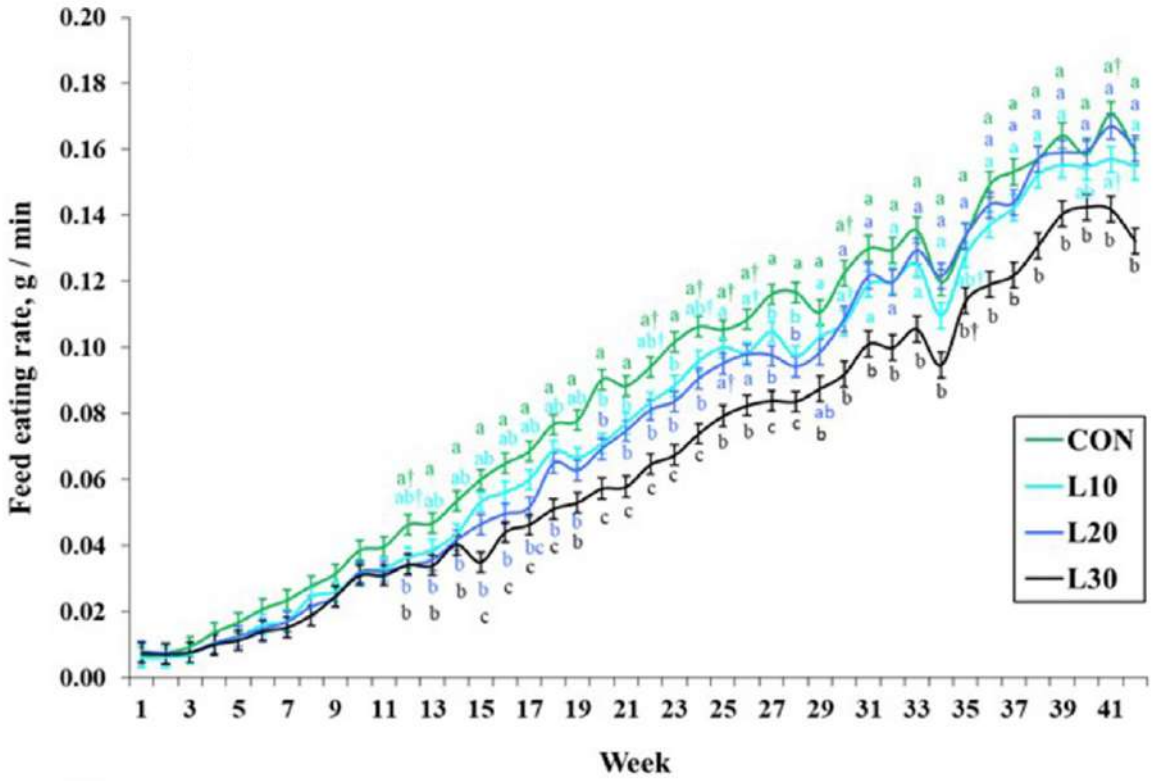
→ 10% DEFROZEN BSLF, 1 time/day

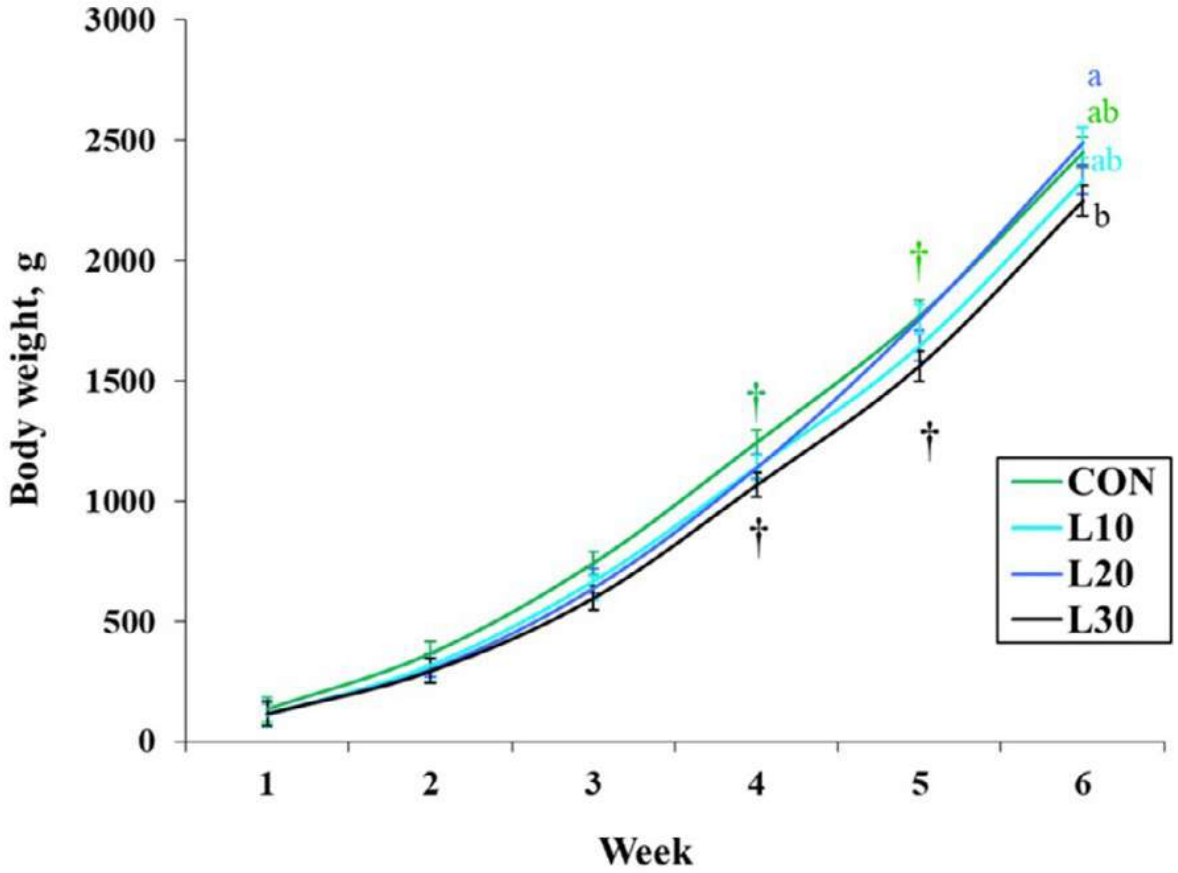
→ 20% DEFROZEN BSLF, 1 time/day

→ 30% DEFROZEN BSLF, 1 time/day



Seyedalmoosavi et al., 2022





Seyedalmoosavi et al., 2022

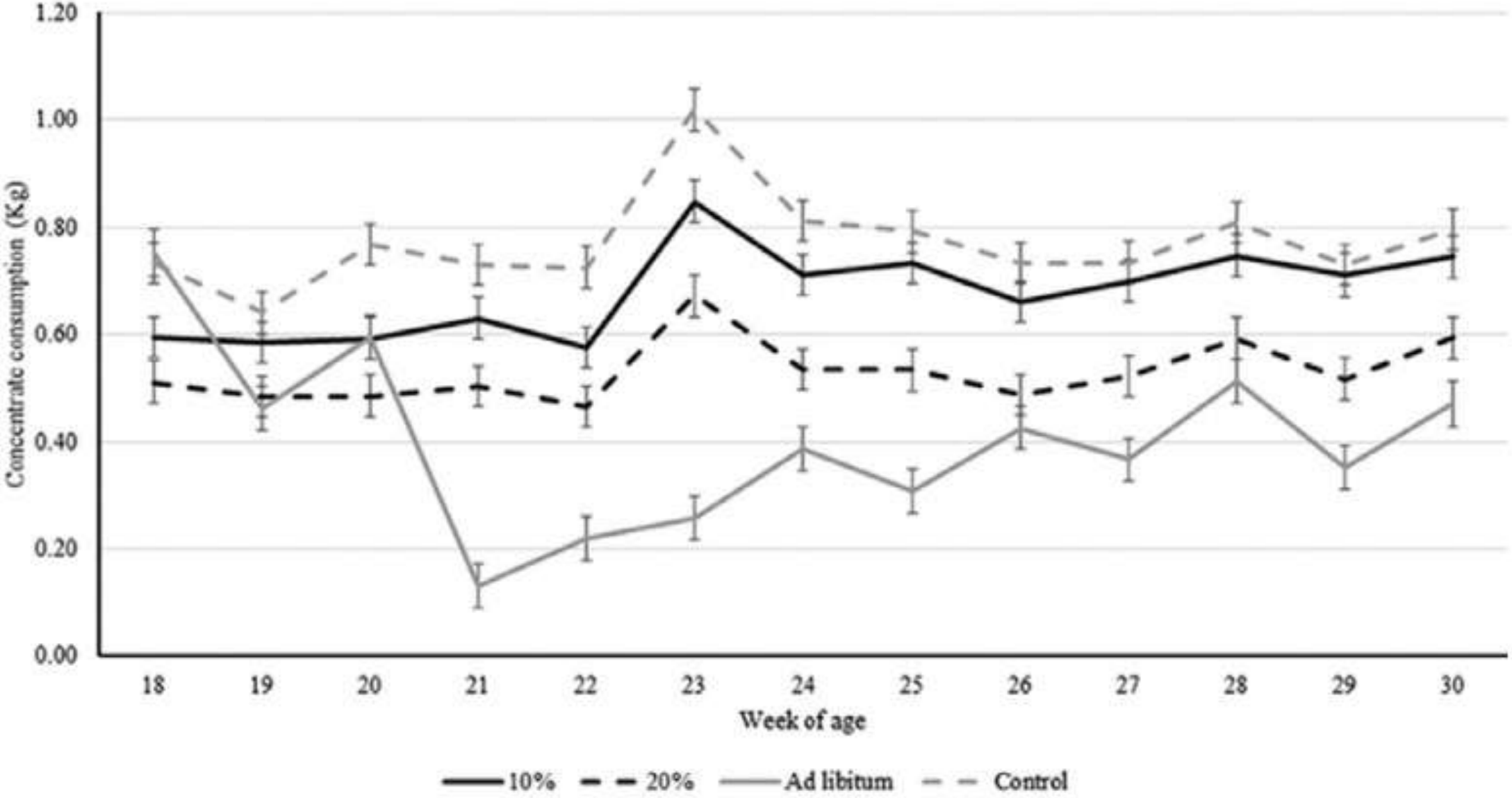
3. WHOLE INSECT LARVAE in LAYING HENS

