From waste to value: the use of black soldier fly larvae in agrofood waste management to produce protein and promote circular bioeconomy

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Royaume du Maroc
Ministère de l'Enseignement Supérieur, de la Recherche Scientifique et de l'Innovation

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

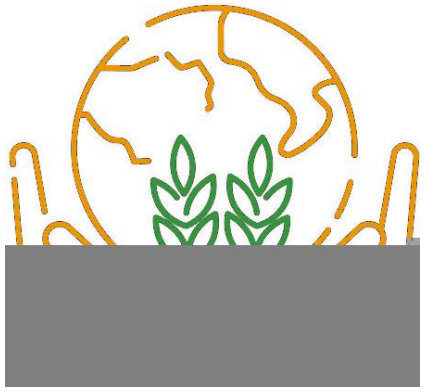
The PRIMA programme is supported and funded under Horizon 2020, the Framework European Union's Programme for Research and Innovation

Main problematics in mediterranean agriculture

Urbanization pressure

Climate change

Inefficient OWM



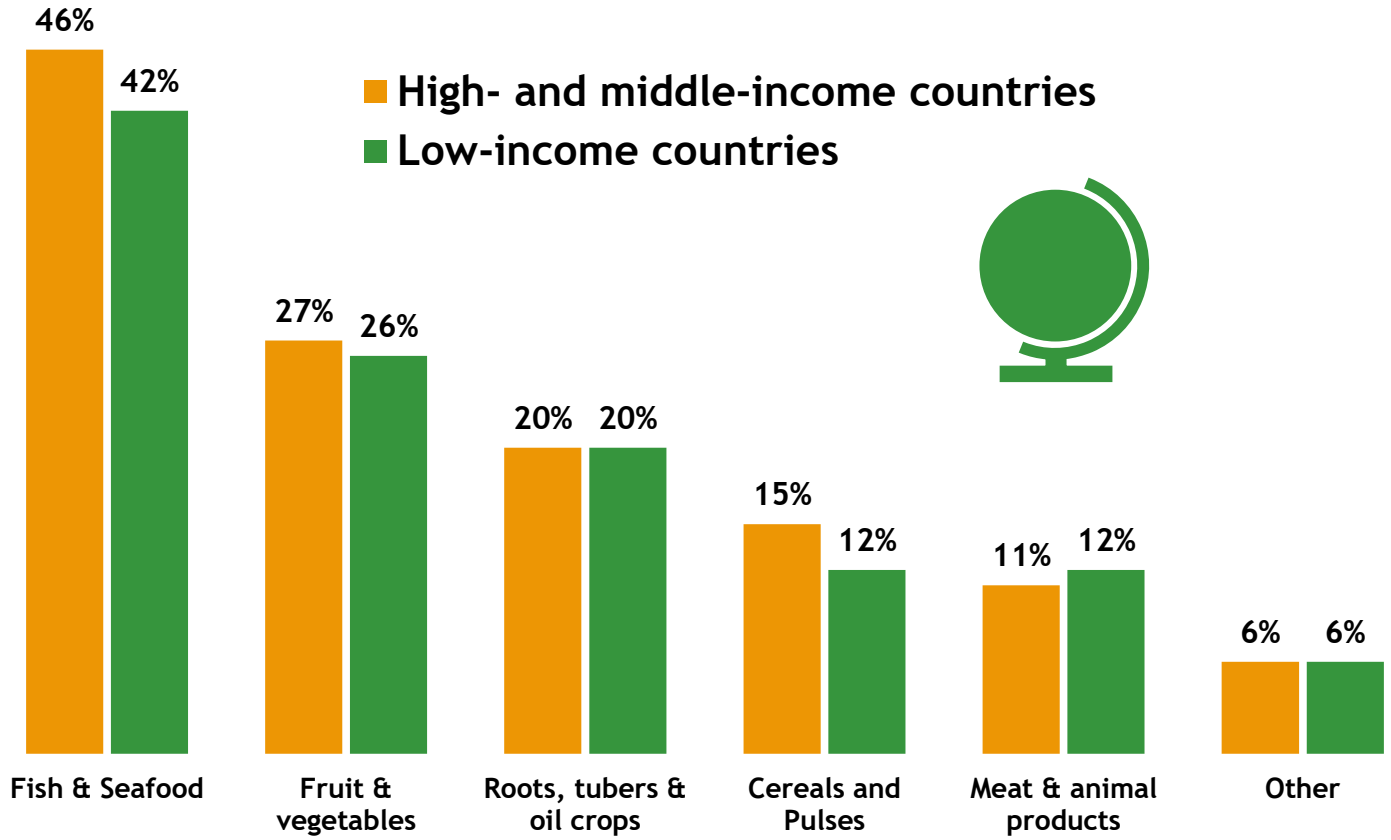
Food insecurity

Policy & governance gaps

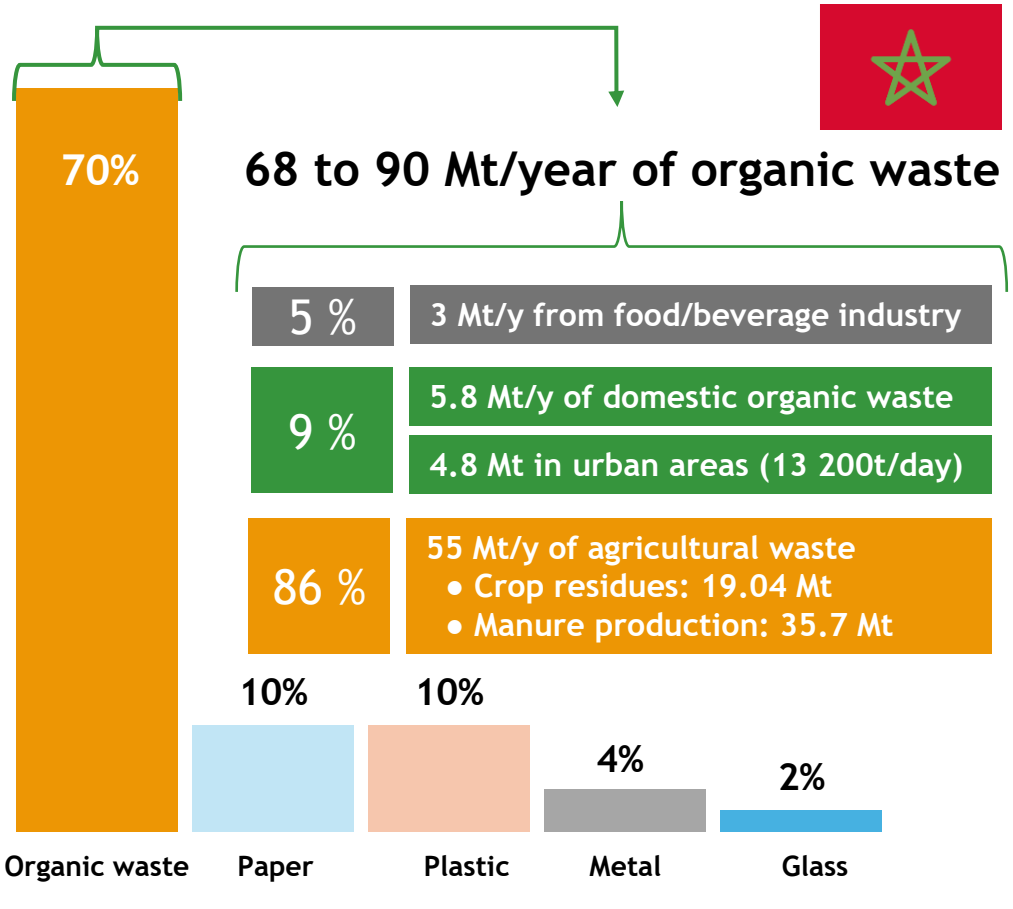
Limited digital integration

Current status of organic waste management

Percentage of farm food waste by sector as % total food production



Distribution of the estimated organic waste in Morocco



Insect rearing … 3 in 1

3 aims:

