20 September 2024

TOHOKU FORUM for CREATIVITY

Potential of edible insects as alternative novel food and feed resources

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Topics

1. Why insects for food and feed ?
2. Edible insects recognized as food in the world ?
3. Safety and nutrients of some edible insect powders ?
4. Nutritional and physiological function of edible insects ?
5. Future perspectives and important issues ?

Why insects for food and feed ?

Edible insects as alternative food and feed resources

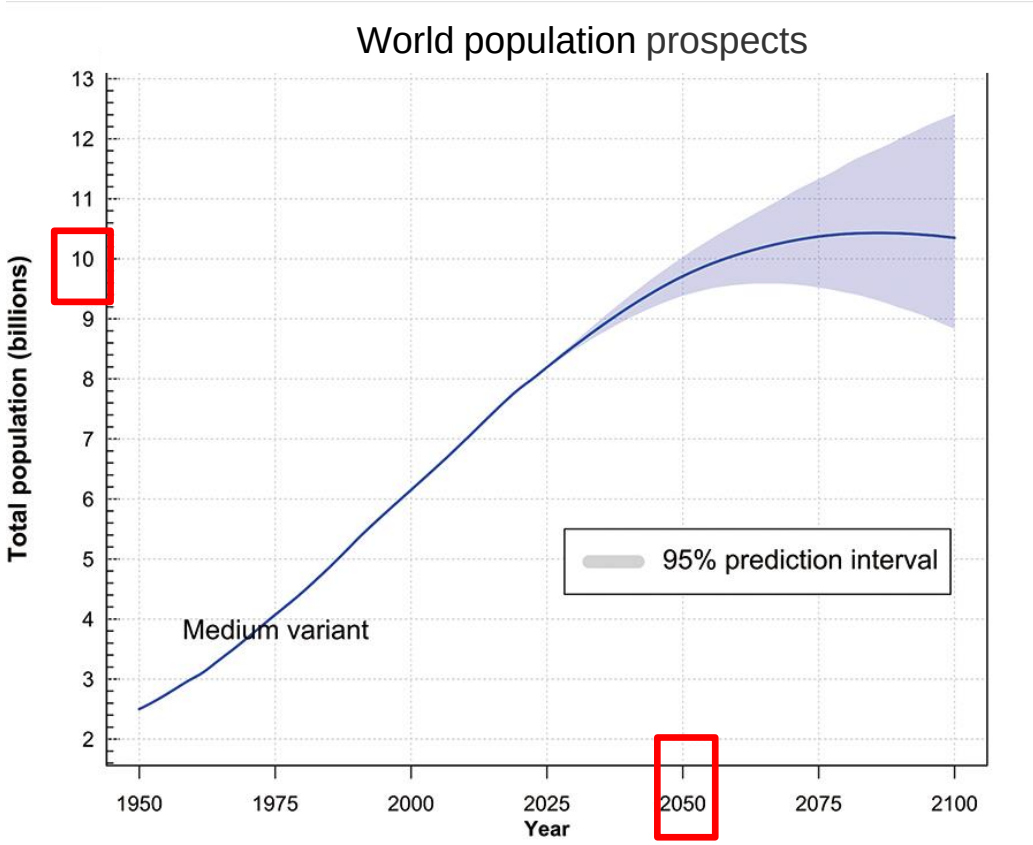
- Increasing world population (9.8 billion, 2050)
- Increasing import prices of livestock feed etc.
- Global warming

↓

- Animal food protein crisis

↓

Alternative protein materials



(United Nations, 2022)

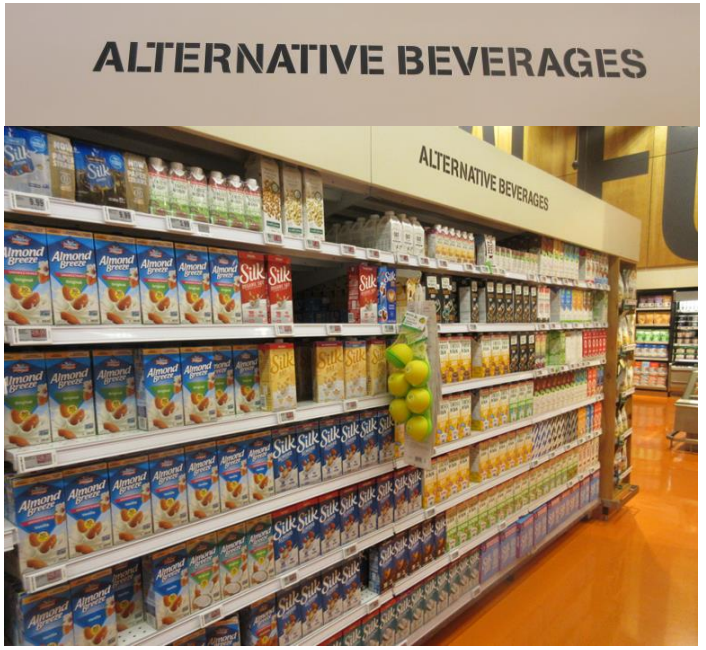
e.g., Japanese books or magazines

NTS publication
2023

Nikkei MJ

CMC publication
2024

e.g., Alternative foods in a USA market



July 2023

e.g., Alternative foods in an Italian market

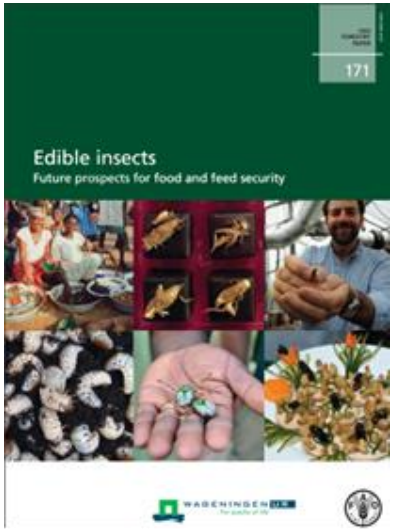
Almond

Oats

Sep 2024

Increasing concerns about alternative food resources for the non-research population

