FOOD & FEED for the FUTURE

A workshop sponsored by the OECD Co-operative Research Programme: Sustainable Agricultural and Food Systems.

Sustainability of insects for feed and food

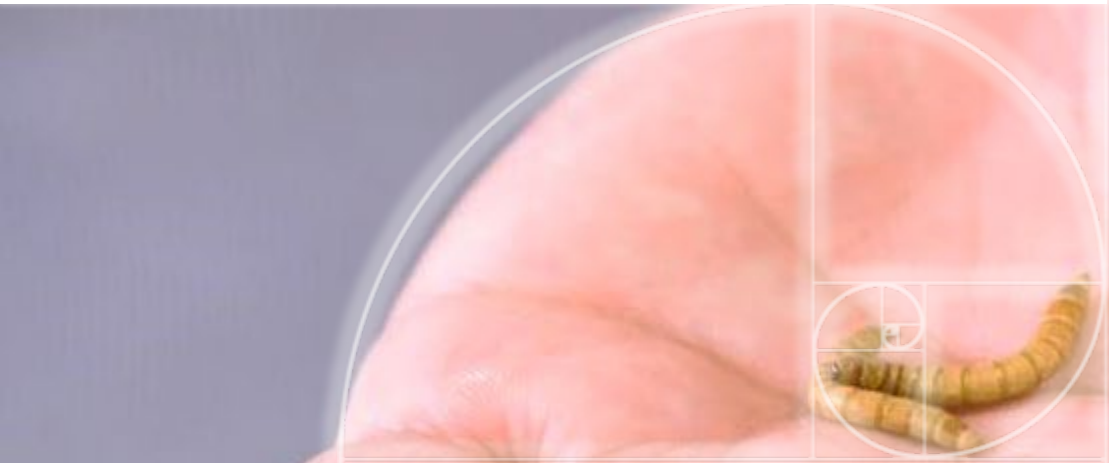
Thomas LEFEBVRE
Ÿnsect France

ISARA Lyon - September 1st, 2023

Ynsect

Sustainability of insects for feed and food

TABLE OF CONTENTS



“Throughout the ages, insects have shown us how to embrace sustainability. ”

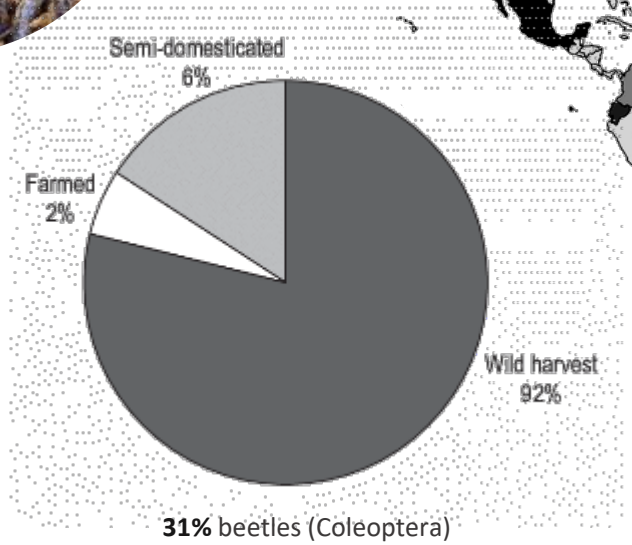
Ynsect

ENTOMOPHAGY : AS ANCIENT AS HUMANITY?