Feeding live Black Soldier Fly larvae (*Hermetia illucens*) to laying hens: effects on feed consumption, hen health, hen behavior, and egg quality

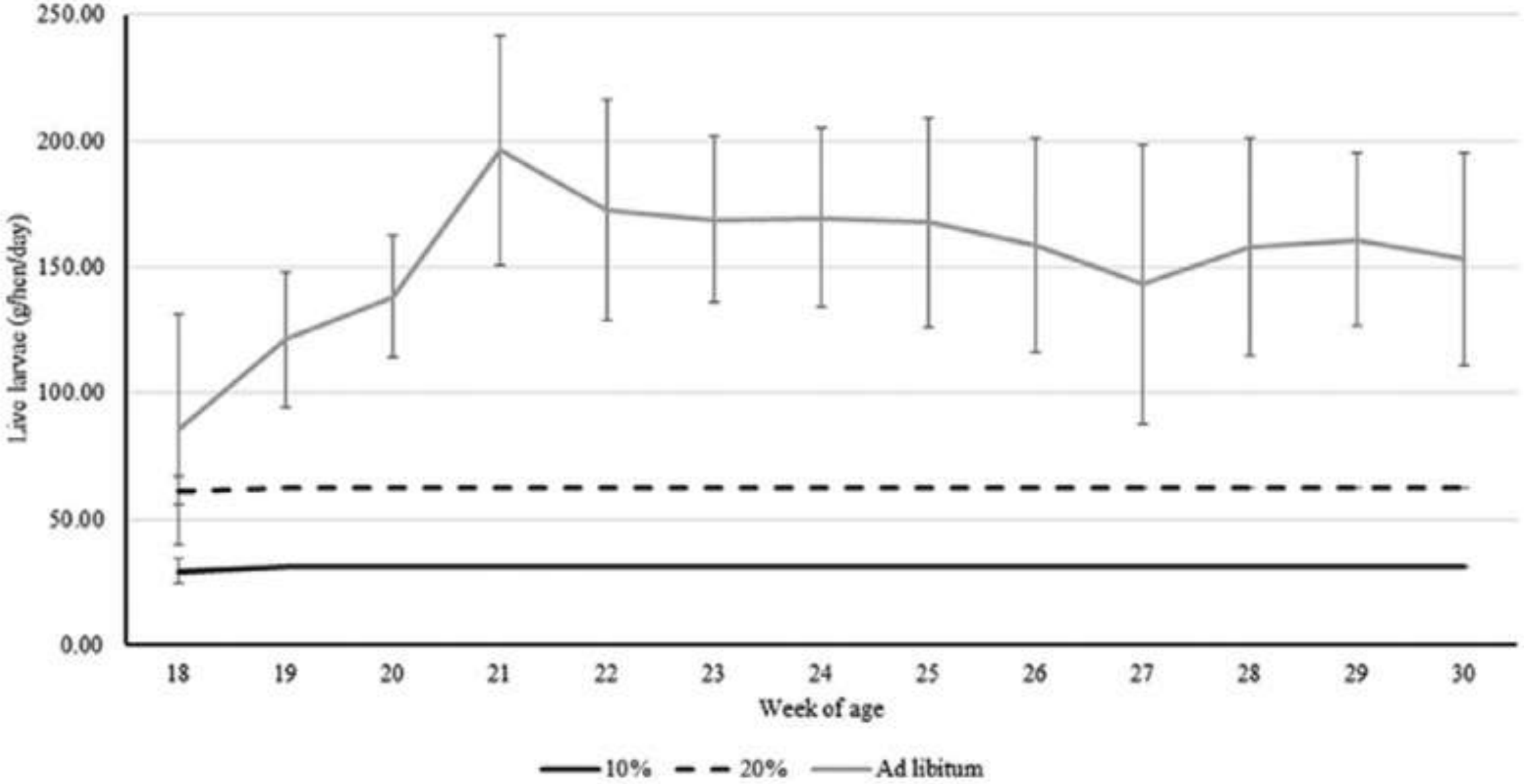
Fernanda M. Tahamtani ,*,[1,2] Emma Ivarsson,* Viktoria Wiklicky,† Cecilia Lalander ,† Helena Wall,* T. Bas Rodenburg ,‡ Frank A. M. Tuyttens,§,# and Carlos E. Hernandez *