Edible insects are expected as possible alternative food protein resources

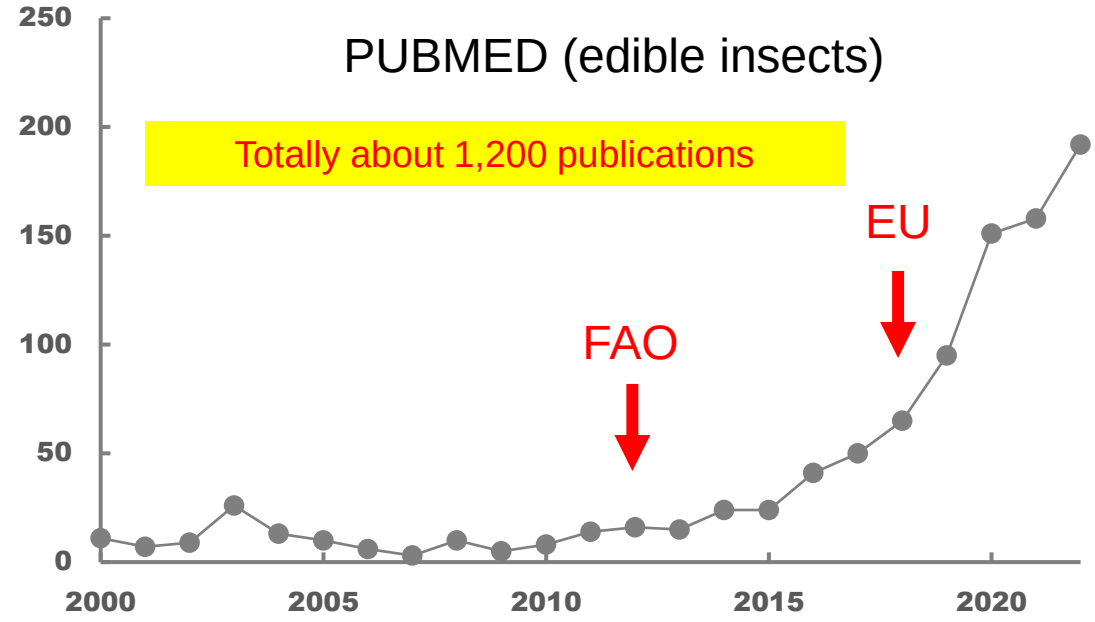


Edible insects

~ Future perspectives for food and feed security ~

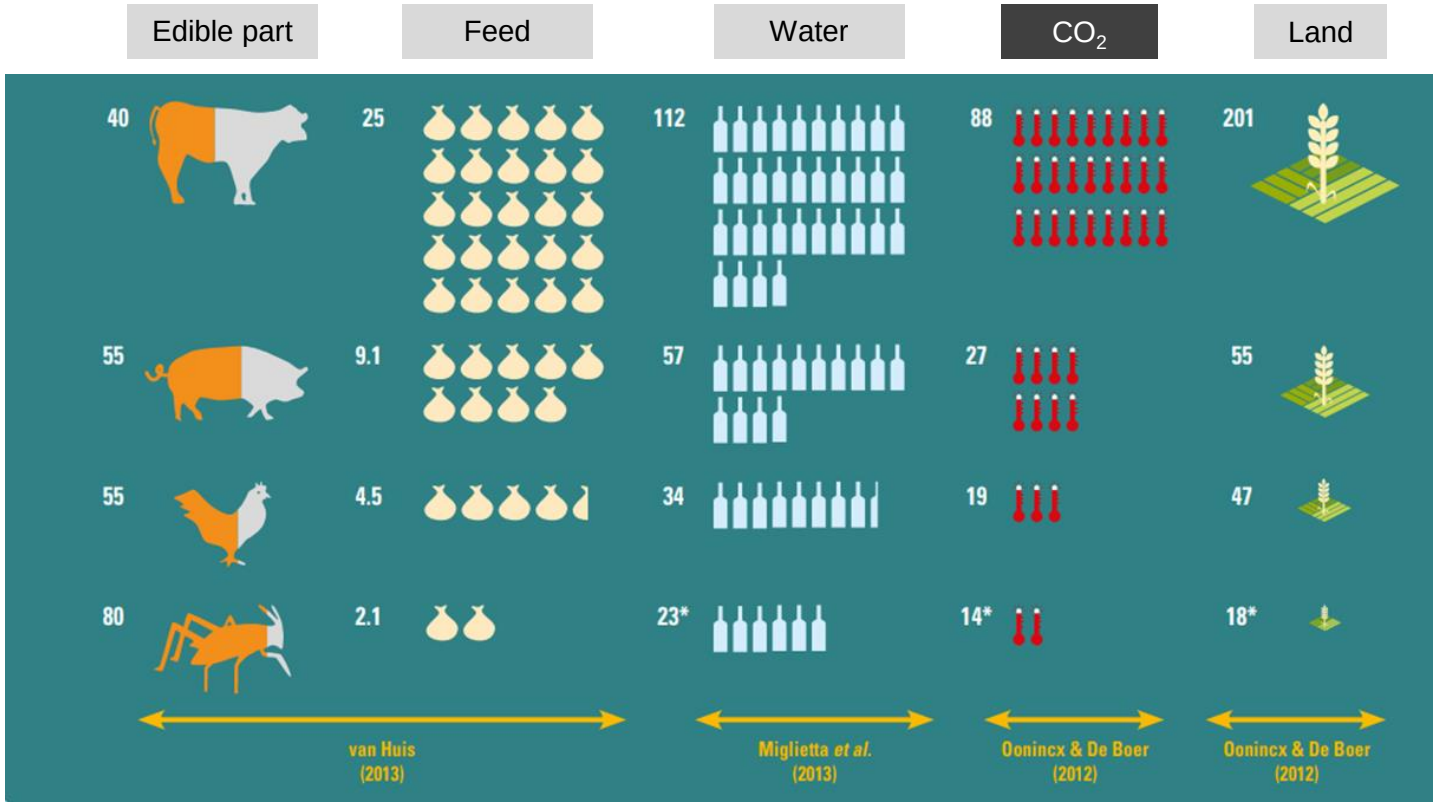
FAO (2013)

FAO (2021)



Some insects were officially recognized as Novel Foods in EU (2018)

Recently more focused on as “ Food Tech ”



Advantages for the utilization of insects

★ **Nutrients: rich in protein, fat, fiber, minerals**

★ Feed efficiency (cost, period, land, edible part)

★ Greenhouse gas emissions

Edible insects recognized as food in the world ?

The number of edible insects are over 2,100 species, but officially recognized as edible with safe is limited. (EFSA reports)

efsa
European Food Safety Authority

An organization that provides impartial information on the risk assessment of food and feed

- **Yellow mealworm (*Tenebrio molitor* larva)**
- **Lesser mealworm (*Alphitobius diaperinus* larva)**
- **Migratory locust (*Locusta migratoria*)**
- **House crickets (*Acheta domesticus*)**

TAKEO

EFSA publications regarding safety evaluations of some edible insect powders

Safety of frozen and dried formulations from whole house crickets (*Acheta domesticus*) as a Novel food pursuant to Regulation (EU) 2015/2283 EFSA J. 2021 Aug 17;19(8):e06779.

Safety of frozen and dried formulations from whole yellow mealworm (*Tenebrio molitor* larva) as a novel food pursuant to Regulation (EU) 2015/2283 EFSA J. 2021 Aug 25;19(8):e06778.

Safety of frozen and freeze-dried formulations of lesser mealworm (*Alphitobius diaperinus* larva) as a Novel food pursuant to Regulation (EU) 2015/2283 EFSA J. 2022 Jul 4;20(7):e07325.

Safety of UV-treated powder of whole yellow mealworm (*Tenebrio molitor* larva) as a novel food pursuant to Regulation (EU) 2015/2283 EFSA J. 2023 Jun 1;21(6):e08009.


SCIENTIFIC OPINION

EFSA Journal

ADOPTED: 25 May 2021

doi: 10.2903/j.efsa.2021.6667

Safety of frozen and dried formulations from migratory locust (*Locusta migratoria*) as a Novel food pursuant to Regulation (EU) 2015/2283

EFSA Panel on Nutrition, Novel Foods and Food Allergens (NDA), Dominique Turck, Jacqueline Castenmiller, Stefaan De Henauw, Karen Ildico Hirsch-Ernst, John Kearney, Alexandre Maciuk, Inge Mangelsdorf, Harry J McArdle, Androniki Naska, Carmen Pelaez, Kristina Pentieva, Alfonso Siani, Frank Thies, Sophia Tsabouri, Marco Vinceti, Francesco Cubadda, Thomas Frenzel, Marina Heinonen, Rosangela Marchelli, Monika Neuhäuser-Berthold, Morten Poulsen, Miguel Prieto Maradona, Josef Rudolf Schlatter, Henk van Loveren, Domenico Azzollini and Helle Katrine Knutsen

30

Migratory locust

More than 30 pages

Safety and nutrients of some edible insect powders

(mainly migratory locust)

Safety of edible migratory locust powder commercially sold in Japan

Journal of Food Science
A Publication of the Institute of Food Technologists

(Ochiai, et al., *J. Food Sci.*, 2020)

Integrated Food Science | Full Access

Nutritional and safety evaluation of locust (*Caelifera*) powder as a novel food material

Masaru Ochiai, Mako Inada, Seiya Horiguchi

Our report was reviewed by EFSA (2021)

EFSA Journal

SCIENTIFIC OPINION

ADOPTED: 25 May 2021

doi: 10.2903/j.efsa.2021.6667

Safety of frozen and dried formulations from migratory locust (*Locusta migratoria*) as a Novel food pursuant to Regulation (EU) 2015/2283