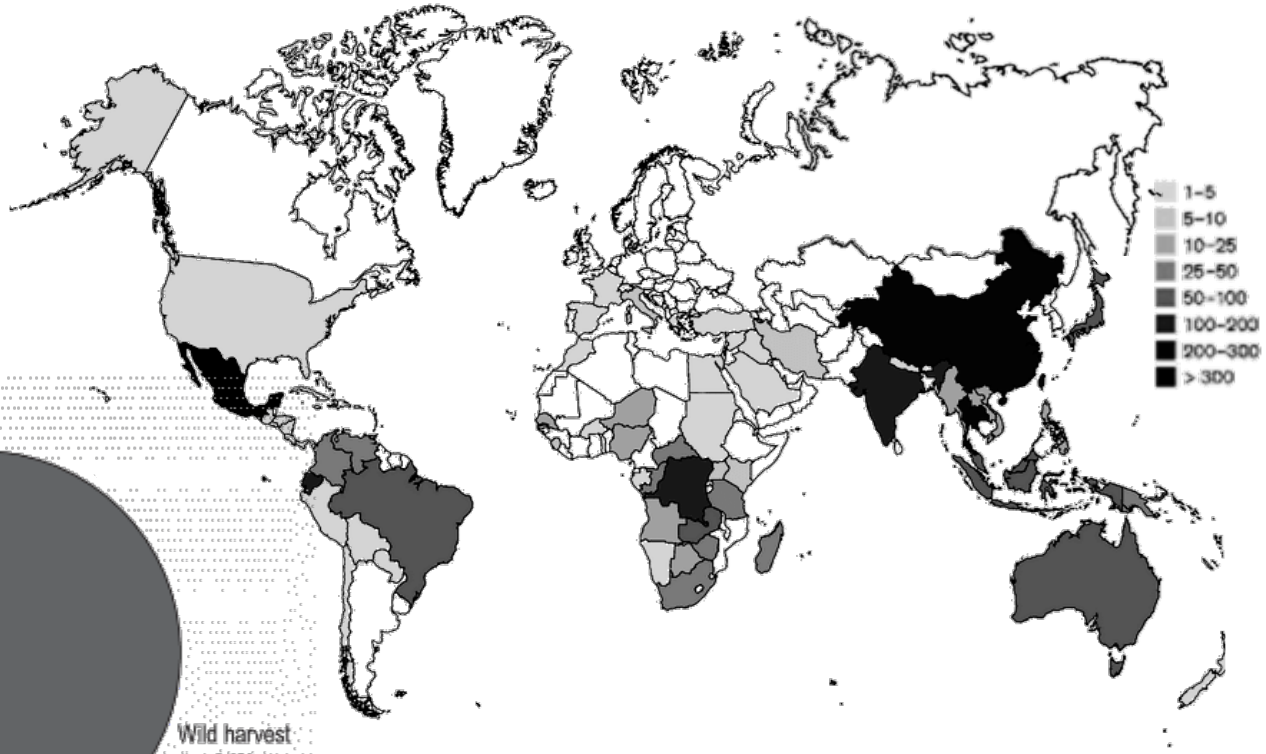
Relief from the palace of Sennachérib (704-681 B.C.)
Bruno Meissner, Babylonien und Assyrien, Erster Band), Abb. 45

From antiquity …

… to modern ages



31% beetles (Coleoptera)
18% caterpillars (Lepidoptera)
14% bees, wasps and ants (Hymenoptera)
13% grasshoppers, locusts (Orthoptera)

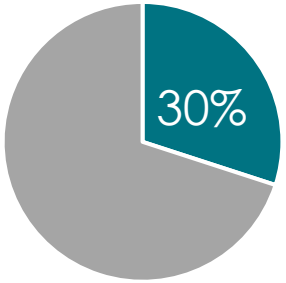


Recorded number of edible insect species by country
Wageningen University, Jongema 2014 & 2017

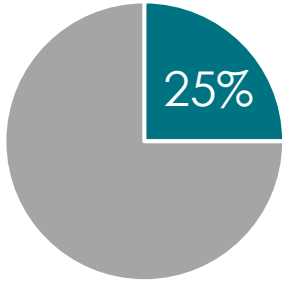
INSECTS ARE PART OF THE NATURAL DIETS OF MANY ANIMALS

Not only humans like eating insects as they form the first link in the food chain