2021 Poultry Science 100:101400

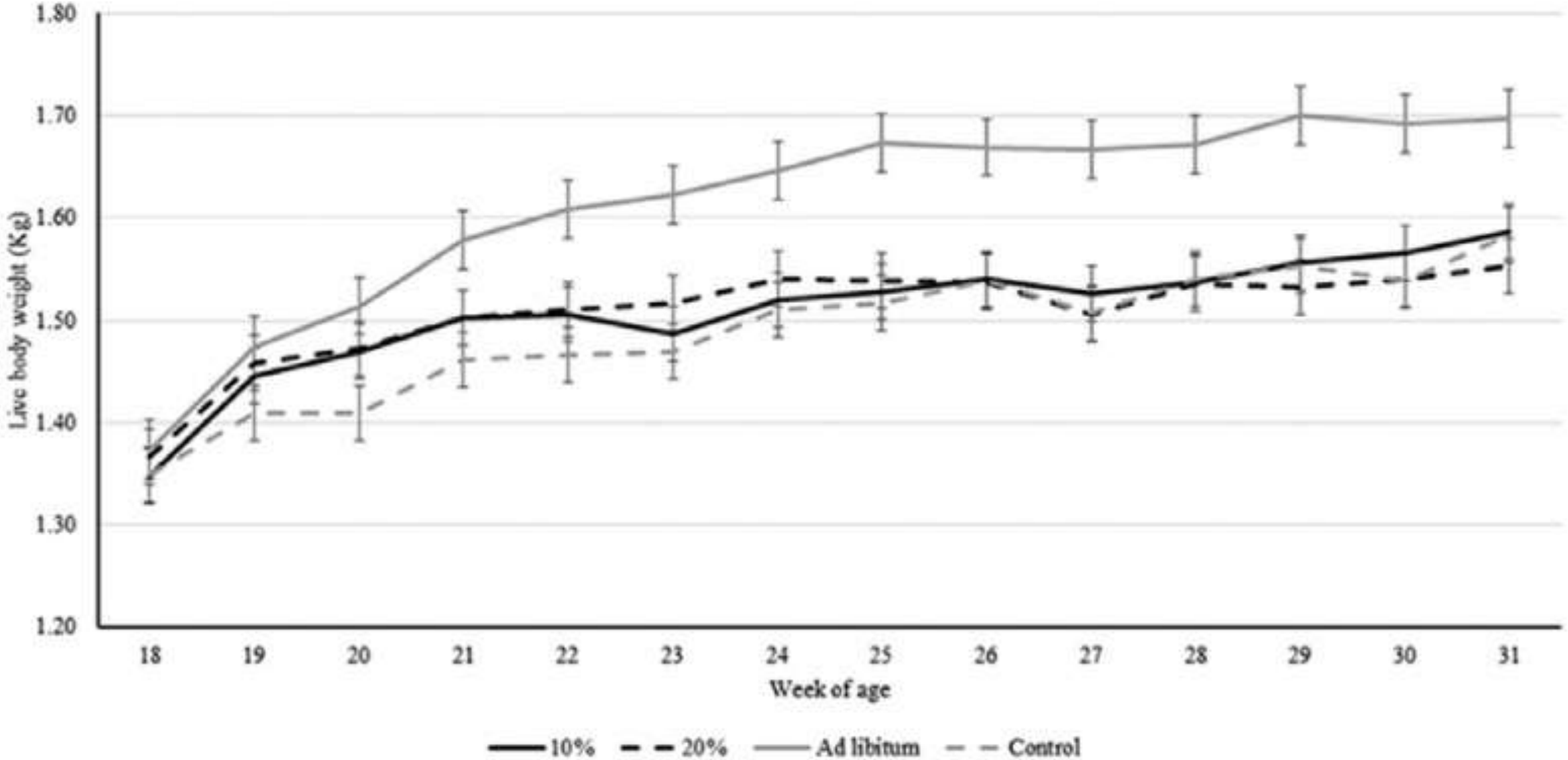
	Amount % feed basis			
Treatment	10%	20%	Ad libitum	Control