1. Organic waste management
2. Production of alternative protein
3. Production of frass (biofertilizer)

Insects as a tool for organic waste management

Feed on urban agro-industrial byproducts and organic waste

Water economy to produce protein

Up to 18 m^2 to produce 1 kg of protein

2 g CO_2 to produce 1 kg of biomass

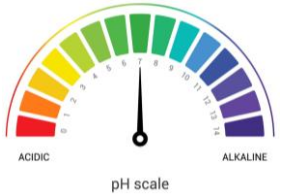
Safe as food, feed and fertilizer

Highly nutritious
High value byproducts

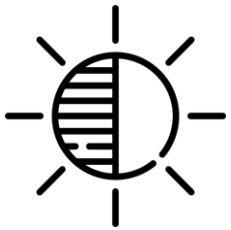
What are their requirements ?

Temperature: 27-32˚C

Humidity: 60-70%



pH 6 to 8



Minimal and non during rearing

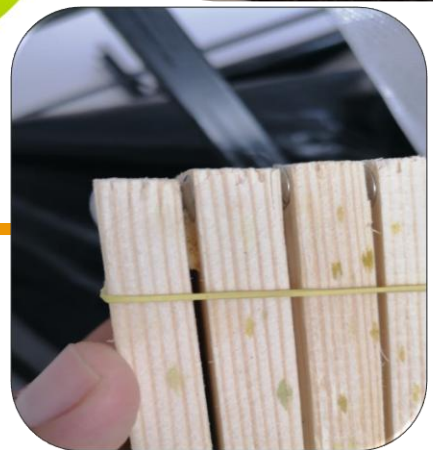
Good cages and units and good ventilation

Substrate types recommended:

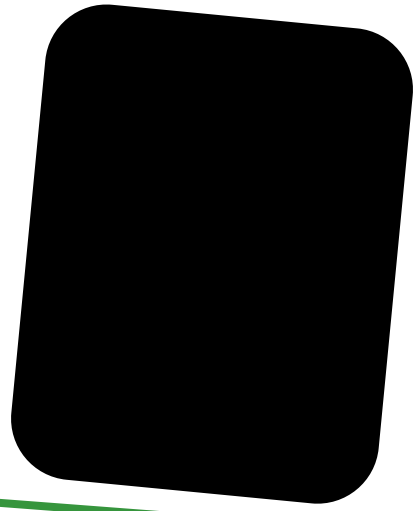
- Fruit and vegetable waste,
- Restaurant and household food waste,
- Agricultural residues such as straw, soybean curd and brewery waste.
- … etc.