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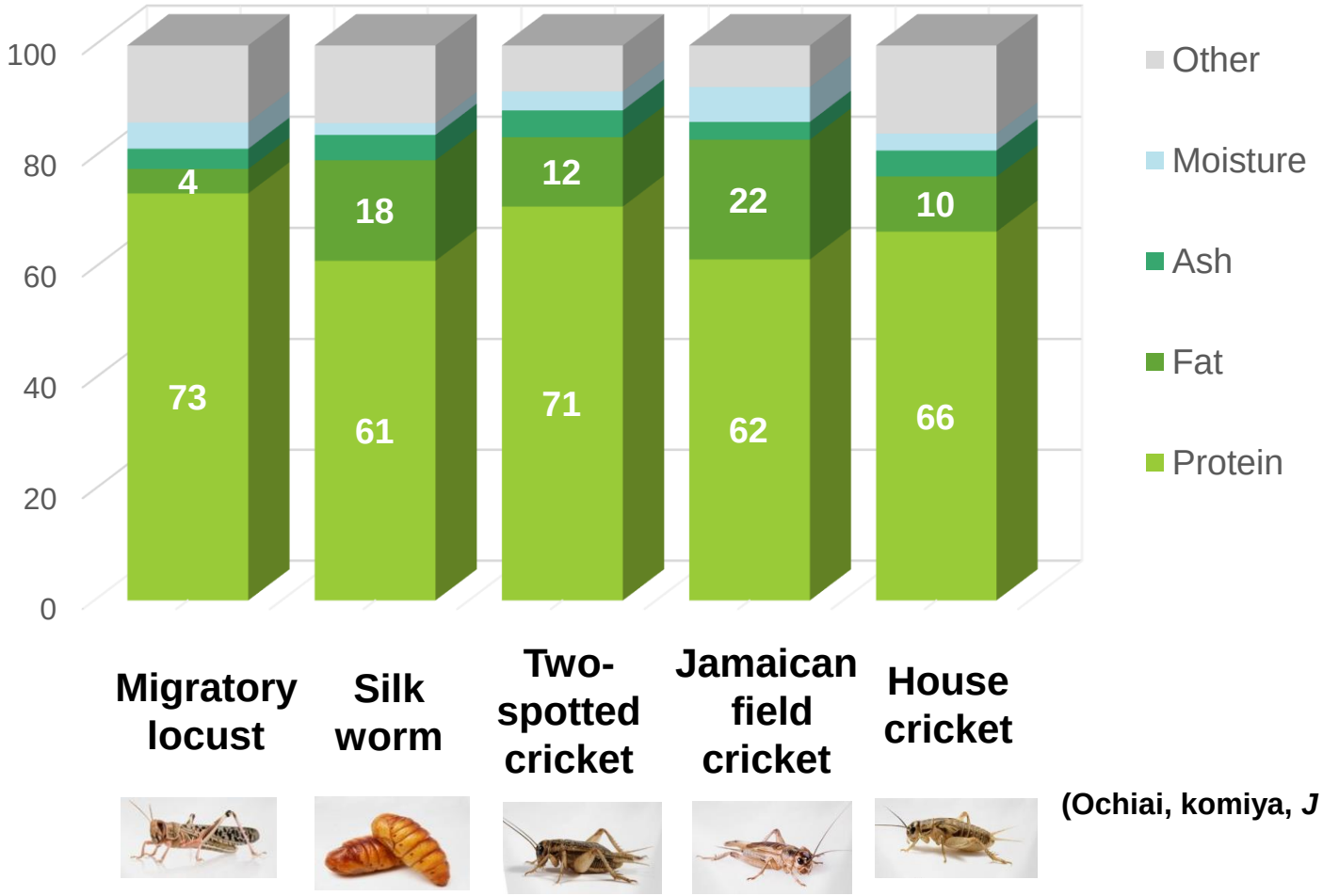
Proximate nutrients in edible insect powder



(Ochiai, komiya, *J Food Compost Anal*. 2021)

Migratory locust powder contains protein (Nitrogen×6.25), fat, and others (dietary fiber)

Protein nutritional property of edible insect powder

Protein value is often evaluated by

- **Protein and amino acid abundance**
- **Amino acid profile and amino acid score**
- **Gut-intestinal digestibility**
- **Bioavailability**

Issues

Presence of non-protein nitrogen ?

Essential amino acid abundance ?

Resistance to digestibility ?

Food Chemistry 396 (2022) 133701

Contents lists available at ScienceDirect

Food Chemistry

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

Edible insect *Locusta migratoria* shows intestinal protein digestibility and improves plasma and hepatic lipid metabolism in male rats

Masaru Ochiai [a,*], Kou Tezuka [a], Haruka Yoshida [a], Takashi Akazawa [b], Yusuke Komiya [a], Hideki Ogasawara [c], Yuto Adachi [a], Minori Nakada [a]

(**Ochiai**, et al., *Food Chem*. 2022)

Food Chemistry 454 (2024) 139781

Contents lists available at ScienceDirect

Food Chemistry

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Low protein digestibility-corrected amino acid score and net nitrogen-to-protein conversion factor value of edible insects

Masaru Ochiai *, Yoshihiro Suzuki, Ren Suzuki, Katsuki Iwata, Marika Murayama

(**Ochiai**, et al., *Food Chem*. 2024)

Major essential amino acid profile and amino acid score

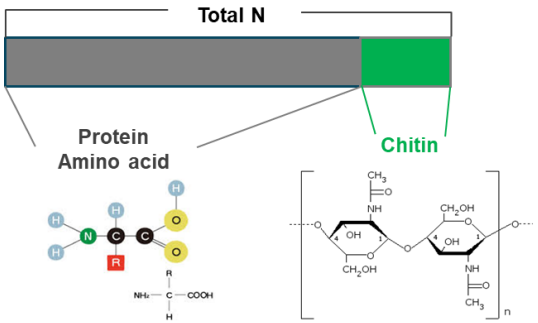
	Migratory locust	Silkworm	Two-spotted cricket	House cricket	Jamaican field Cricket	Casein
Essential amino acid						
Ile	124	131	134	128	124	177
Leu	115	94	108	101	108	181
Lys	83	98	88	90	90	177
Met	71	152	92	90	98	133
Phe	137	147	127	135	132	105
The	105	111	102	104	106	165
Trp	63	126	87	84	85	135
Val	162	139	160	154	147	189
His	105	134	106	100	108	181
1st	Trp 63	Leu 94	Trp 87	Trp 84	Trp 85	-
2nd	Met 71	Lys 98	Lys 88	Met 90	Lys 90	-
3rd	Lys 83	-	Met 92	Lys 90	Met 98	-

Limiting amino acids are Trp (63) and Met and Lys are limiting amino acids.

(Ochiai, et al., *Food Chem*. 2022; 2024)

Protein abundance in edible insects

Issues regarding the Kjeldhal method for the protein quantification



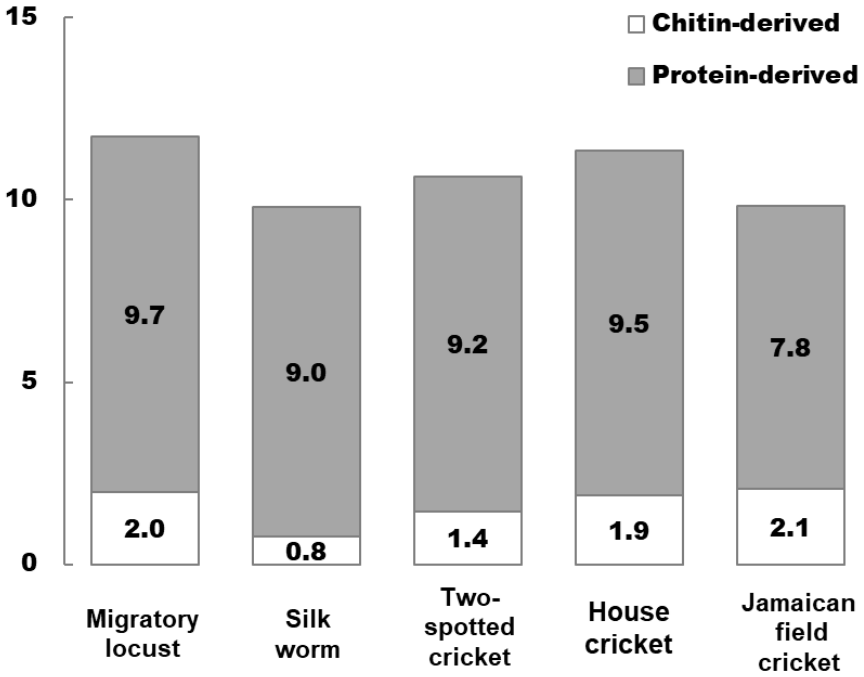
Kjeldhal method

↓

Total N content

↓ N×6.25

Protein content



Chitin					
	10.7%	1.6%	6.3%	5.9%	7.2%

Migratory locust

Total N Protein
73.4 g/100 g (K_P, 6.25)

↕ 12.5 g/100 g

True protein content

60.9 g/100 g (K_P, 6.25)

Insects are categorized as "other food materials" and NPF 6.25 is used.