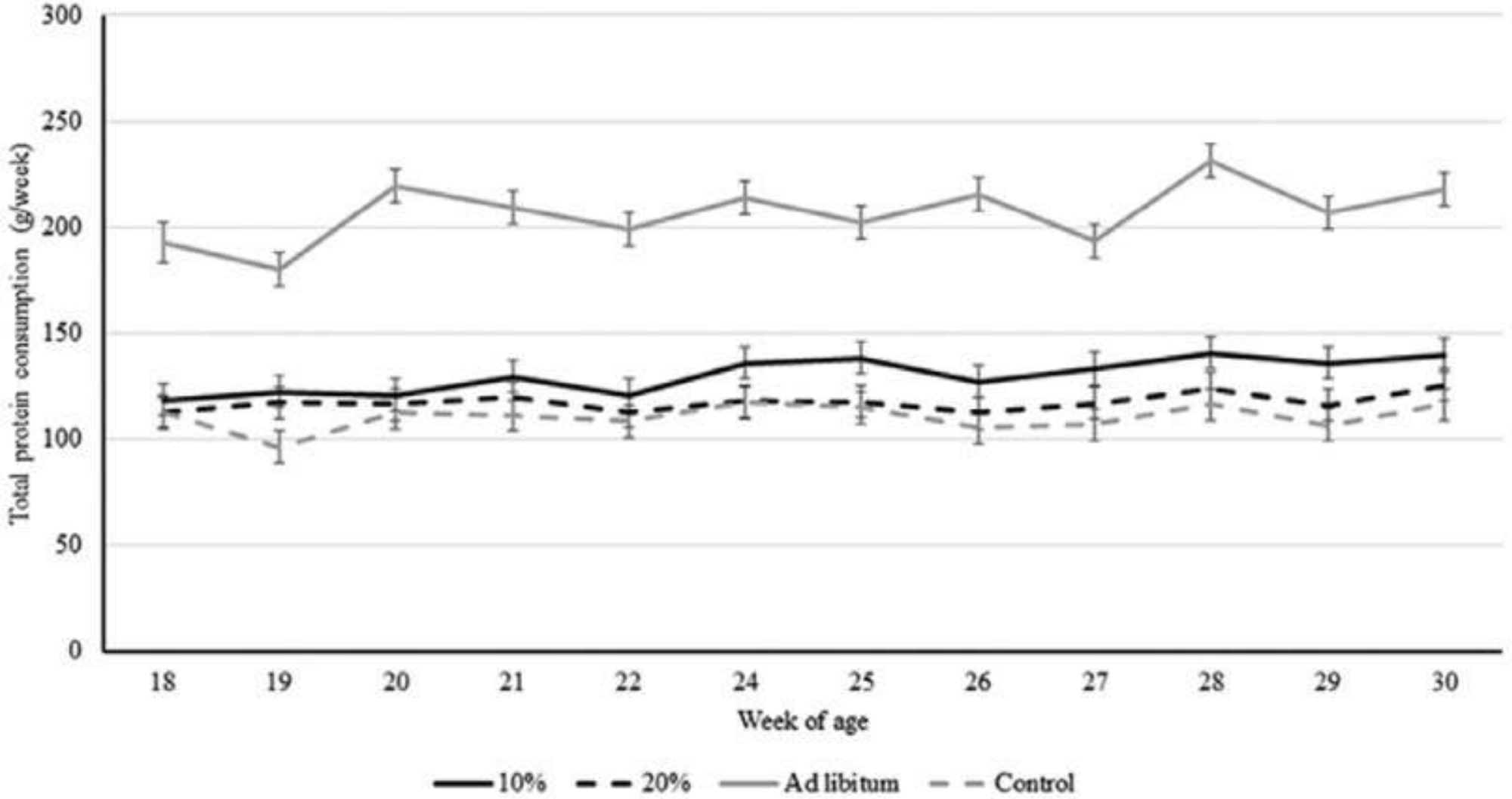
Tahamtani et al., 2021



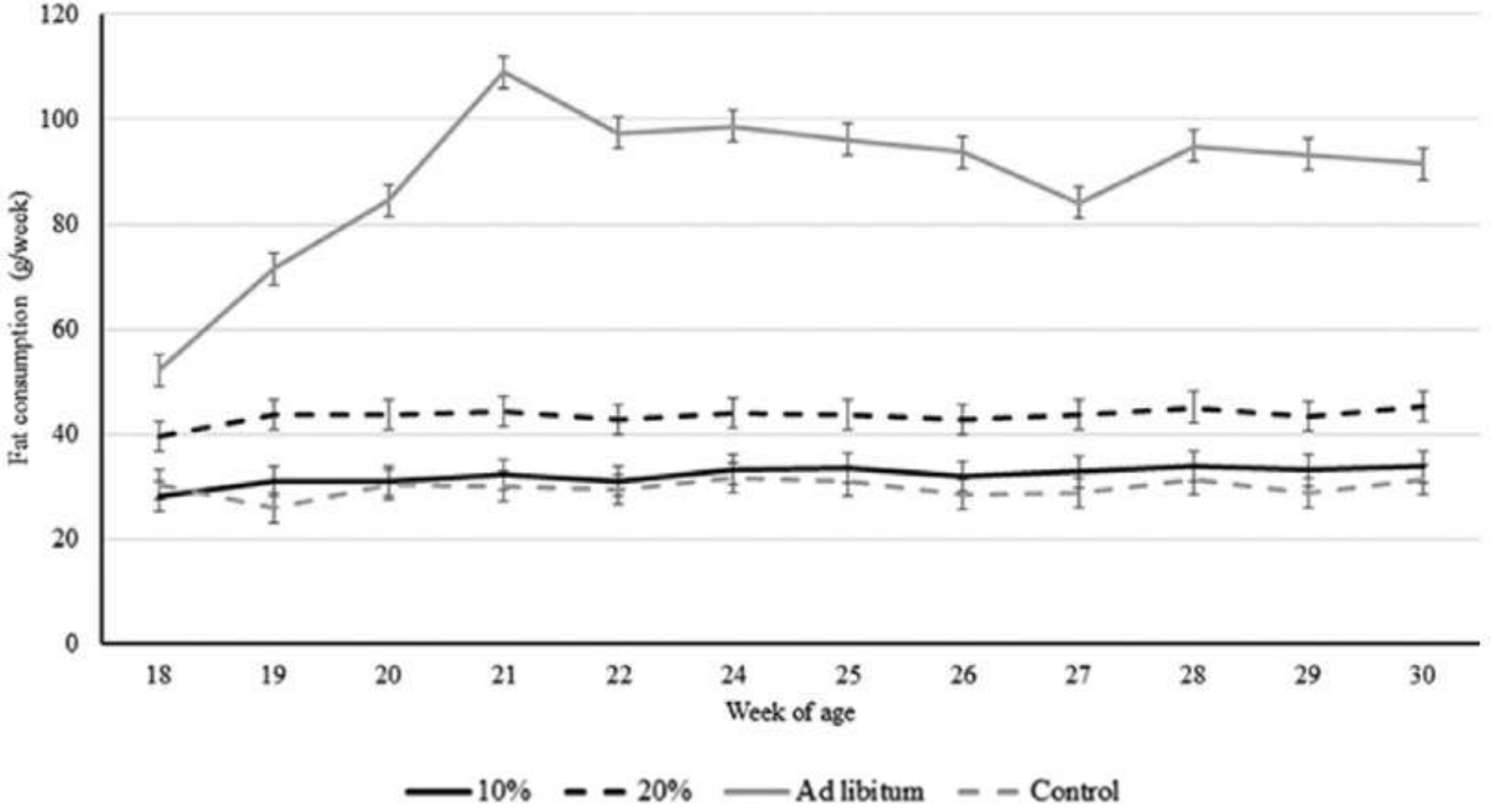
Tahamtani et al., 2021



Tahamtani et al., 2021



Tahamtani et al., 2021



Tahamtani et al., 2021

Organ	Weight ± SE (g)			
	10%	20%	Ad libitum	Control
Proventriculus	7.65 ± 0.36^{b} (0.48%)	7.66 ± 0.35^{b} (0.49%)	9.34 ± 0.39^{a} (0.55%)	7.72 ± 0.34^{b} (0.49%)
Gizzard	22.68 ± 1.00 (1.43%)	23.30 ± 1.02 (1.50%)	23.21 ± 1.10 (1.36%)	23.91 ± 0.95 (1.51%)
Liver	54.21 ± 1.95 (3.42%)	50.91 ± 1.89 (3.28%)	45.73 ± 2.12 (2.68%)	50.06 ± 1.85 (3.16%)
Abdominal fat	40.95 ± 3.86^{b} (2.58%)	47.22 ± 3.75^{b} (3.04%)	68.56 ± 4.20^{a} (4.04%)	39.74 ± 3.66^{b} (2.51%)
Live hen bodyweight	$1{,}585 \pm 37^{ab}$	$1{,}553 \pm 35^{a}$	$1{,}697 \pm 37^{b}$	$1{,}583 \pm 35^{ab}$

Tahamtani et al., 2021

There was no effect of larvae consumption on egg production, egg weight, shell thickness, shell breaking strength, or Haugh unit ($P > 0.05$).

There was also no effect on hen behavior toward a novel object or in an open field test.

Tahamtani et al., 2021

animals

MDPI

Article

Gradual Provision of Live Black Soldier Fly (*Hermetia illucens*) Larvae to Older Laying Hens: Effect on Production Performance, Egg Quality, Feather Condition and Behavior

Laura Star [1], Tarique Arsiwalla [2], Francesc Molist [1], Raymond Leushuis [2], Monika Dalim [2] and Aman Paul [2,*]

Animals **2020**, *10*, 216; doi:10.3390/ani10020216

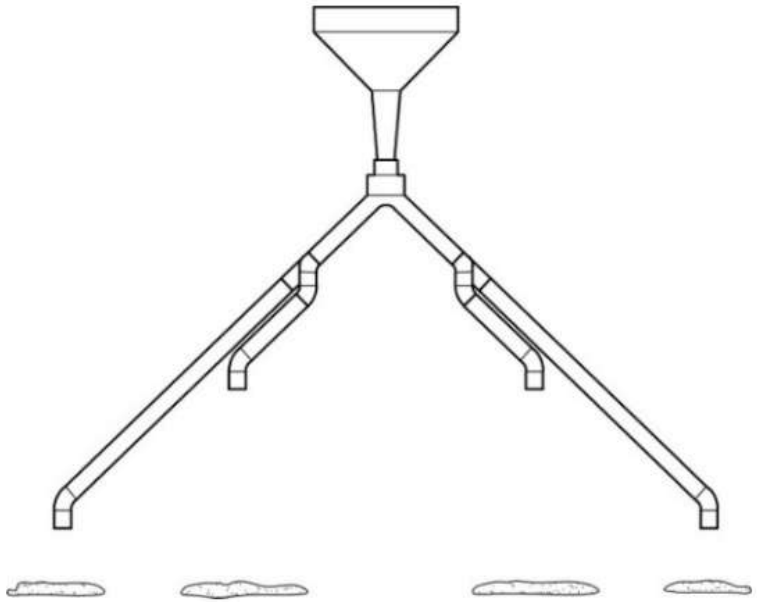


Figure 1. Live black soldier fly larvae dispenser.

Table 1. Nutritional composition of live larvae (as in basis, provided by supplier).

Nutrients	Live Larvae
Moisture (g/kg)	700.0
Crude protein (g/kg)	135.0
Crude fat (g/kg)	105.0

Star et al., 2020

Table 6. Total crude protein and fat intake by laying hens fed with a commercial diet (Group A) or a soy-free diet + live larvae (Group B) from 67 to 78 weeks of age (as in basis).