Pilot production unit for insect rearing

Green
Development and Innovation



Process of insect-based organic waste management



BSF larvae fed agricultural and agro-industrial waste

1

BSF Egg-incubation for hatching

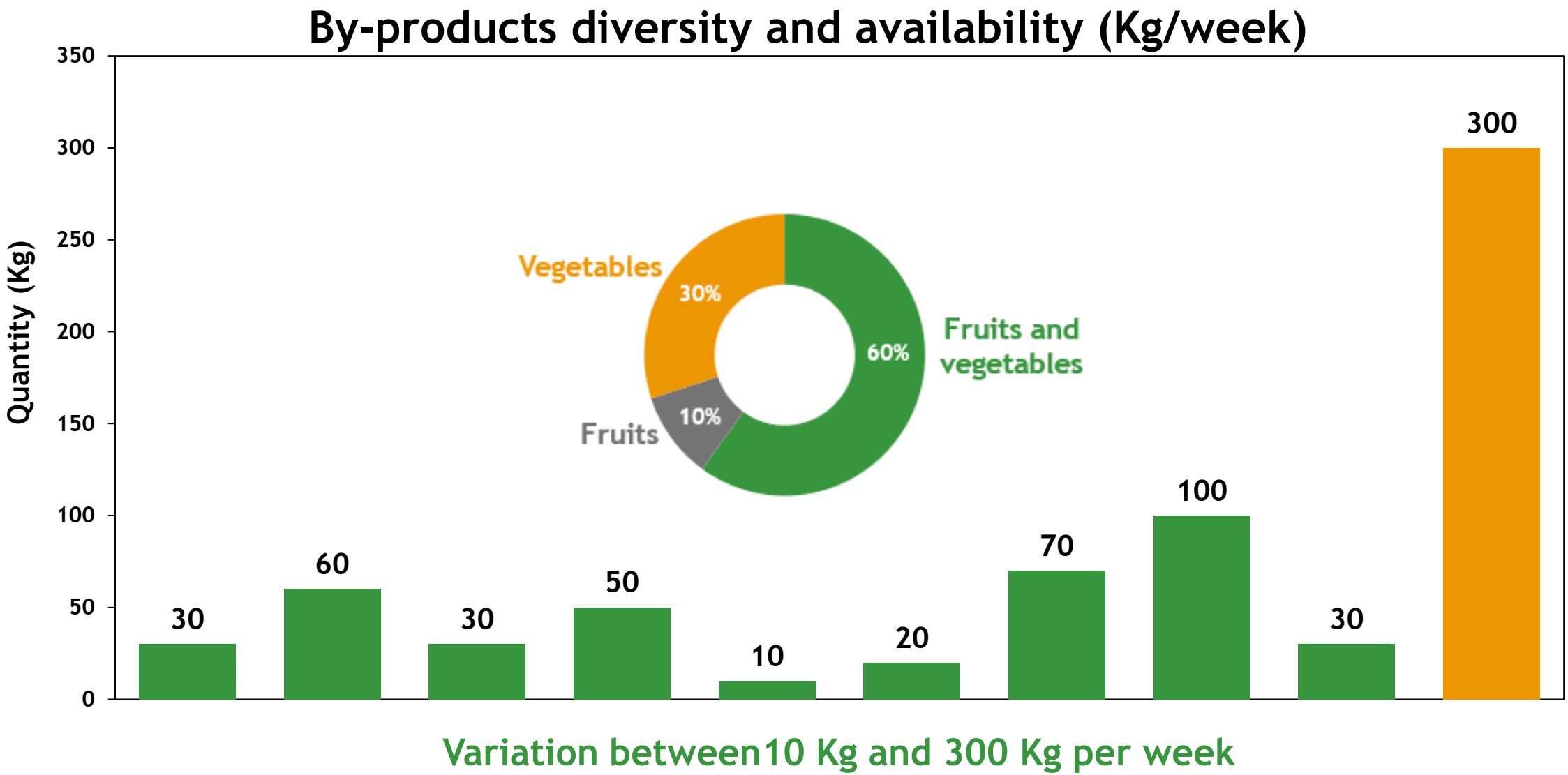
BSF Egg-laying process

BSF pupae in the black cage for adult emergence

Larval growth until pupae stage

2 3 4 5 6

Assessment of organic byproducts for rearing



Variation between10 Kg and 300 Kg per week

Collected organic waste from local markets

Sorting and analysis of nutritional composition

10 species were identified

10 km radius

Green pepper

Pumpkin

Beetroot

Orange

Turnip

Banana

Eggplant

Carrots

Apples

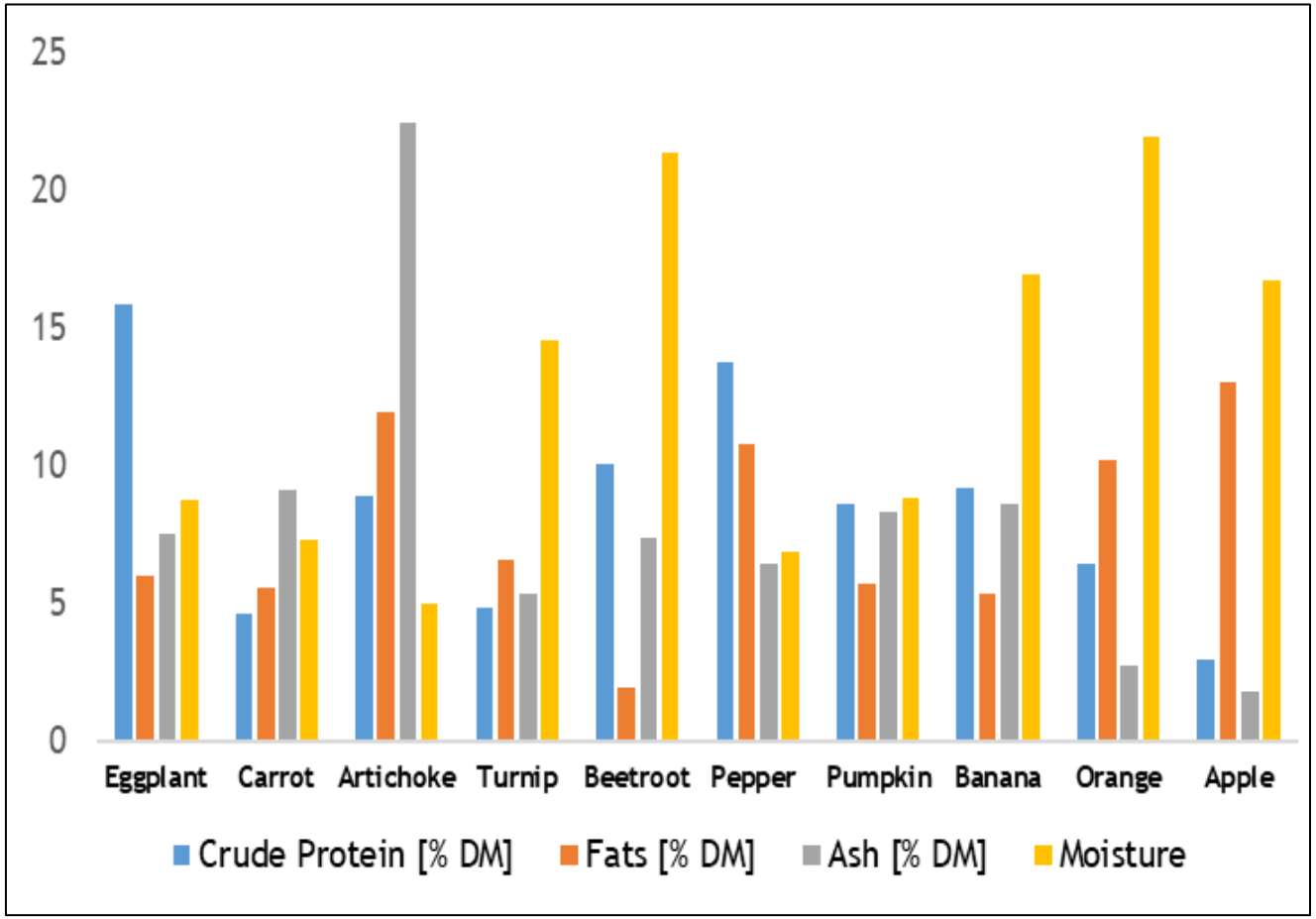
Artichoke

10 km radius

Collected organic waste from local areas

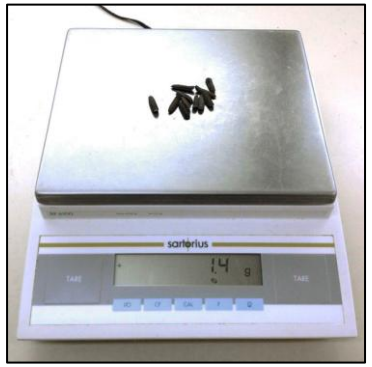
Diet formulation based on raw material analysis and BSF growth requirements