(Ochiai, et al., *Food Chem*. 2024)

Example exception
- Wheat flour 5.70
- Rice material 5.95

Chitin-derived nitrogen content can affect net protein content

Gut-intestinal digestibility of edible insects

Edible insect proteins are resistant to gut digestibility

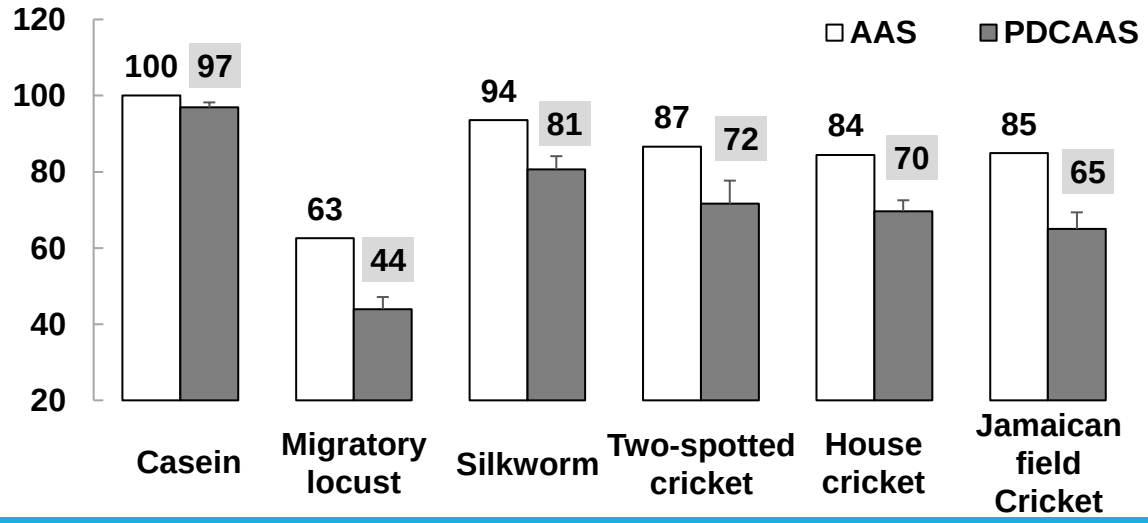
Tropomyosin-like compounds can not be degraded by pepsin treatment in vitro.

can not be degraded in gut of rats.

(Ochiai, et al., *Food Chem*. 2022)

Gut-intestinal digestibility (%) of edible insects in rat study

Migratory locust	Silkworm	Two-spotted cricket	House cricket	Jamaican field Cricket	Casein
70 ± 5	86 ± 4	83 ± 7	82 ± 3	77 ± 5	97 ± 1



Protein digestibility-correlated amino acid score

PDCAAS = AAS × gut-intestinal digestibility

Lower gut-intestinal protein digestibility suppressed their PDCAAS

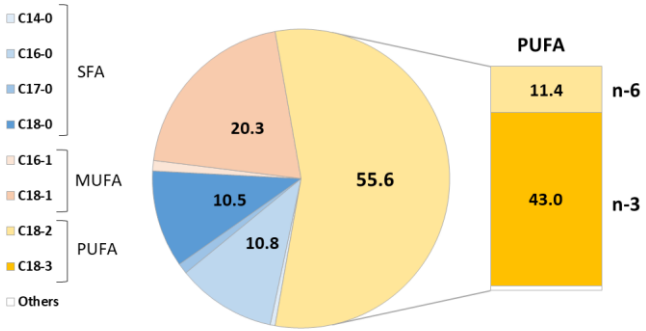
(Ochiai, et al., *Food Chem*. 2024)