Parameters	Group A	Group B
Nutrient composition of diets [1]		
Crude protein (g/kg)	158.0	160.0
Crude fat (g/kg)	50.0	48.3
Energy (kcal/kg)	2800.0	2800.0
Nutrient composition of larvae [2]		
Crude protein (g/kg)	-	135.0
Crude fat (g/kg)	-	105.0
Total feed and nutrient intake		
Feed intake (g/h/d)	133.1	123.3
Larvae intake (g/h/d)	0	12.0
Crude protein intake (g/d)	21.0	21.3
Crude fat intake (g/d)	6.66	7.21

Table 7. Body weight (g) of laying hens fed a commercial diet (Group A) or a soy-free diet + live larvae (Group B) from 67 to 78 weeks of age.

Treatment	67 Weeks (g)	78 Weeks (g)
Group A	1669	1660
Group B	1664	1675
SEM [1]	11.1	16.2
p-value	0.752	0.529

Star et al., 2020

Table 5. Production performance and mortality rate of laying hens fed a commercial diet (Group A) or a soy-free diet + live larvae (Group B) from 67 to 78 weeks of age.

Treatment	Feed Intake [2] (g/h/d)	Laying Rate (%)	Egg Weight (g)	Egg Mass (g/d)	Mortality (%)	Feed Conversion Ratio (g/g)
Group A	133 [a]	83.3	63.11	52.58	2.8	2.534
Group B	123 [b]	81.9	63.32	51.79	1.1	2.391
SEM [1]	2.538	1.893	0.153	1.193	0.845	0.0238
p-value	0.029	0.601	0.353	0.657	0.197	0.004

Star et al., 2020

Table 9. Feather condition score of laying hens fed a commercial diet (Group A) or a soy-free diet + live larvae (Group B) from 67 to 78 weeks of age.

Treatment	Feather Score [2]	
	67 Weeks (g)	78 Weeks (g)
Group A	3.4	2.9 [a]
Group B	3.6	2.2 [b]
SEM [1]	0.077	0.107
p-value	0.060	0.004

Star et al., 2020

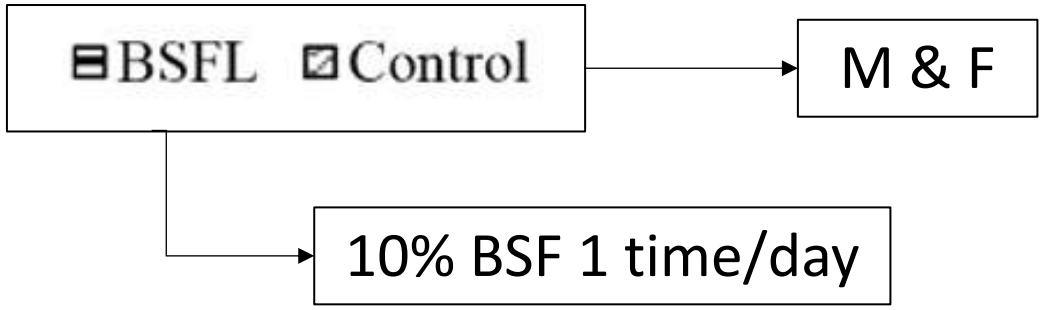
4. WHOLE INSECT LARVAE in SLOW GROWING CHICKENS

Black soldier fly larvae used for environmental enrichment purposes: Can they affect the growth, slaughter performance, and blood chemistry of medium-growing chickens?