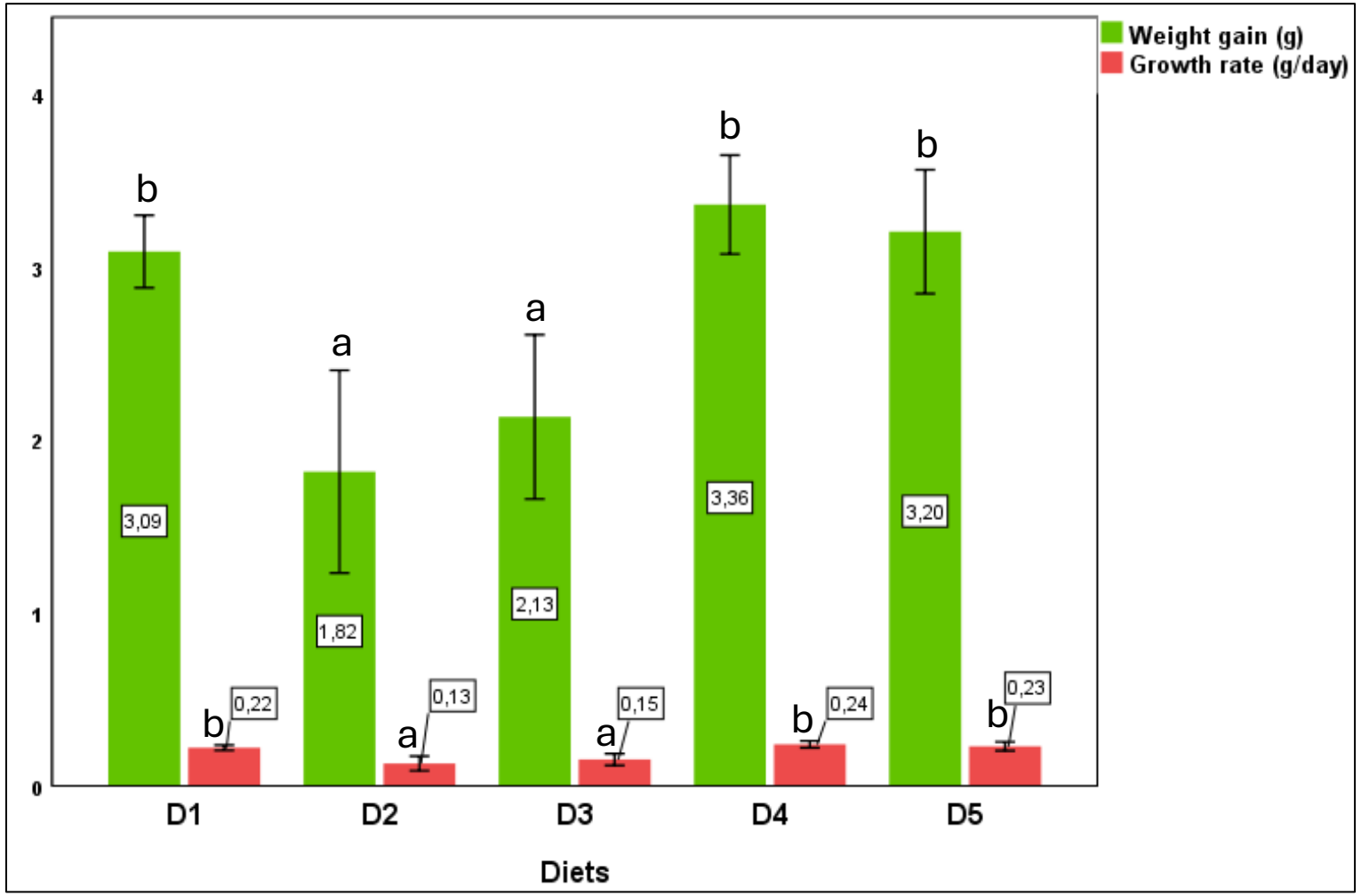
Ingredients	Wheat bran	Maize	Alfalfa	Cattle feed pellets	Poultry feed pellets	Potato waste	Bakery waste
DM	93.50	93.12	94.74	93.89	95.06	90.72	94.76
CP	16.06	3.70	35.70	3.61	11.15	9.74	13.05
EE	9.01	6.94	11.96	11.75	7.27	39.45	2.25
Ash	1.72	0.35	3.84	6.19	21.86	2.82	3.64
GE	19.30	18.04	21.50	18.61	15.23	24.81	17.26



End-products: Larvae biomass

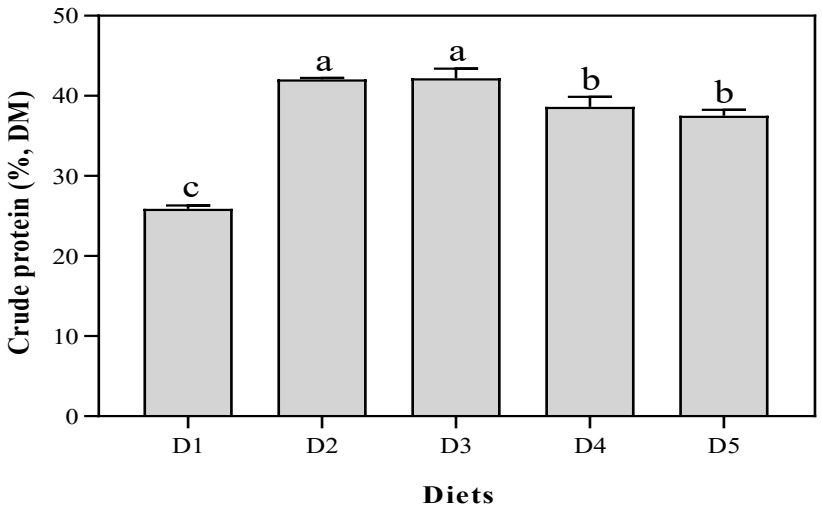
Ingredients (%)	Diets				
	D1	D2	D3	D4	D5 (C)
Water	68.31	68.27	68.19	68.23	70
Wheat bran	—	—	—	—	15
Maize	—	2.98	9.41	12.44	6
Alfalfa	4.53	9.28	10.74	10	9
Cattle feed pellets	—	9.47	6.66	—	—
Poultry feed pellets	—	—	—	9.33	—
Potato waste	2.59	—	—	—	—
Bread waste	24.58	10	5	—	—



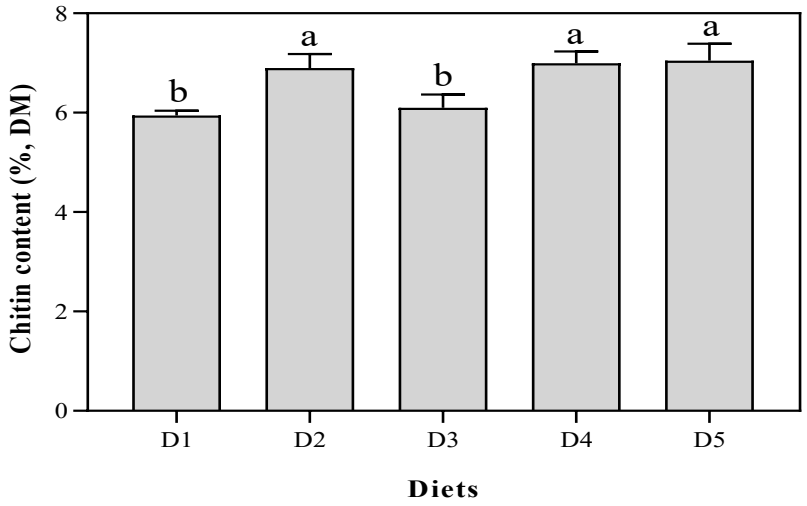


End-products: Larvae biomass

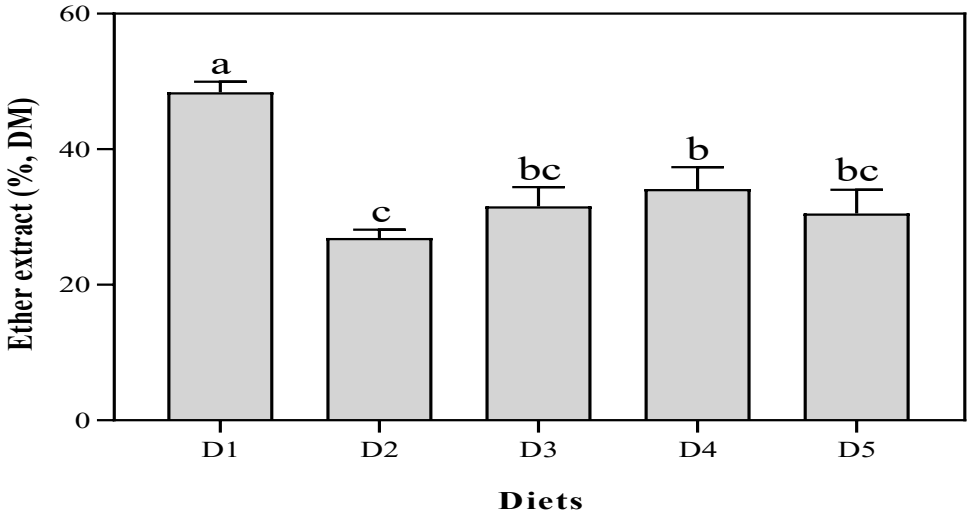
Protein content (%, DM)