Fat / Lipid

Locust and silkworm contain n-3 polyunsaturated fatty acid

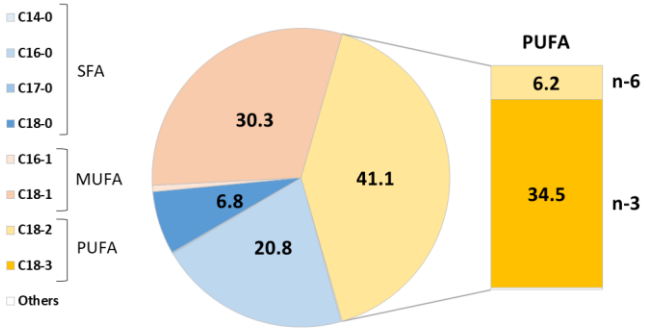
Migratory locust

Locusta migratoria



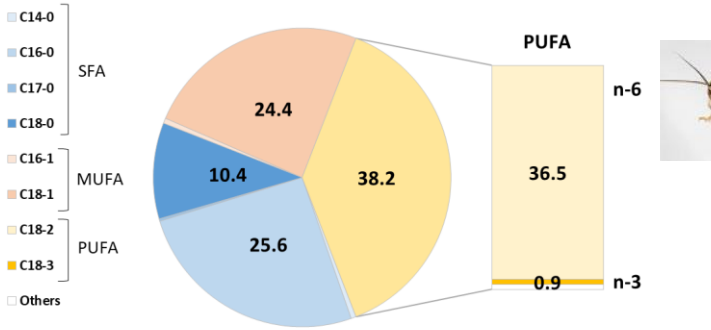
Silkworm

Bombyx mori



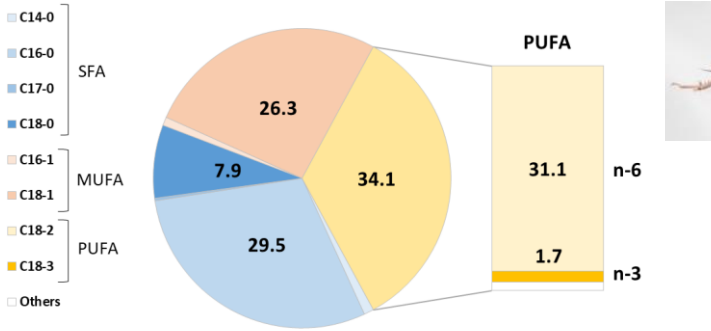
House cricket

Acheta domestica



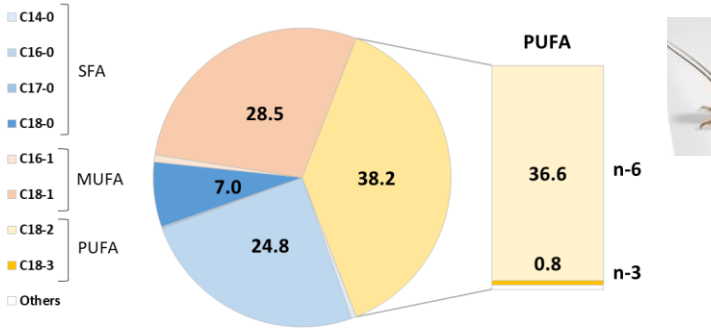
Jamaican field cricket

Gryllus assimilis

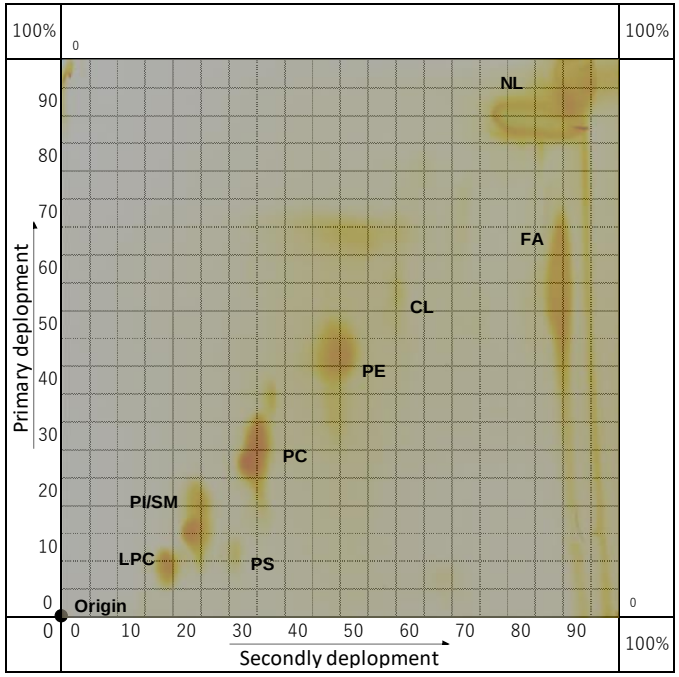


Two-spotted cricket

Gryllus bimaculatus

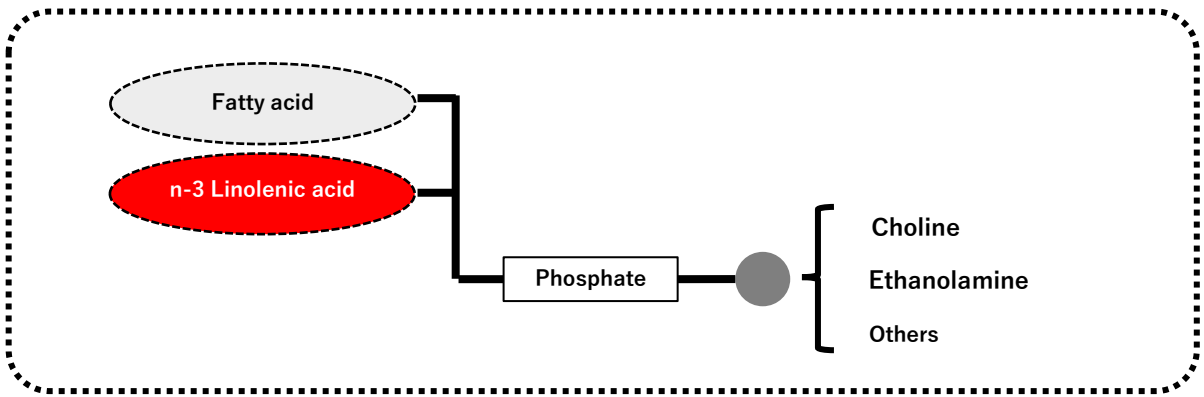


TLC figure and lipid molecular model



Migratory locust

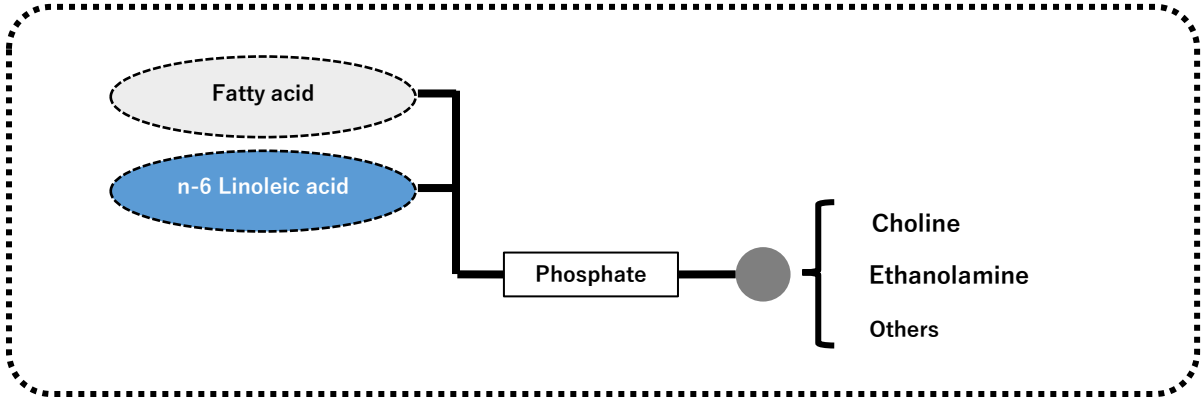
Silkworm



Jamaican field cricket

House cricket

Two-spotted cricket



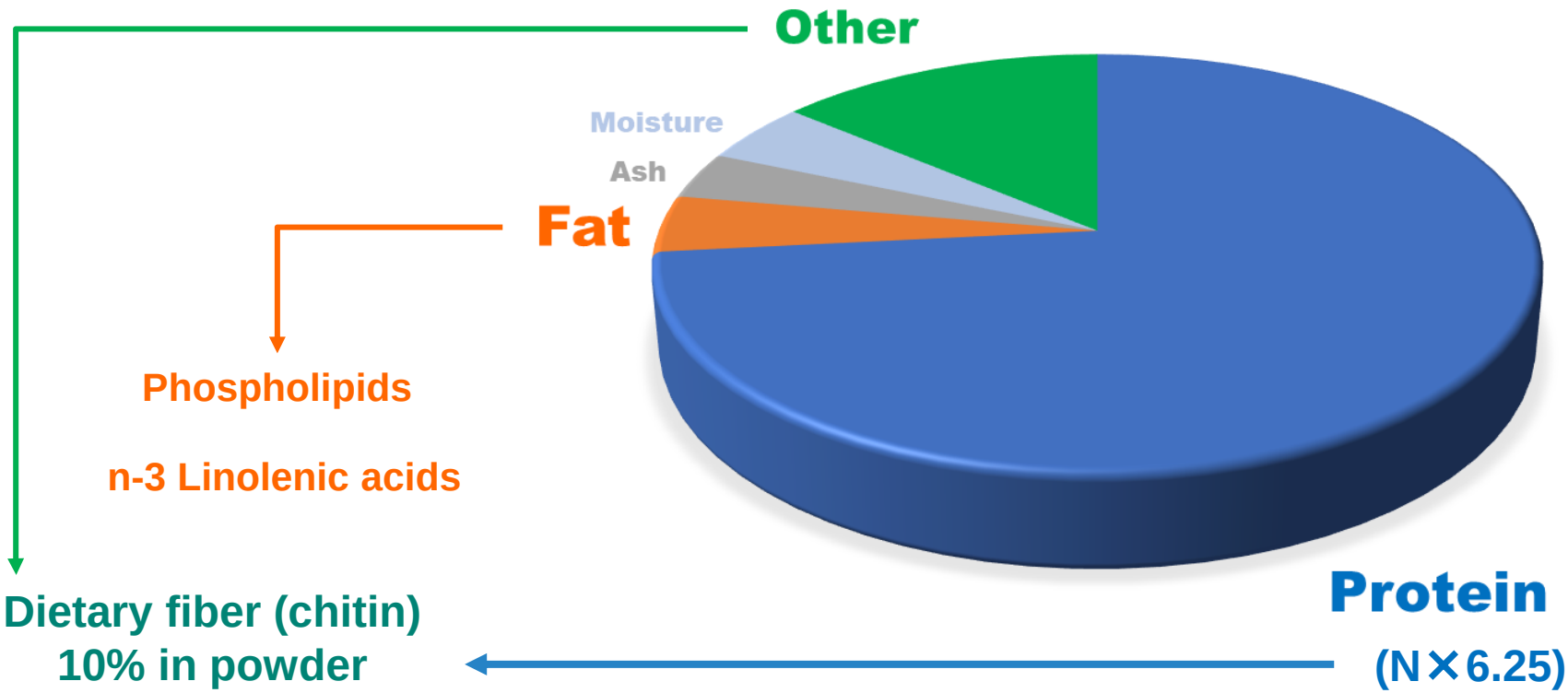
Locust and silkworm contain n-3 PUFA as a form of phospholipid as well as triglyceride

Crickets contain n-6 PUFA

Nutritional and physiological function of edible insects ?