Valentina Bongiorno[1], Marta Gariglio[1]*, Valeria Zambotto[2], Eleonora Erika Cappone[1], Ilaria Biasato[3], Manuela Renna[1], Claudio Forte[1], Carl Coudron[4], Stefania Bergagna[5], Francesco Gai[2] and Achille Schiavone[1]

frontiers | Frontiers in Veterinary Science
PUBLISHED 14 December 2022
DOI 10.3389/fvets.2022.1064017

Proximate composition, g/100 g on an as fed basis	Values[a]
DM	33.63
CP	14.39
EE	9.56
Ash	4.34
Chitin	2.00
GE, MJ/kg	8.69



Bongiorno et al., 2022

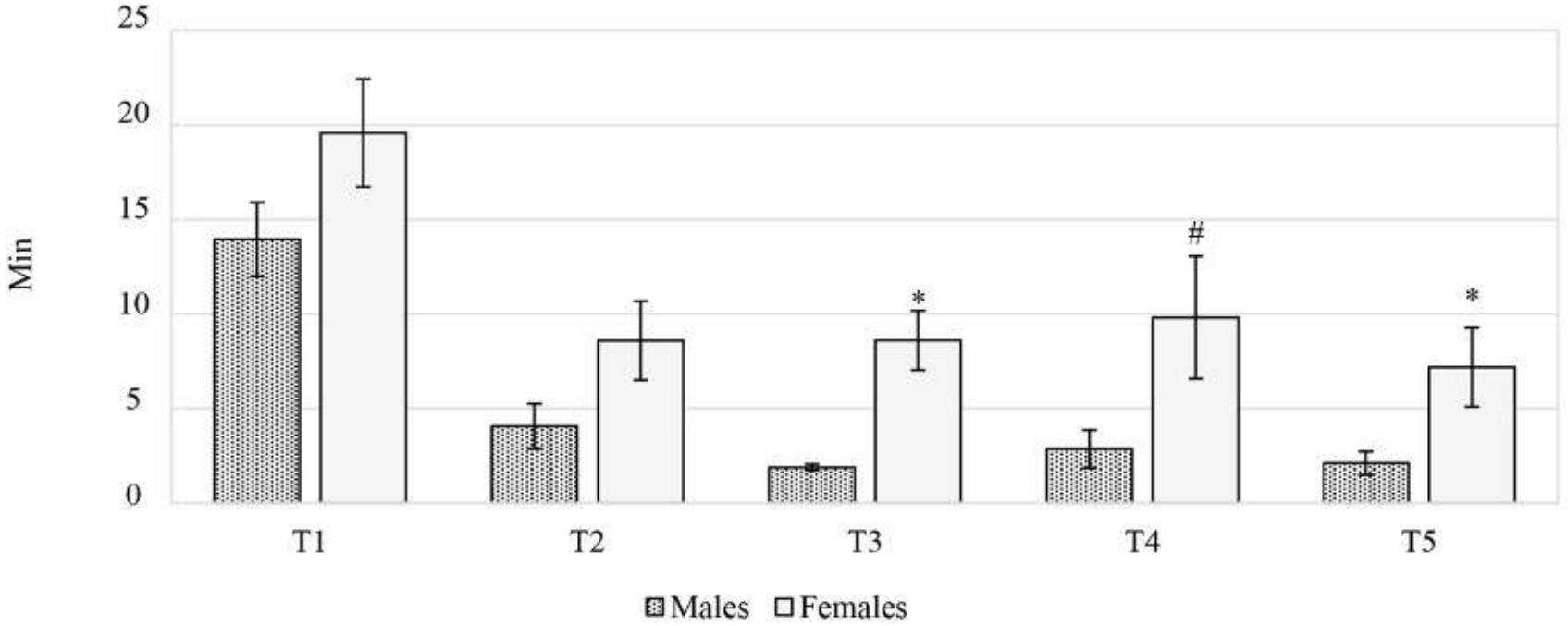
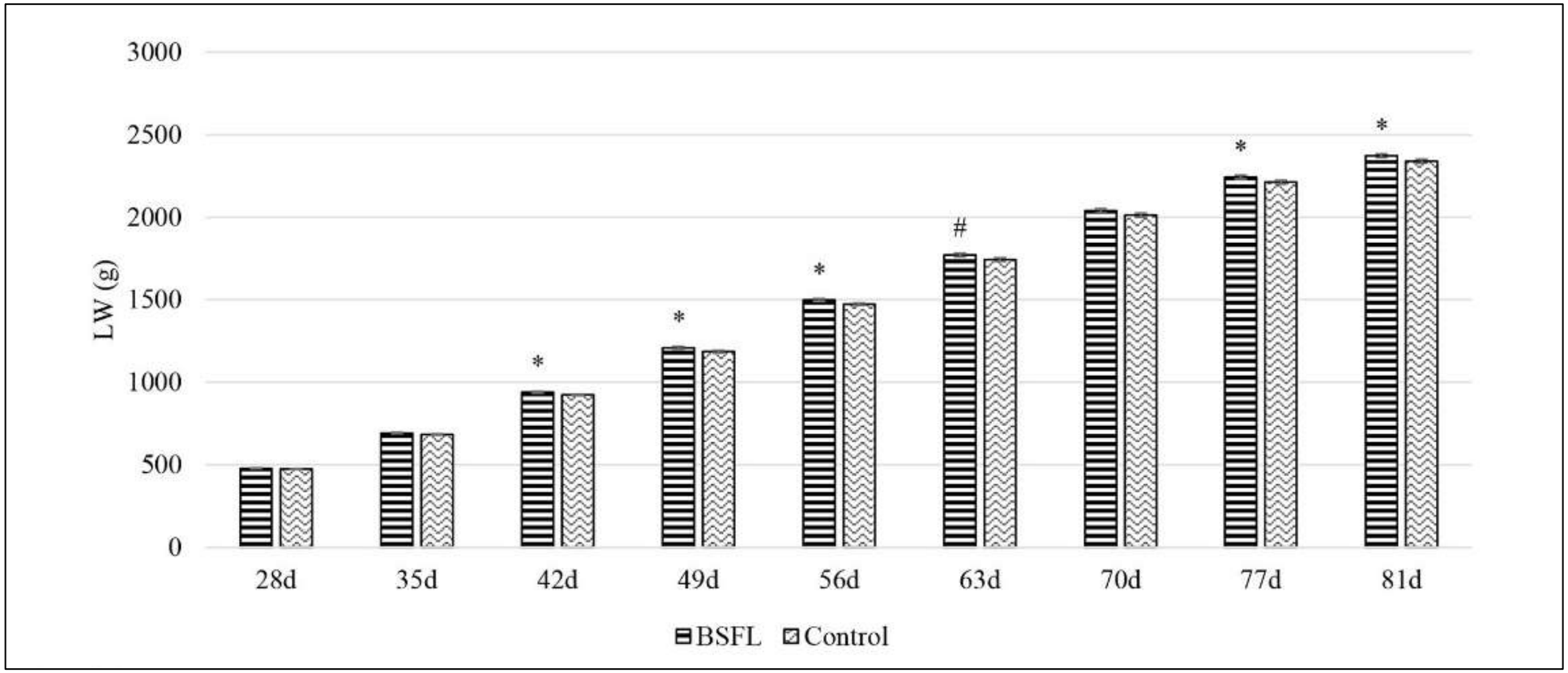