Chitin content (%, DM)



Ether extract (%, DM)



End-products: Larvae biomass

$$\text{FCR} = \frac{\text{Feed intake (g)}}{\text{Weight gain (g)}}$$

$$\text{BER} = \frac{\text{Final larval biomass (g)} - \text{Initial larval biomass (g)}}{\text{Distributed substrate (g)} - \text{Residual substrate (g)}} \times 100$$

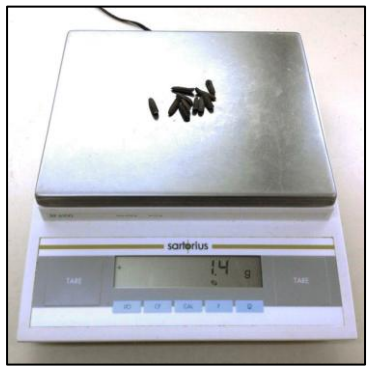
Parameters	Diets				
	D1	D2	D3	D4	D5 (C)
Feed conversion ratio	6.80^{a}	11.68^{b}	9.89^{b}	6.25^{a}	6.56^{a}
Bioconversion efficiency corrected for residue (%)	15.79^{b}	9.04^{a}	9.61^{a}	16.02^{b}	14.24^{b}
Fresh frass weight (g)	1176.33^{c}	1093.33^{bc}	808.67^{ab}	985.33^{abc}	764^{a}
Survival rate (%)	72.96	86.77	91.95	80.31	86.59

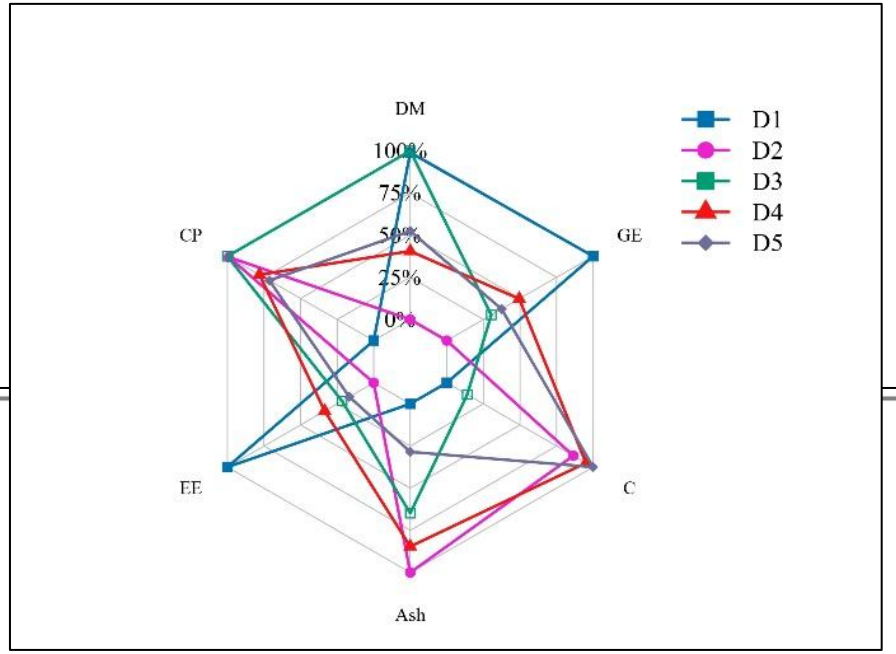
D4 :

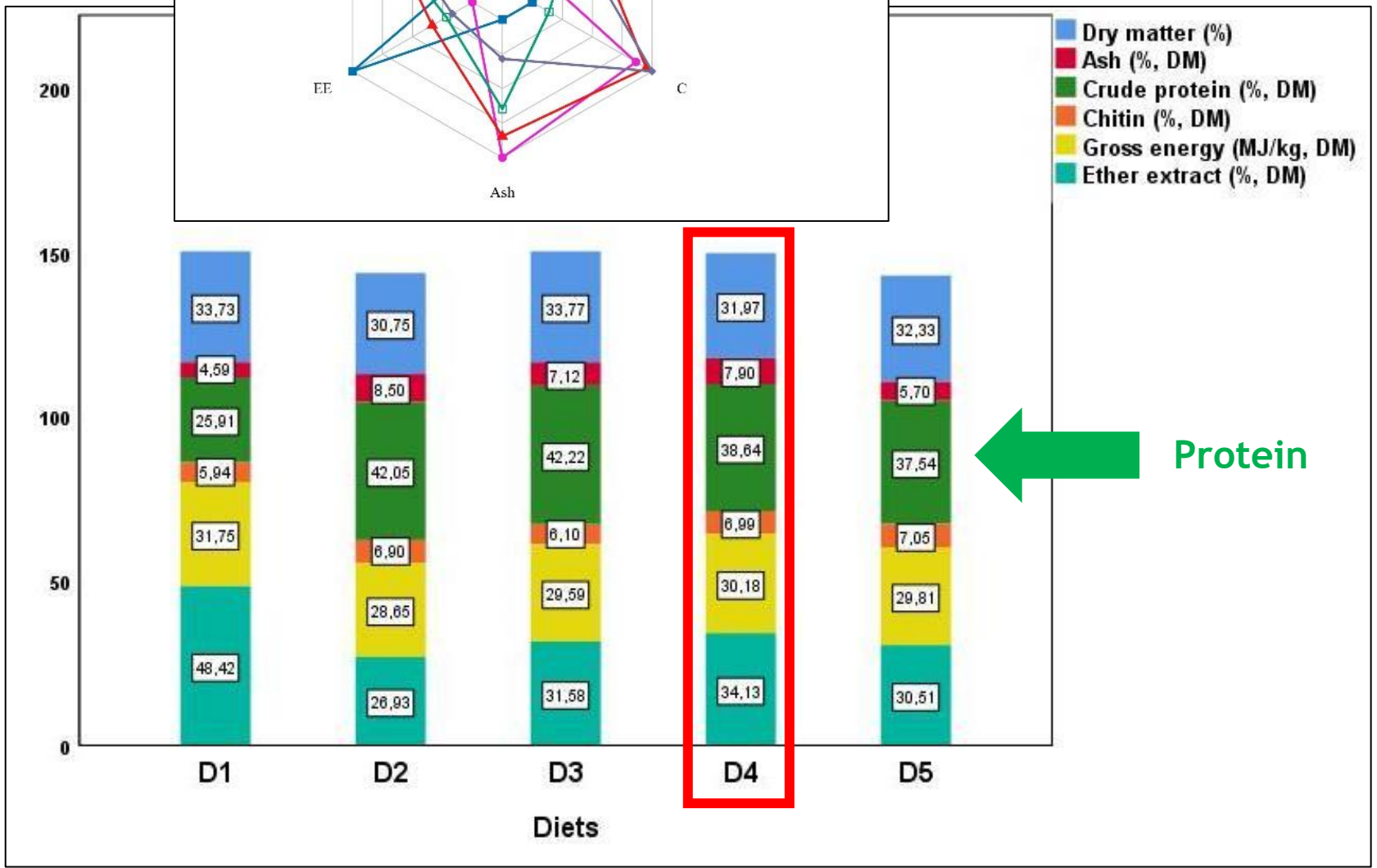
- A low feed conversion ratio indicates BSF are efficiently turning feed into biomass.