(limited to the migratory locust powder)

Nutritional profile of migratory locust powder



(Ochiai, komiya, *J Food Compost Anal*., 2021)

Possibilities of improving lipid metabolism by edible insects ??

Effect of dietary migratory locust on lipid metabolism ?? (rat study)

Methods

Wistar rats
- Control (CA)
- Migratory locust (ML)

***Ad libitum* feeding for 5 weeks**

Analysis

- Plasma biochemical components
- Plasma lipoprotein and fatty acid composition
- Liver lipid accumulation
- mRNA expression and enzymatic activity in the liver

Diet

Casein	100
Casein or locust	**100**
L-Cystin	3.0
Starch	529
Sucrose	100
Cellulose	50
Soybean oil	70
Vitamin mixture	10
Mineral mixture	35
Choline	2.5
BHT	0.014
Total	1000.0

Results

	CA	ML
Triglyceride	214 ± 25	121 ± 9**
Phospholipids	197 ± 13	120 ± 5***
Total-cholesterol	123 ± 12	73 ± 5**
Urea nitrogen	15.5 ± 0.7	11.4 ± 0.4***
AST	60 ± 2	55 ± 1*
ALT	29 ± 1	25 ± 1*

Separation and quantification by lipoprotein fraction

↓

Chylomicron (2 sub-fractions), VLDL (5), LDL (6), HDL (7)

Energy %	
Carbohydrate	64
Fat	16
Protein	20
Total	**100**

Migratory locust lowered plasma lipid levels and liver function index

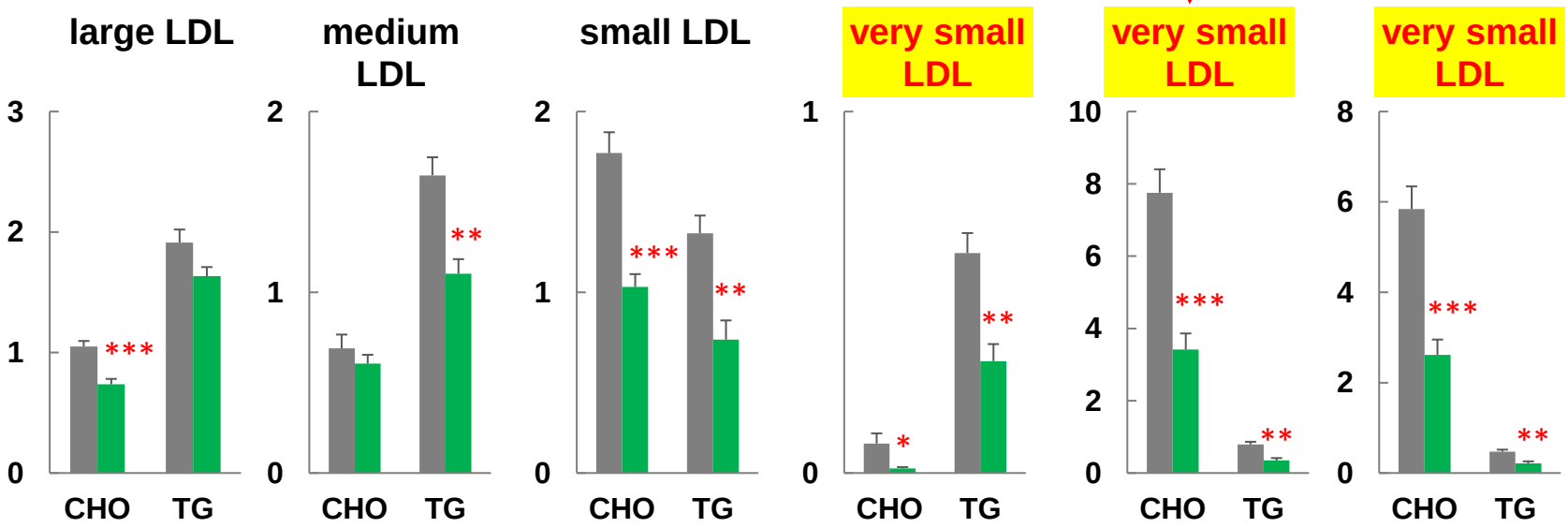
(Ochiai, et al., *Food Chem*. 2022)

Results

	Cholesterol		Triglyceride	
	CA	ML	CA	ML
Total	77.2	55.9	152	120
CM	1.04	0.54	13.9	5.95
VLDL	10.4	10.9	127	106
LDL	17.2	8.41	6.76	4.35
HDL	48.6	36.1	3.99	2.99

very-small LDL lipids:
Association with atherosclerosis and lipid metabolic disorders

Separation

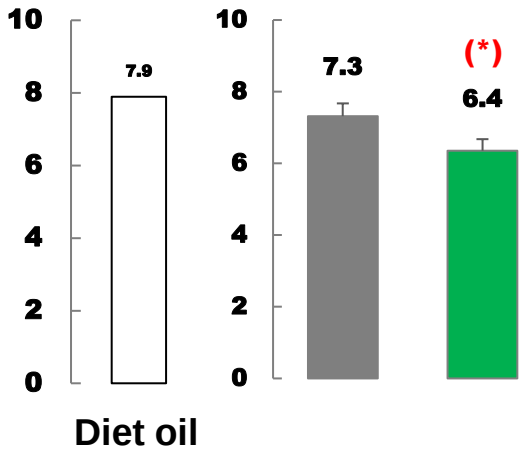


Migratory locust lowered plasma LDL and very-small LDL levels

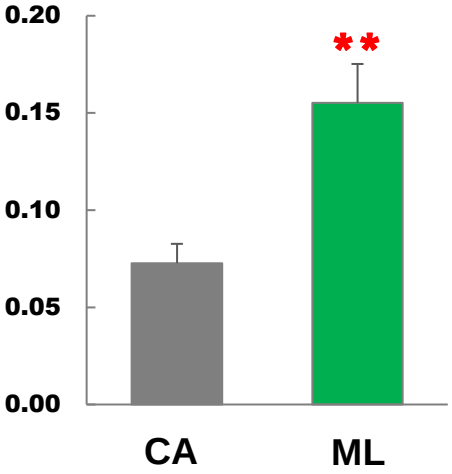
(Ochiai, et al., *Food Chem*. 2022)