FIGURE 3
The time spent by the Label Rouge Naked Neck birds on eating live black soldier fly larvae ($n = 10$). *$P \leq 0.05$; #$P \leq 0.10$. T1, 28–39 days of age; T2, 40–50 days of age; T3, 51–62 days of age; T4, 63–74 days of age; T5, 75–81 days of age.

BSFL Control

10% BSF 1 time/day

Bongiorno et al., 2022



BSFL Control

10% BSF 1 time/day

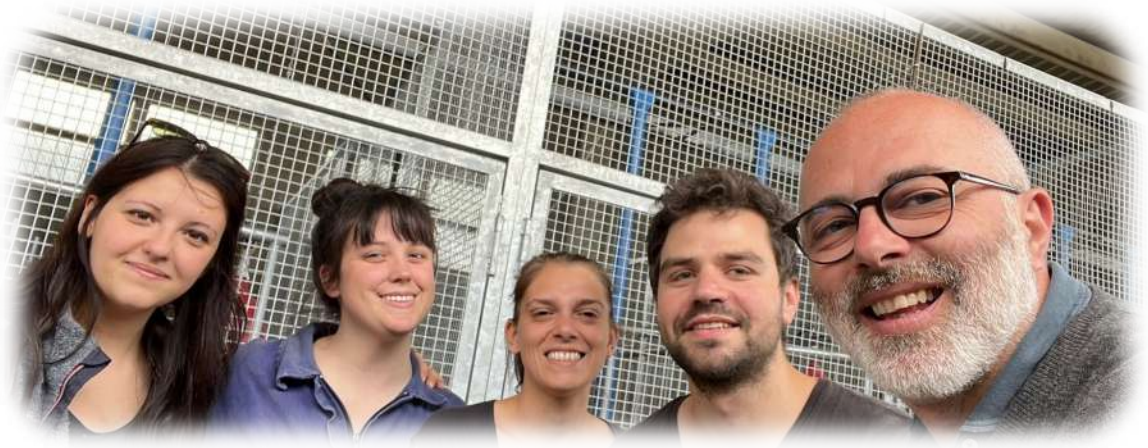
Bongiorno et al., 2022

PS2 - Nutritional intervention for climate changes

PS2-011 - **Growth and slaughtering performance of a local chicken breed fed dried and live Black soldier fly larvae as environmental enrichment**

E. Fiorilla, M. Gariglio, V. Bongiorno, E.E. Cappone, V. Zambotto, F. Gai, J. Cortes, C. Coudron, I. Biasato, A. Schiavone

- C
- P → Alternative Protein sources
- PE → P+ 4% DM dried BSFL, 1 time/day
- PL → P+ 4% DM live BSFL, 1 time/day