- A high Bioconversion efficiency corrected for residue → a large proportion of the organic waste is successfully incorporated into the larval biomass.

End-products: Larvae biomass



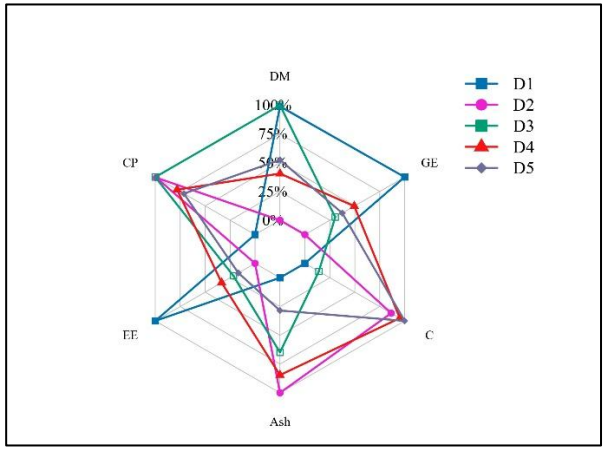




Protein

End-products: Larvae biomass

Ingredients (%)	D4
Water	68.23
Maize	12.44
Alfalfa	10
Poultry feed pellets	9.33



Growth performance

Slaughter performance

Animal welfare

Never on Moroccan context

End-products: Larvae biomass … for chicken feeding

Experimental design

3 experimental treatments, 3 replicates, 8 birds/replicate (24 birds/treatment = 72 birds in total):

♂

Domestic chickens
Gallus gallus domesticus

50d rearing cycle
72 males
60-110d of age

DFI: daily feed intake
HI: *Hermetia illucens*

End-products: Larvae biomass … for chicken feeding

Data collection

Growth performance

- Weight gain (g)
- Average Daily Feed Intake (ADFI) (g)
- Feed Conversion Ratio (FCR) (g)

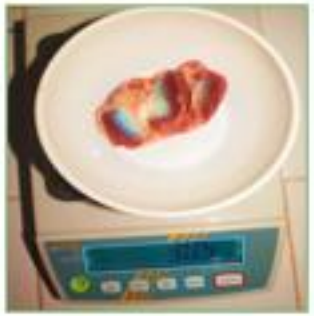
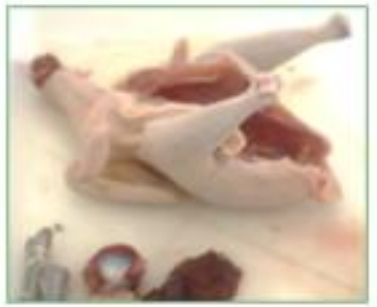
Slaughter performance

- Drip loss (%)
  24h post-slaughter (4°C)
- Cold carcass weight (g)
  after 24h refrigeration @4°C
- Dressing:
  (Warm Carcass Weight÷Live Weight)×100

Meat physical quality

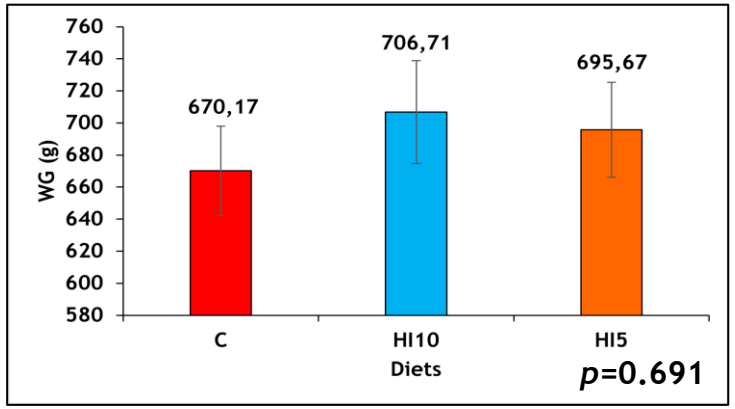
- Meat pH
  24h post-slaughter (4°C)