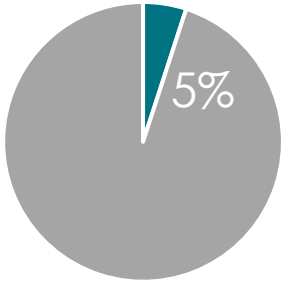
Wild fish



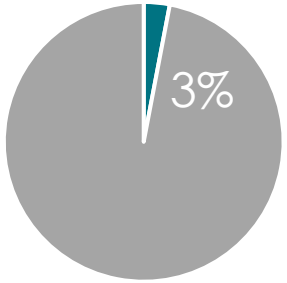
Wild fowls



Wild pigs



Wild cats

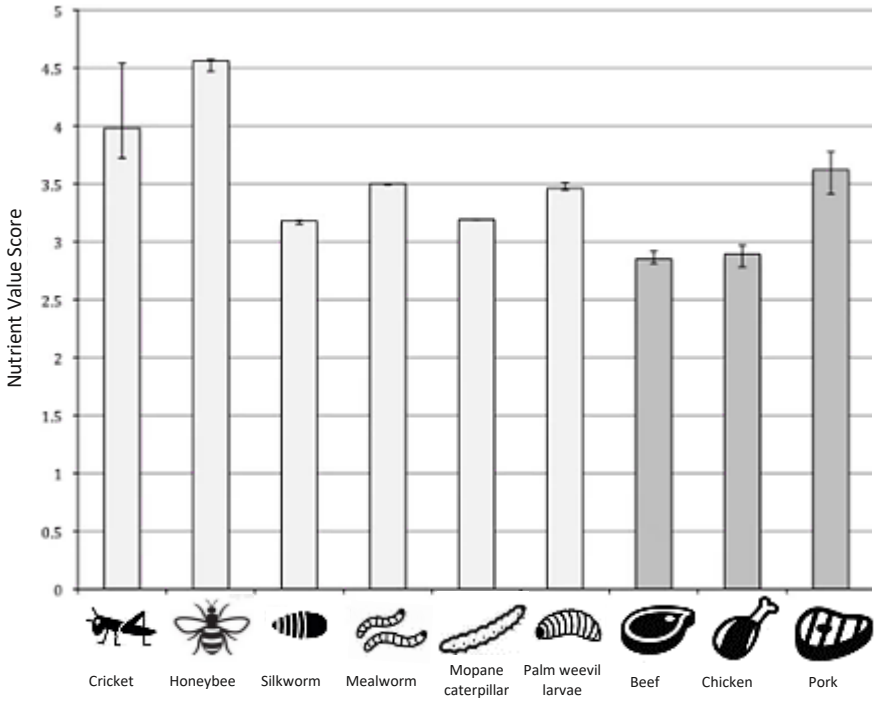


Proportion of **insects** in natural diets of wild animals

Wageningen University

INSECTS AS VERY NUTRITIVE INGREDIENTS FOR FEED AND FOOD

Insect-based ingredient benefits for people and animals in terms of nutrition and health



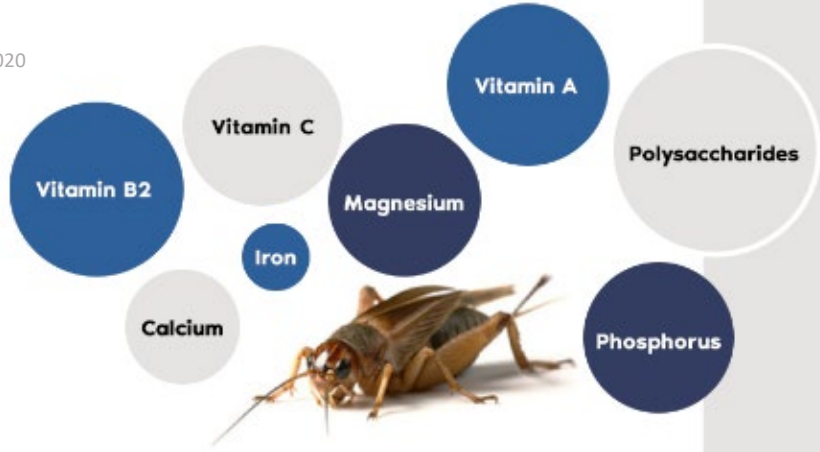
Median values and inter-quartile range of Nutrient Value Scores for insects and meat. Higher scores indicate healthier foods. (Payne et al. 2016)

>70% protein in mealworm defatted powder

Nutritional characteristics[14]

- Rich in protein and essential amino acids
- Good source of unsaturated fats (e.g. good Omega 3:6 balance)
- Rich in vitamins and minerals (vitamins A, B, B12, magnesium, iron...)
- Prebiotic fibres like chitin provide nutrients for probiotic gut bacteria
- Digestibility is higher than many vegetable-based protein sources but slightly lower than traditional animal protein sources

IPIFF 2020



Health benefits

- Positive effects on type 2 diabetes and cardiovascular disease
- Antioxidants concentration higher than in orange juice or olive oil, recommended to limit free radicals

Lacroix et al 2019; Micek et al 2019; Mota de Carvalho et al 2019; Doi Mattia et al 2019, Dutta et al 2016