Plasma fatty acid composition

n-6/n-3 ratio

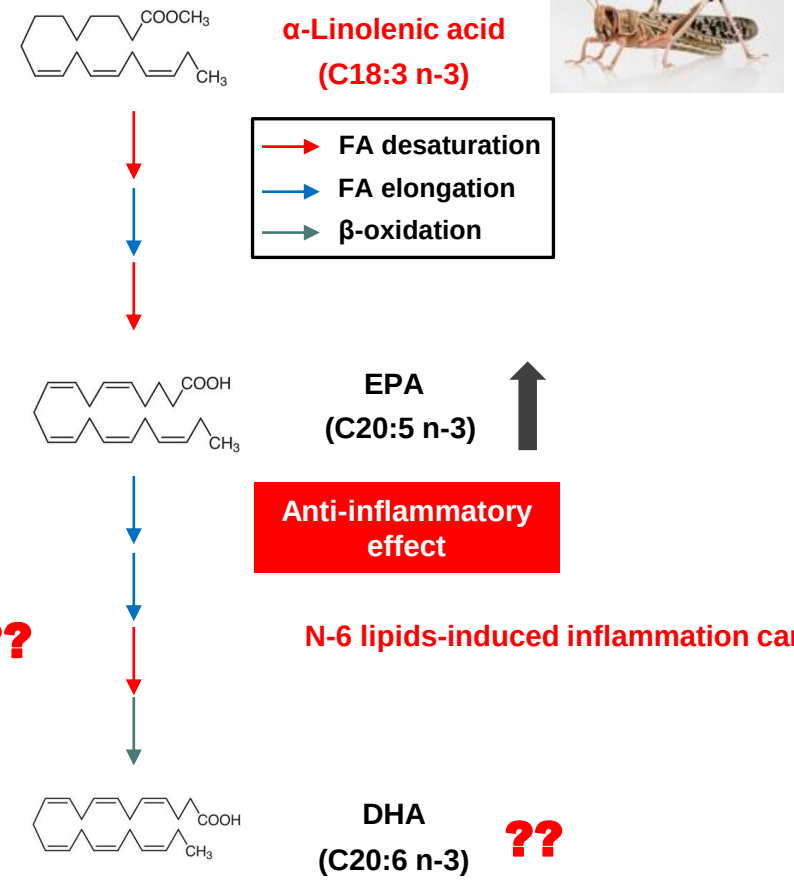


Atherosclerosis index
C20:5/C20:4



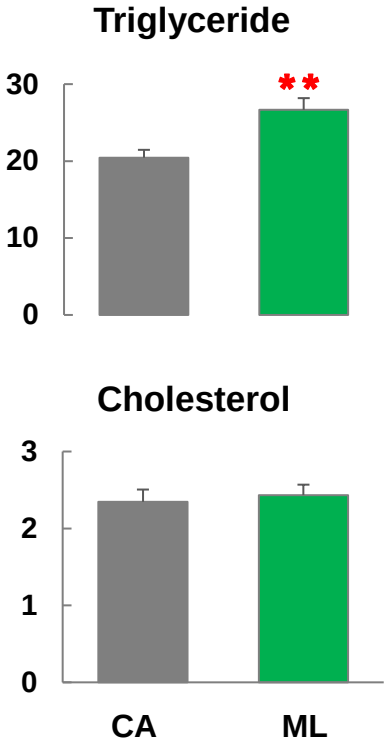
(Ochiai, et al., *Food Chem*. 2022)

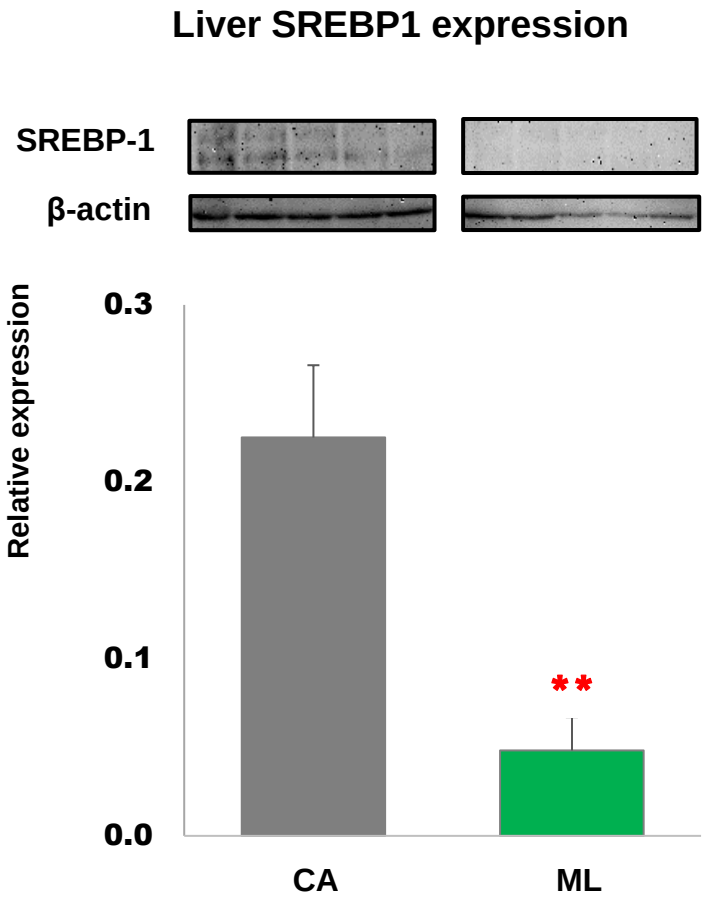
Fatty acid composition in plasma is important for the improvement of lipid metabolism

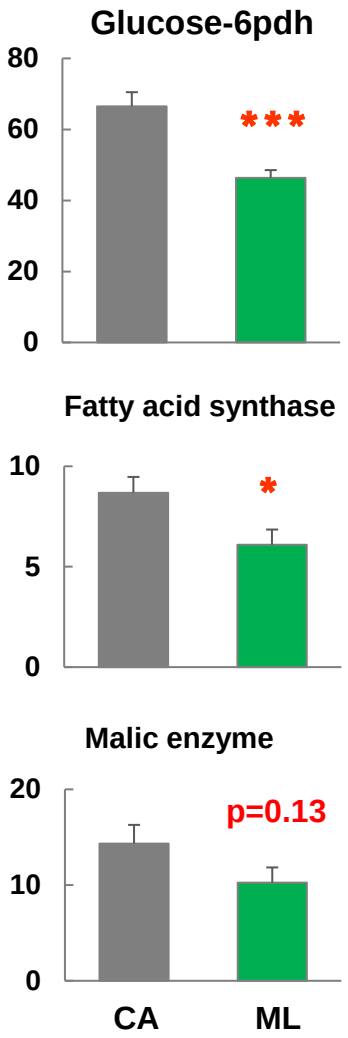


Lowered n-6/n-3 ratio and arteriosclerosis indices of plasma FA can prevent lipid metabolic disorders??