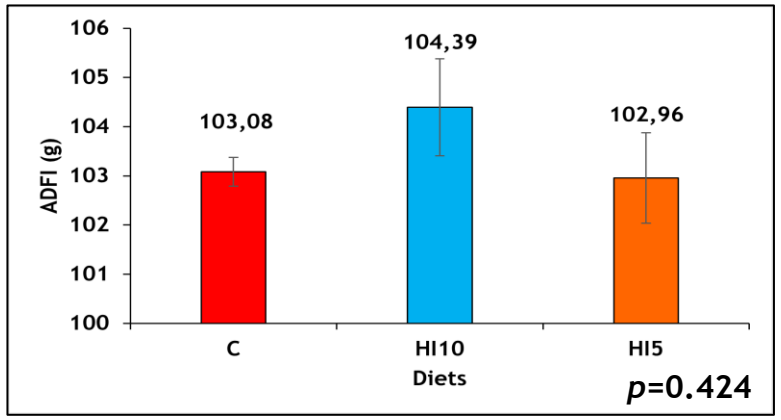





End-products: Larvae biomass … for chicken feeding

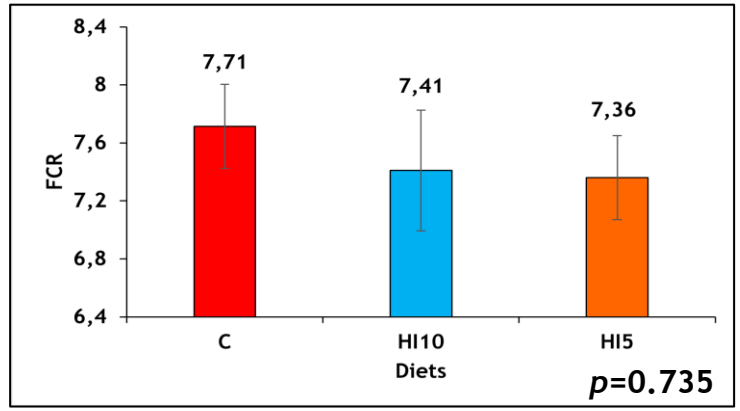
Main results



Weight gain

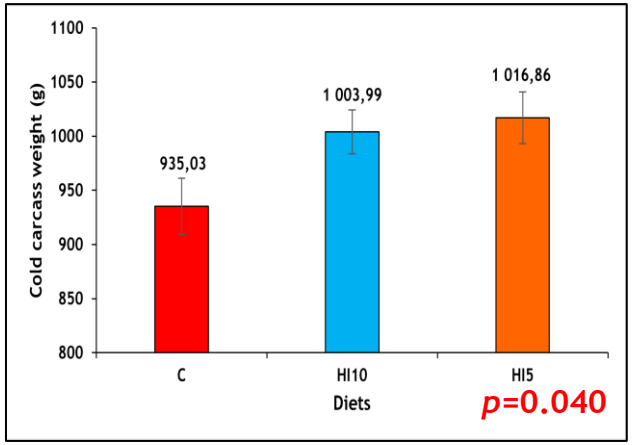


Average Daily Feed Intake

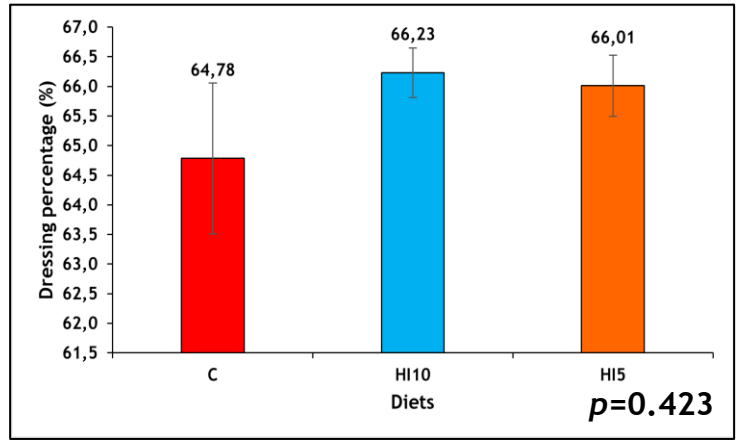


Feed conversion ratio

Items	C	HI5	HI10	*p*-value
Meat pH	6.42	6.47	6.51	0.097
Drip loss (%)	1.80	1.29	1.41	0.509



Cold carcass weight



Dressing %

End-products: Larvae biomass … for chicken feeding

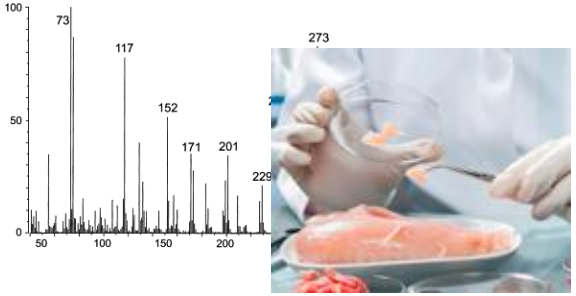
Main results

Live HI larvae supplementation

- No negative effects on the growth or slaughter performance. However, HI-fed birds show increased values in most of the parameters
- HI-fed groups show good meat quality reflected by low drip loss value

Work in progress

Animal welfare



Meat chemical quality

End-products: Frass

Frass is obtained by separating the residues from harvested black soldier fly larvae during the rearing process.

Moisture (%)	10.49
pH	8.81
Dry matter (%)	89.51
Total N (%)	**2.07**
P_2O_5 (%)	**5.74**
K_20 (%)	**2.76**
Na (%)	0.50
EC (ms/cm)	15.31
Organic matter (%)	47.23
Organic carbon (%)	23.61
C/N ratio	11.42

Precautions and recommendations

1. Adjust dose to crop needs (check nutrient content),
2. Avoid applying too close to young seedlings,
3. Mix frass into soil, not just on the surface,
4. Apply at planting or early growth, avoid excess later,
5. Combine with other fertilizers for balanced nutrition.

End-products: Frass

Field trials : Frass as an organic fertilizer for crops

Barley

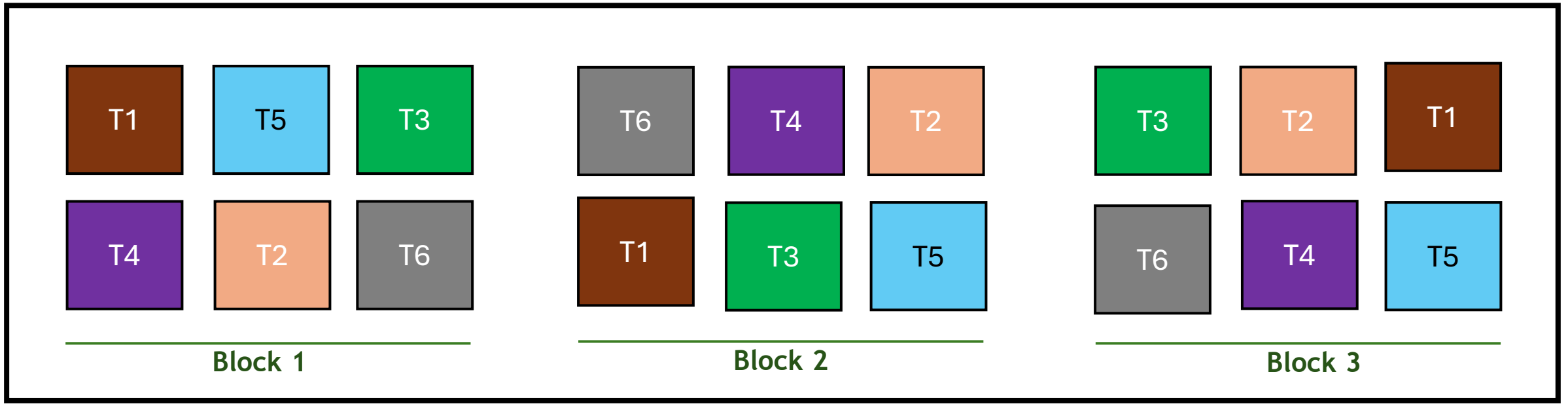
Onion

White lupin

Faba bean

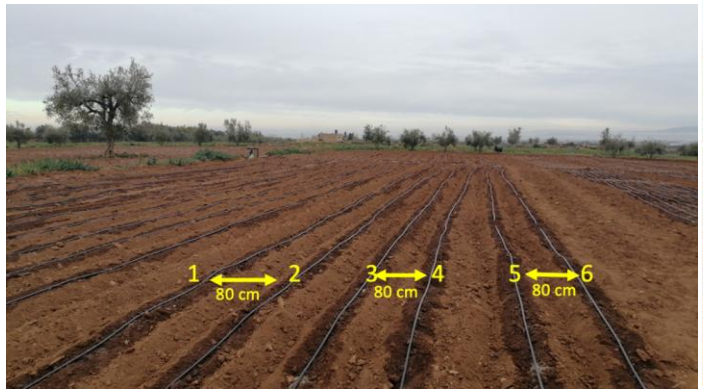
End-products: Frass

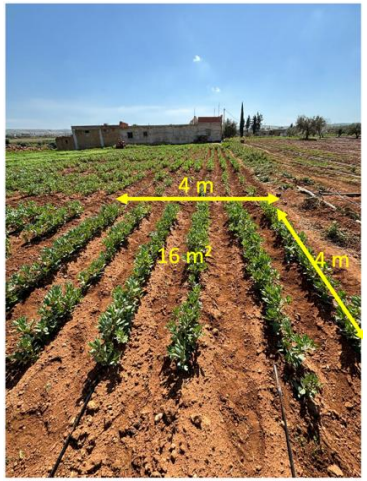
Field trials: randomized blocks



Treatments used for Greek fava bean and lupin, quantities are in t/ha during 2024-2025