-60% cholesterol in livers of obese mice feed with mealworms

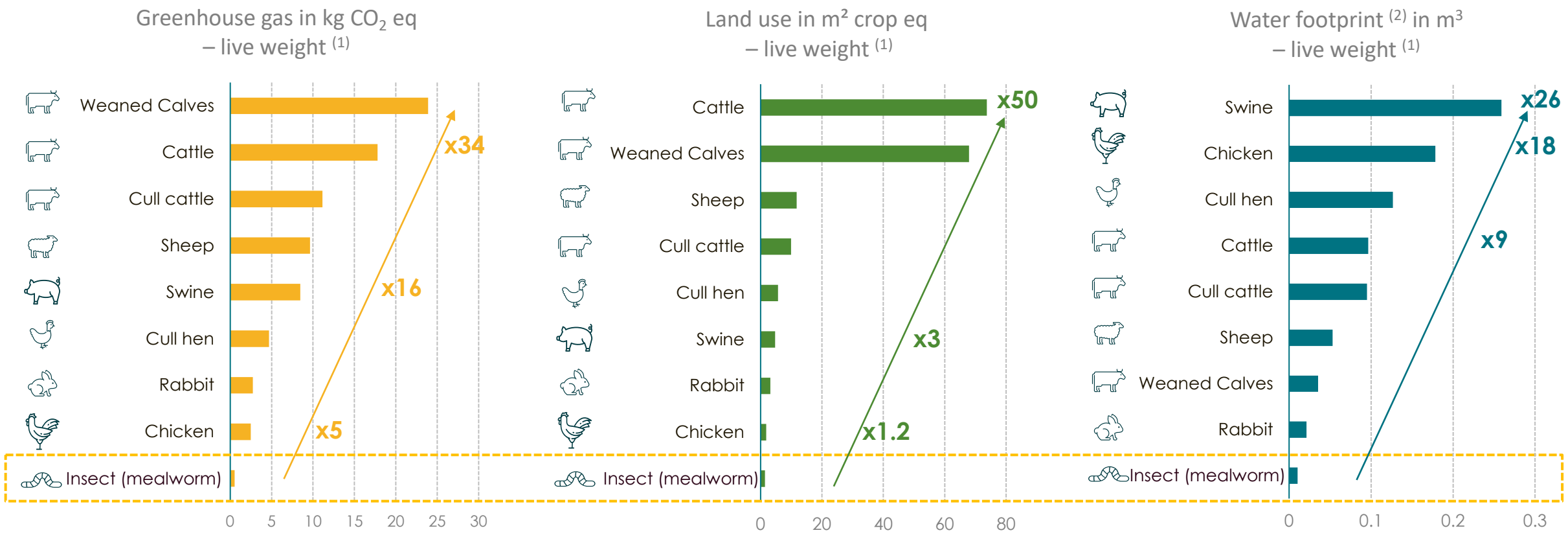
Molecular Nutrition & Food Research 2019

Whole mealworm powder is **ingested & assimilated as fast and as good as milk** in people muscles

American Journal of Clinical Nutrition 2021

HIGH SUSTAINABILITY OF INSECT PRODUCTION

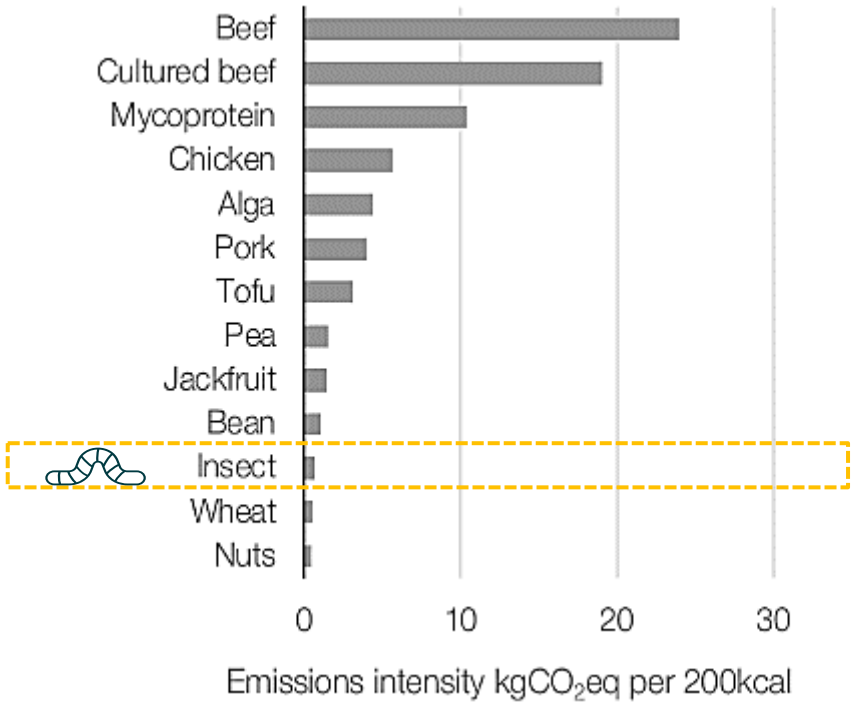
A planet-friendly alternative to our current food system compared to traditional livestock…



Note: (1) Live weight is the average weight of the animal at maturity (before slaughtering), (2) Water footprint based on ReCiPe Midpoint (H) method, cradle to gat
Source: Company information; Source: Ecoinvent 3.8 – WFLDB 3.5; Agribalyse v3.0.1

HIGH SUSTAINABILITY OF INSECT PRODUCTION

… and also compared to plant-based and alternative proteins



Source: Meat: the Future Series. Alternative Proteins" World Economic Forum 2019

Zero Waste production and carbon sequestration

Valorization of insect frass in high-grade fertilizer

Increased microbial activity

Substitution
for mineral fertilizers without modifying the yield performance on grass, carrots, potatoes .....