23rd European Symposium on Poultry Nutrition

ESPN 2023

Whole larvae in autochthonous chicken breeds

Piedmont

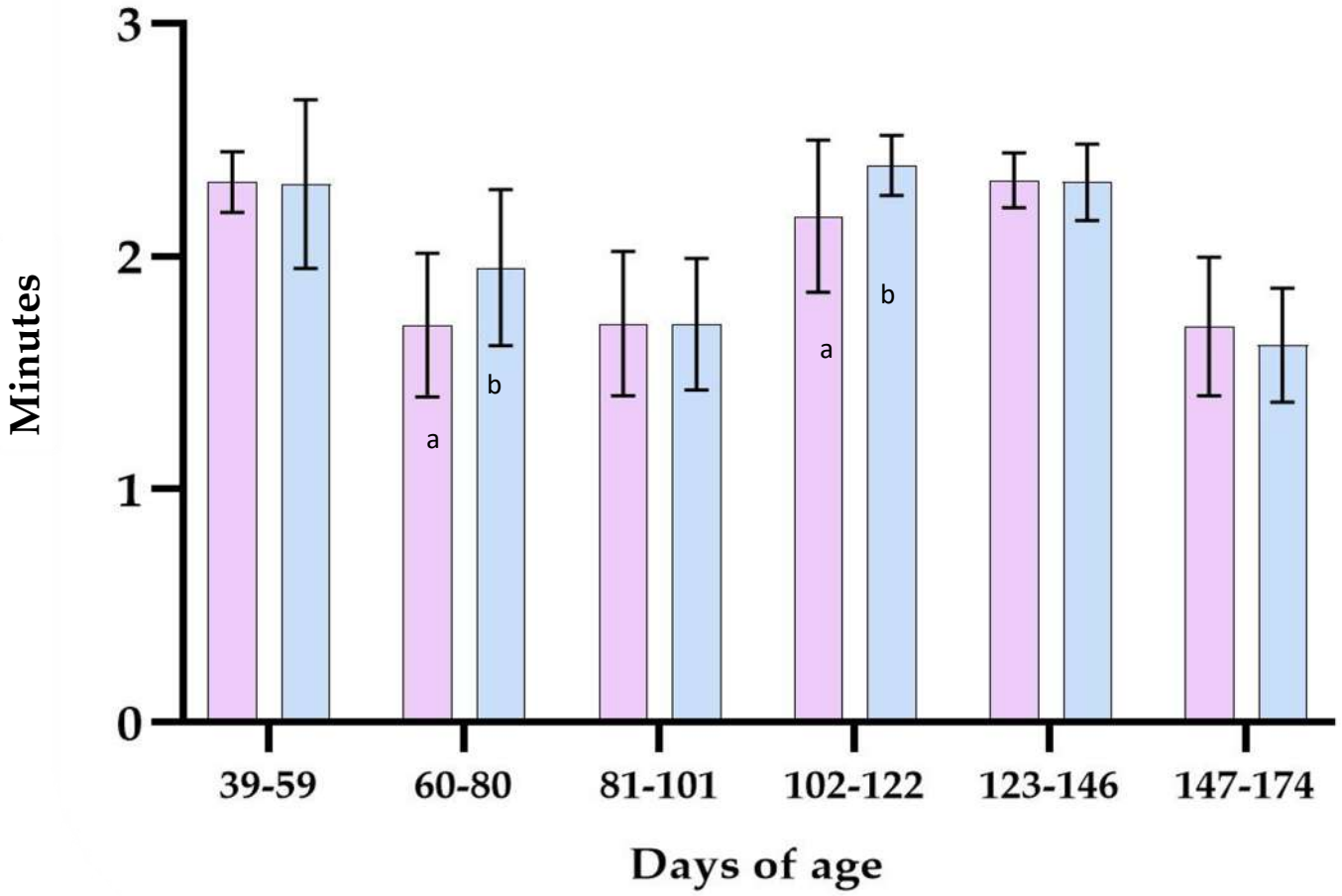
Biondа Piemontese

Millefiori Piemontese

Bianca di Saluzzo

Slow Food®

Larvae **consumption** time



PE — P + 4% DM dried BSFL

PL — P+ 4% DM live BSFL

Fiorilla et al., 2023

5. WHOLE INSECT LARVAE in OTHER AVIAN SPECIES

		BIRD'S AGE (Days)	INSECT INCLUSION	INSECT DISTRIBUTION	EFFECTS ON BIRD
	BSF	0 to 35	10 % DFI	Once	Increased daily feed intake and body weight gain; lower feed conversion ratio; reduced aggressive pecking; a tendency of lowered incidence of feather and skin damage (Veldkamp & van Niekerk 2019)
	Dried maggot	308 to 357	50 g	Three times	Preference for cereal grains rather than dried maggots (Traore et al. 2020)
	Live BSF Live YMW	3 to 62	5% DFI	Once	Reduced H/L ratio; reduced fecal corticosterone (Gariglio et al. *submitted*)

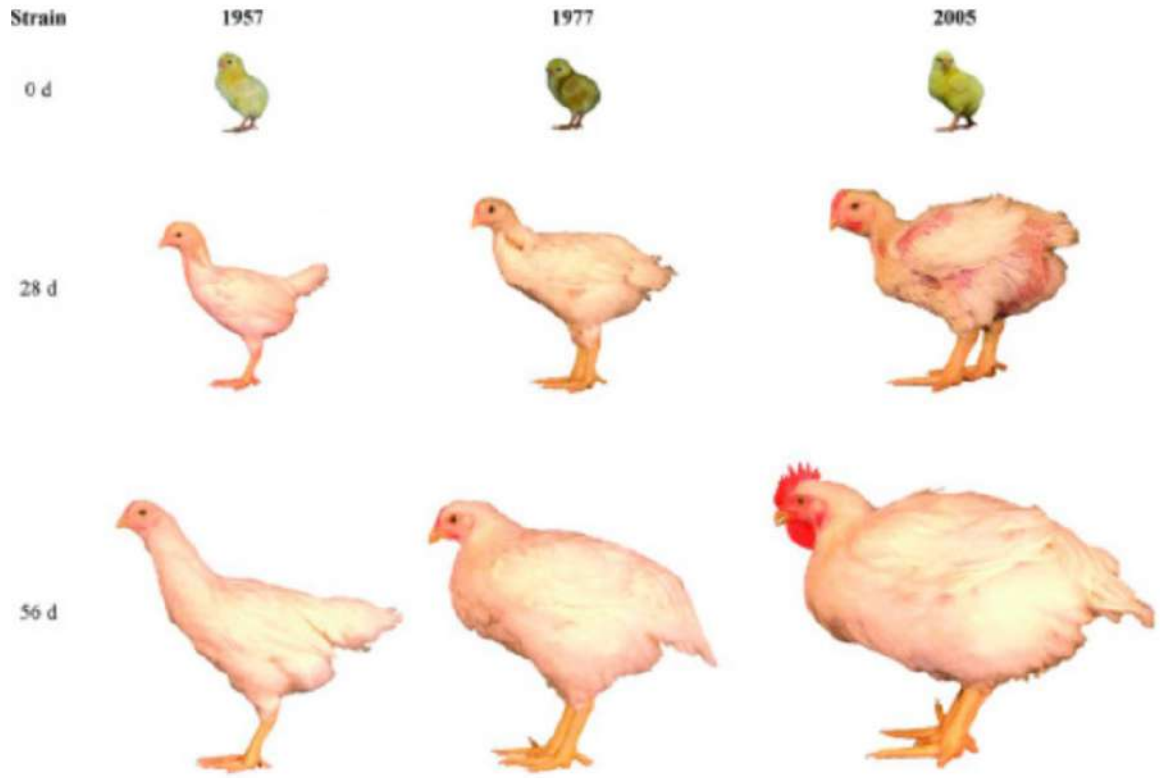
6. CONCLUSION AND RECOMENTADTION

FUTURE PERSPECTIVE

- ✓ POULTRY GUT HEALT
- ✓ DRIED LARVAE THE BEST? (no water transport, easy storage and handling, biosecurity, etc.)
- ✓ TOOLS FOR LARVAE ADMINISTRATION
- ✓ DIGESTIBILITY TEST IN POULTRY
- ✓ POULTRY PRODUCT QUALITY
- ✓ WELFARE RELATED TO AVIAN GENOTYPE and ADMINISTRATION SYSTEM
- ✓ GAMEBIRDS?

CONCLUSIONS

- ✓ IN CHICKENS DRIED/FROZEN LARVAE ACCEPTABILITY SIMILAR TO LIVE LARVAE
- ✓ WHOLE LARVAE STIMULATES BROILER CHICKEN ACTIVITY
- ✓ WHOLE LARVE IMPROVE RELATIONSHIP BETWEEN HUMANS AND CHICKENS
- ✓ WHOLE LARVAE PROMISING TO IMPROVE AVIAN BEAHVIOUR and WELFARE



THE BROILER CHICKEN IS STILL A BIRD!

SUSTAvianFEED

POULTRYNSECT

THANK YOU FOR ATTENTION!

achille.schiavone@unito.it