Treatments	Frass	Urea	MKP (0-52-34)	K_2SO_4 (0-0-50)	$MgSO_4$ (16S-16Mg)
T1	0	0	0	0	0
T2	0	0,065	0,133	0,056	0,200
T3	1,435	0	0,133	0,056	0,200
T4	0,717	0	0,133	0,056	0,200
T5	1,435	0	0	0	0
T6	2,870	0	0	0	0



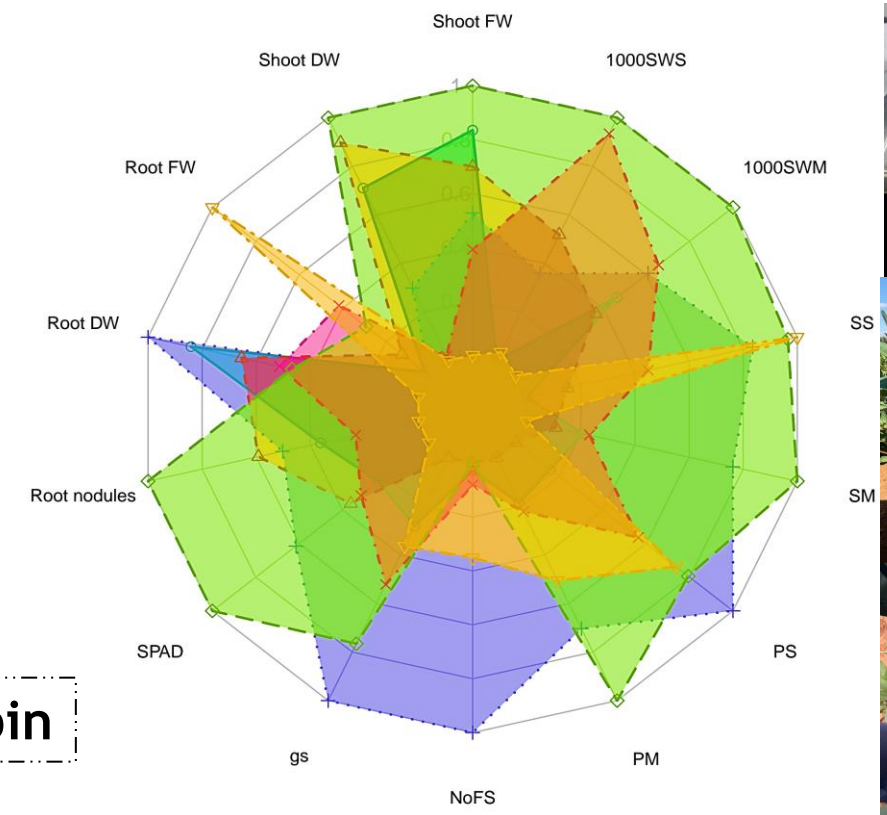


End-products: Frass

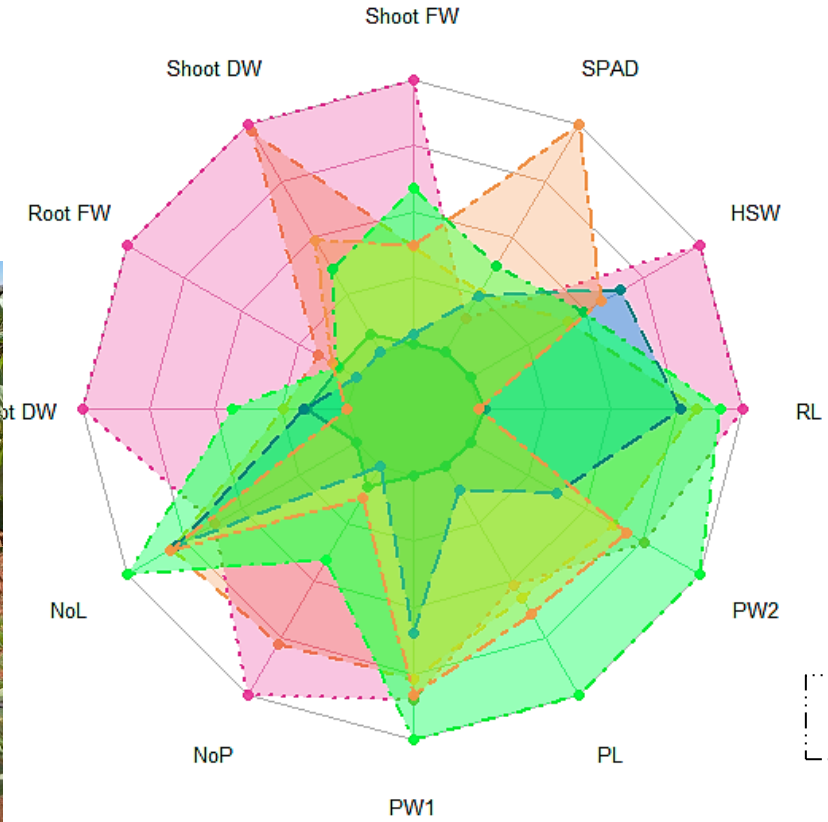
Frass as an organic fertilizer for crops

Results from the stated trials (White lupin & Faba bean)

T1
T2
T3
T4
T5
T6



White lupin



T1
T2
T3
T4
T5
T6

Faba bean

Measured parameters:

gs : stomatal conductance
NoFS : number of flowered spikes
PM : number of pods in mainstem
PS : n° pods secondary stems
SM : no° seeds in mainsteam
SS : no° seeds in secondary stems
1000SWM : weight of 1000 seeds from mainstem

1000 SWS : weight of 1000 seeds from secondary stems
PW1: Pod weight
PW2 : pod width
PL : pod length
RL : root length
HSW: 100 Seeds weight
NoP: n° pods
NoL: n° leaves

Environmental and socio-economic benefits

Economic returns

20 000 €/ton

Larvae biomass

≈3500 €/ton

Exuviae

200 €/ton

Frass

600 €/ton

Compost

From exuviae, it will be possible to extract chitin and chitosan, two valuable biopolymers widely used in agriculture, medicine, food technology, cosmetics and water treatment

Thank you for your attention

Royaume du Maroc
Ministère de l'Enseignement Supérieur,
de la Recherche Scientifique et de l'Innovation

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IN THE MEDITERRANEAN AREA

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