Increased flowering

Increased crop performances
+20% wheat and vine yields
+35% protein content in corn

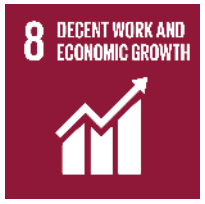
RESPECTING MOST UN'S SUSTAINABLE DEVELOPMENT GOALS (SDGS)

Enabling large scale food production

Yielding organic products, low in cholesterol, several animal & plants health benefits

Gender policies (e.g paternity leave, etc.)

Reselling residual heat & cold
Renewable energy on roofs



Top employee satisfaction

Highly automated "industry 4.0" production facility

Circular economy with zero waste

Low greenhouse gas emissions

Protecting the ocean's biodiversity

Intensive vertical farming delivering effective use of land

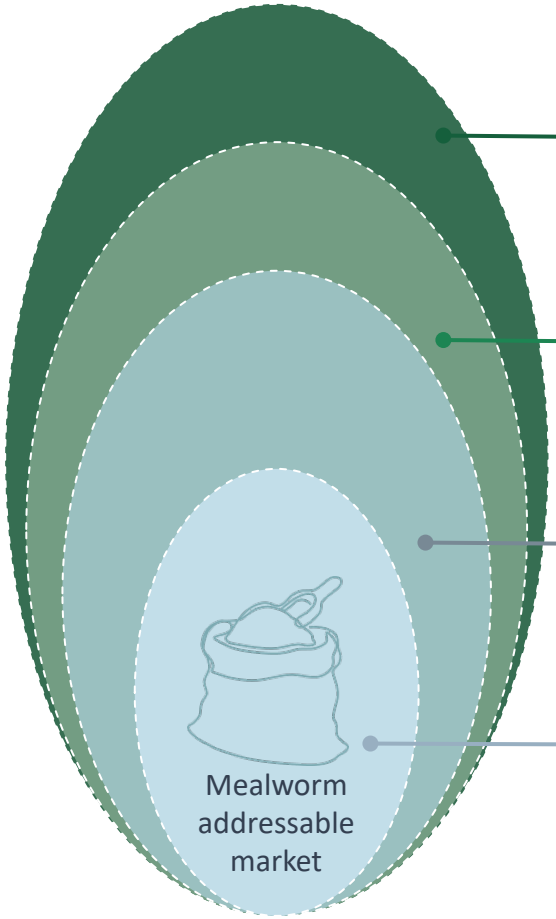
Active collaboration with govts. And NGOs to regulate new products and promote product sustainability

SUSTAINABLE DEVELOPMENT GOALS

Sustainability of insects for feed and food

MATURITY OF THE INSECT INDUSTRY

ADDRESSABLE MARKET IN COMING YEARS



TECHNICALLY

Can **technically substitute** existing protein

REGULATORY

Is **legally allowed** based on regs

ADOPTION

Is **adopted by customers** with desire to consume

ECONOMICALLY

Is **economically viable** based on price, benefits

2.5MT current mealworm addressable market…

- Based on current regulations, adoption behavior, and proven technical profiles + additional health benefits

…where cost positioning drives addressable market…

- Cost positioning informs substitutability for current protein sources, informing the accessible portion of market

…with potential market upside resulting in an addressable market of ~ 9MT in the medium-term

- Based on proven technical profiles benefits, changing regulations, & adoptions; assuming a competitive production cost positioning

Addressable market in human food applications : ~100kT

Source: BCG analysis for Ÿnsect

TECHNICAL CLAIMS BEYOND THE INITIAL EXPECTATIONS

TECHNICALLY

Investigations in Research & Development have given evidences that insects products combine unique features, offering strong and proven benefits across the board

With nutritional benefits for farm animals, pets and plants…

All essential amino acids, high protein concentrate (72%) and **90+%** digestibility

+ 2%
breast yield on chicken

+ 34%
growth rate on trout and shrimp

+ 23%
increase in crop yield

As well as significant health benefits…

- 40%
mortality reduction for shrimp

- 10%
in mortality rate for salmon and seabass

Reduction of skins lesions
and diseases for various pets

Improvement of poultry litter quality for less legs skin disease

35%
lipid lowering effect in the liver

And a well positioned food ingredient for people

Improved shrimp and fish taste

Unflavored ingredient enabling wide-ranging applications

6x
more efficient as a protein source than beef

Matches quality of milk protein in terms of digestion, absorption and muscle growth

60 %
cholesterol reduction (pre-clinical trial on mice)

FAST PROGRESS IN EU REGULATIONS THESE LAST YEARS

REGULATORY

Already authorized in most applications in feed …

Insects as feed - **Regulation (EU) No 68/2013** on the Catalogue of feed materials and in accordance with **Regulation (EC) No 999/2001 and Regulation (EC) No 1069/2009**	Ruminant animals	Aquaculture	Poultry	Pigs	Pets	Fur and other animals (e.g. zoo)	Technical uses (e.g. cosmetic industry, bio-based fuels, production of other bio-based materials such as bioplastics)
Insect proteins (under entry 9.4.1. 'Processed animal protein')	✗	✓ **	✓ **	✓ **	✓	✓	✓
Insect fats (under entry 9.2.1 'animal fat')	✓	✓	✓	✓	✓	✓	✓
Whole insects (untreated) (under entry 9.16.2. 'terrestrial invertebrates, dead')	✗	✗	✗	✗	✓ *	✓ *	✓
Whole insects (treated- e.g. Freeze drying) (under entry 9.16.2.'terrestrial invertebrates, dead')	✗	✗	✗	✗	✓ *	✓ *	✓
Live insects (under entry 9.16.1 'terrestrial invertebrates, live')	✗	✓ *	✓ *	✓ *	✓ *	✓ *	✓
Hydrolysed insect proteins (under entry 9.6.1. 'Hydrolysed animal proteins')	✓	✓	✓	✓	✓	✓	✓

… and food

The approach of the Member States on the implementation of the 'EU novel food transitional measure for whole insects and their preparations'

- EU countries in which national authorities have agreed to grant the novel food transitional measure to whole insects and/or their derived products;
- EU countries in which national authorities do apply the novel food transitional measure, but have imposed specific conditions (e.g. the transitional measure only applies to whole insects and not to powder derived from it, the implementation of the transitional measure is limited to certain administrative regions);
- EU countries in which national authorities took the position to deny the implementation of the transitional measure (or applied it restrictively) and whose position may possibly evolve, following the Court of Justice of the European Union ruling (see question 8 for further details);
- **EU Member States whose position is unknown to the authors** at the time of drafting this document;
- **Non-EU countries** from which **insects as food may not be placed on the EU market;**
- Insect food products originating from these non-EU Member States may be placed on the market of those EU Member States which apply the transitional measure under national legislation. Once a novel food authorisation has been granted for a specific product, it can be exported to the EU.

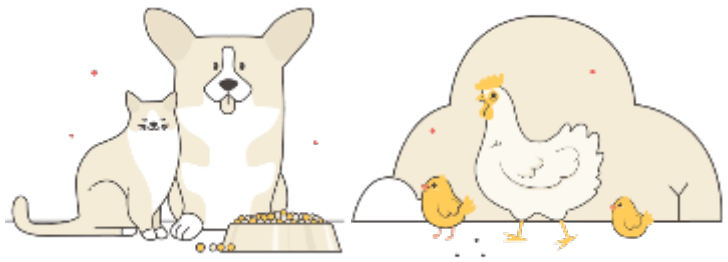
THE YUCK FACTOR IS NOT A BIG ISSUE

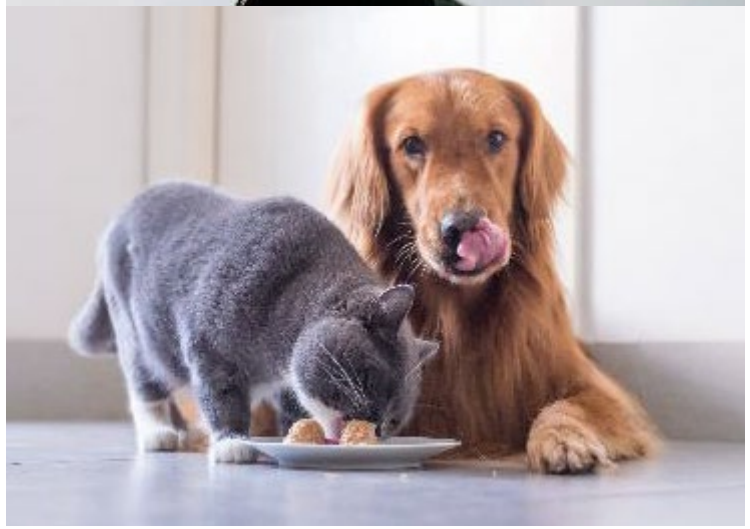
Naturally consumed by farmed animals,

Already adopted by owners of pets and backyard chicken!

According to a study by OnePoll, 83% of dog and cat owners in the USA would feed their pets insect-based ingredients.

According to research by Emerton, 82% of backyard chicken owners' insect of choice is the mealworm.





Early adopters will drive the market. Many ways to obtain their adoption:

Energy bars, energy shakes and burger with insects scored highest; preferred place to buy –supermarket (Van Thielen et al. 2019)

Psychology – more positive evaluation giving information : pre-tasting (Schouteten et al. 2016), post-tasting (Suzuki and Park, 2018) or involvement of peers/experts (Berger et al. 2019)

Overcome barriers by giving opportunities to taste and provide information (Hunts et al 2020, Pambo et al. 2018)

More innovative methods like giving to consumers multi-sensorial experiences (projections and audio means) (Youssef et al. 2019)

LEVEL UP IN HIGH TECH IS THE KEY FOR PROFITABILITY

ECONOMICALLY

Production also needs great scale-up for commodities profitability

Manual farming for food production

> 500 € / kg

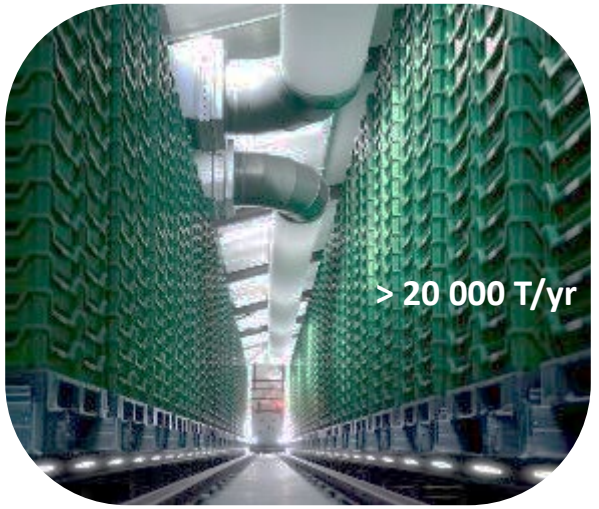
Manual or semi-manual farming for Exotic Pet Food

> 50 € / kg

innovation

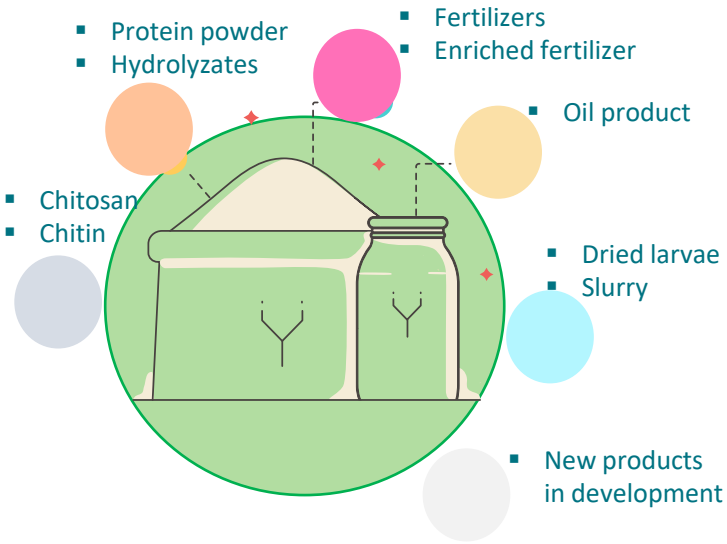
disruptive

Industrial automated farming for feed and food commodities



< 5 € / kg

as well as product diversification in compliance with market needs



+40 funded R&D projects over the world

farmYng · SUSINCHAIN · PROteINSECT · DREAM INSECT · inVALUABLE · InvertebrateIT · INSECT DOCTORS · NEXTGEN PROTEINS

Required solid synergy between
R&D, Engineering, IP, IT, Ops, Sales

+700 patents over the world, mainly poduct- or process-oriented

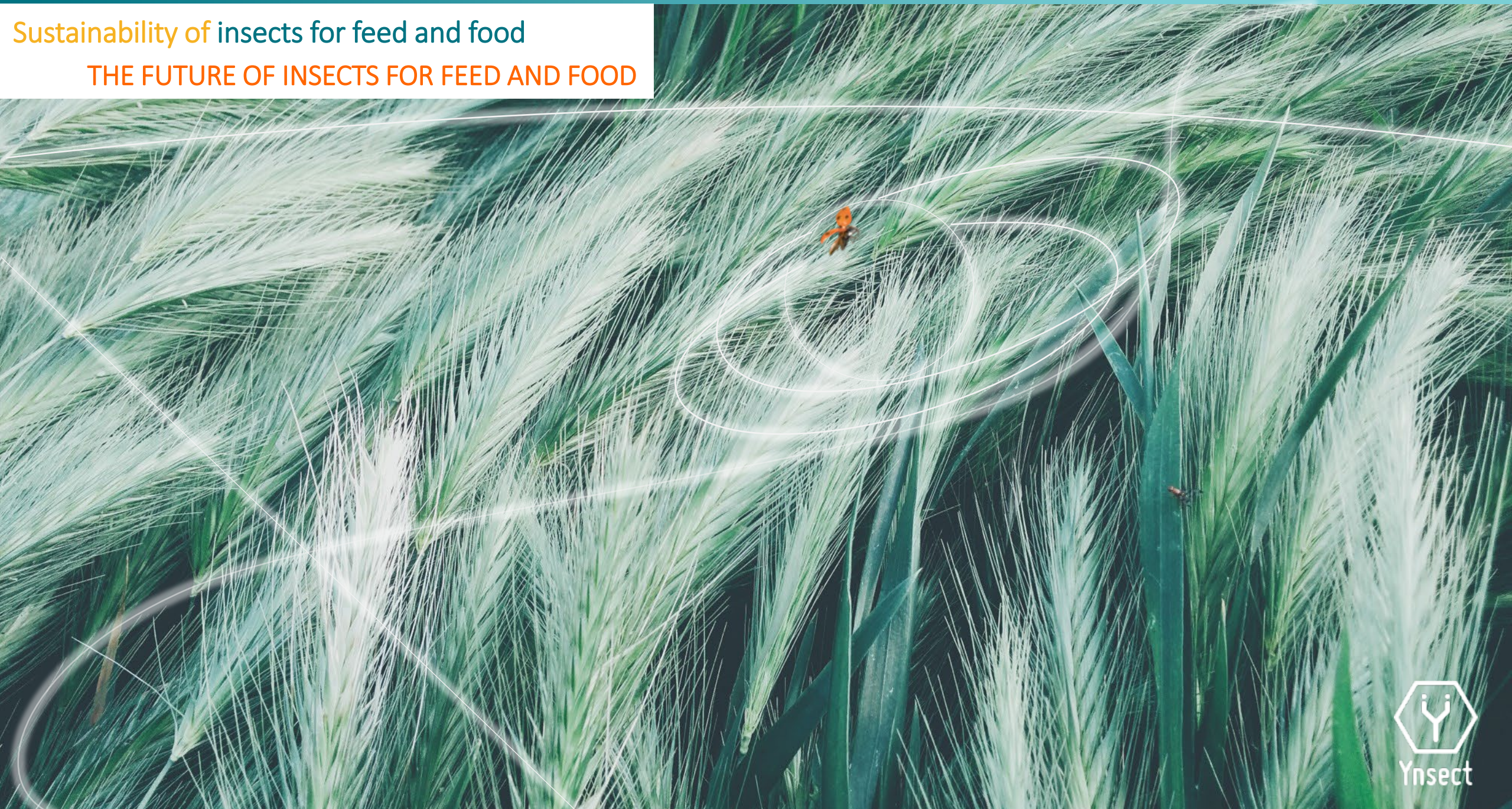
+10 vertical farms already running

THE BIGGEST VERTICAL FARM IN THE WORLD

ECONOMICALLY

Sustainability of insects for feed and food

THE FUTURE OF INSECTS FOR FEED AND FOOD



THAT IS JUST THE BEGINNING OF THE STORY!

Combining advanced biology, technology, AI and smart connectivity

Best foundations to deploy future growth with asset-light model, secure margins

Biology

Need to bring farmed insect science to the same level of technicality as other livestock

High potential for Genetic improvement of not-yet domesticated farmed insect species based on sustainable breeding strategies. Several programs already on going.

Deep nutritional knowledge to develop to ensure flexibility of supply, enabling mix of byproducts and food waste as input for full circular economy aligned with IPCC 1.5° target

Infrastructure

The feedback from the first vertical farms will be very rich in lessons for future improvements

Easy to replicate cost effective vertical farms with controlled and optimized environments, from design right through to operation.

Advanced farm design in favor of decarbonation and efficient use of energy and materials

New infrastructures adapted to new environment and local constraints (feedstock, climate, …)

Artificial Intelligence

Benefit from the current technological leap on AI to improve the automated management of farms

1bn data points collected daily at ŸnFARM (Ÿnsect Fr)

Industry 4.0 neural network, advanced OS and data analysis, supporting remote operations and predictive maintenance

Tracking various insect production parameters with high reactivity through AI

Thank ÿou

Ynsect