Liver lipid accumulation and suppressing lipogenesis mechanism



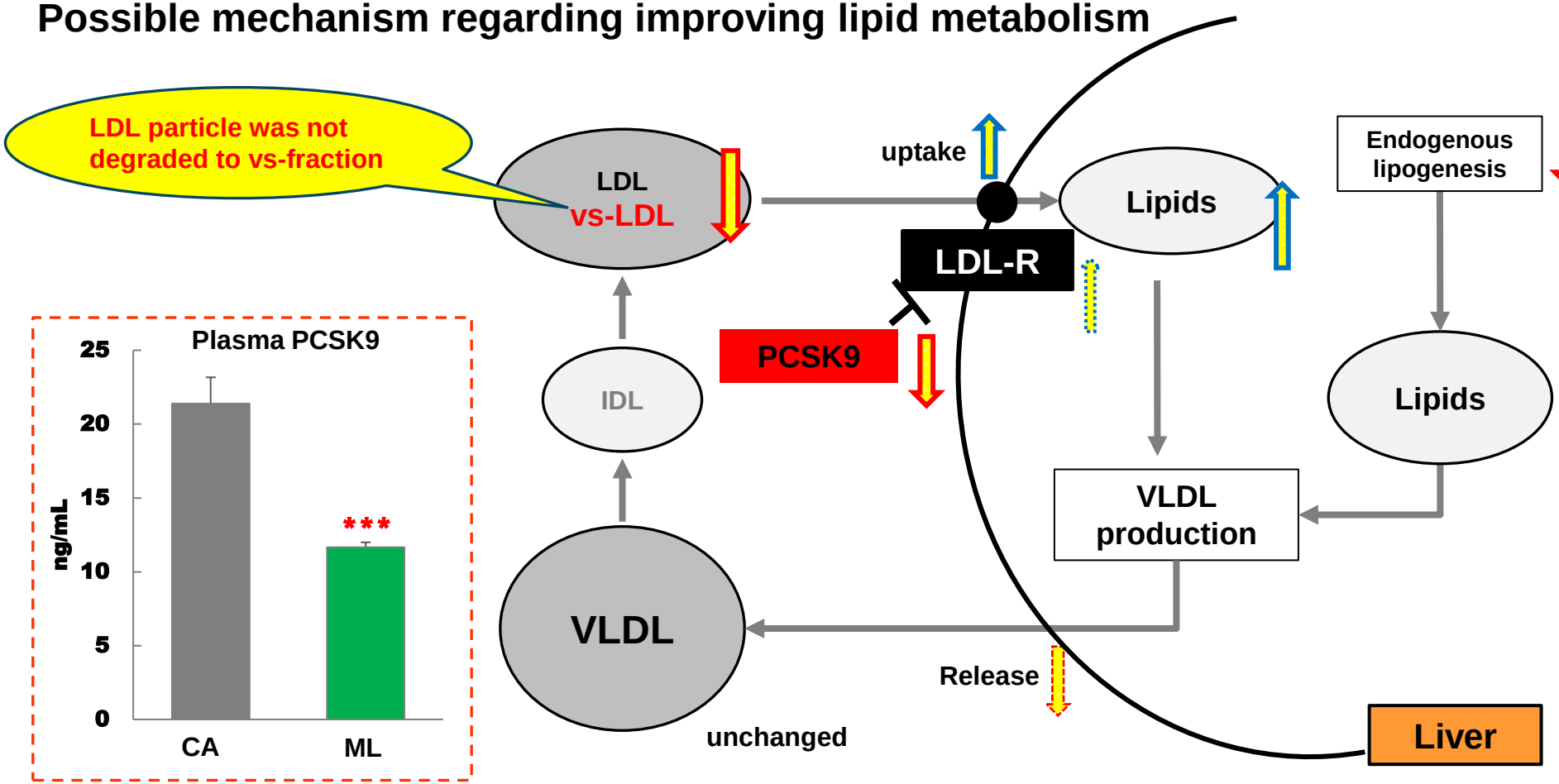




Liver triglyceride content was increased, but suppresses endogenous lipogenesis

(Ochiai, et al., *Food Chem*. 2022)

Discussion
Possible mechanism regarding improving lipid metabolism



Migratory locust can prevent lipid disorders through the improving lipoprotein cycle and FA profile.

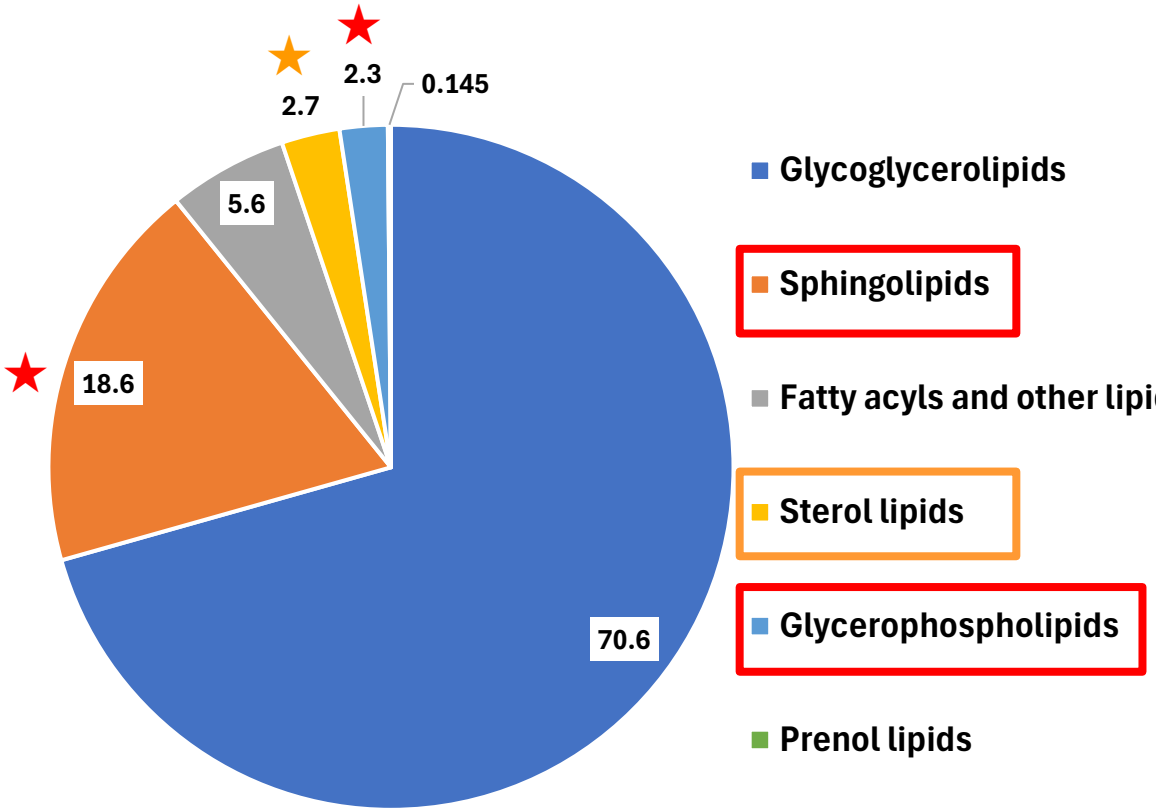
(Ochiai, et al., *Food Chem*. 2022)

(Regulation of the lipoprotein mechanism and key chemical compounds are investigated in progress.)

Discussion-2 (*In progress*, unpublished data)

~~ Functional compounds in the lipids from migratory locust ~~

Lipidomics analysis has indicated the presence of many species of lipid forms and that n-3 α-linolenic acid (C18:3) is dominant FA bounded to lipids



Extraction
Bligh & Dyer method

Total lipids

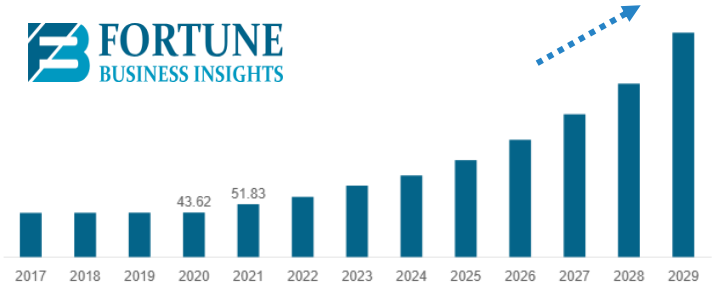
Lipidomics analysis

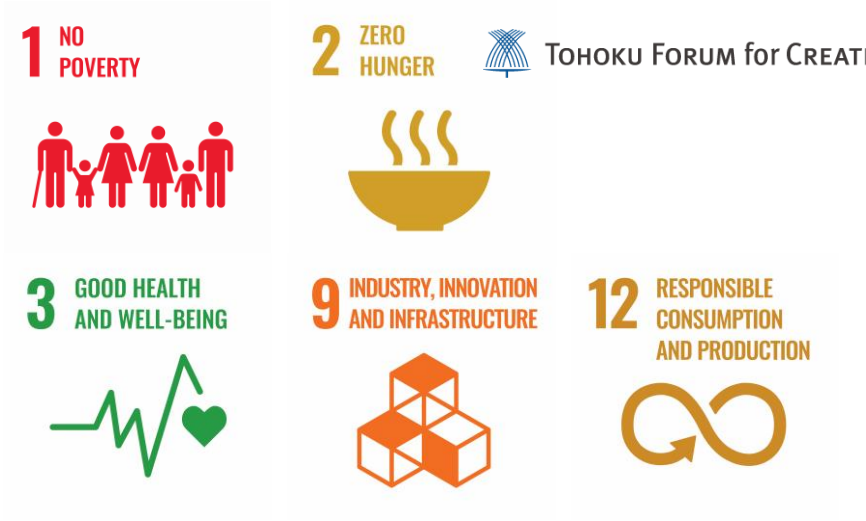
Detection of chemical compounds

Sphingolipids (SM etc.) with n-3 FA and sterol lipids are quantitatively abundant.

Future perspectives and important issues ?

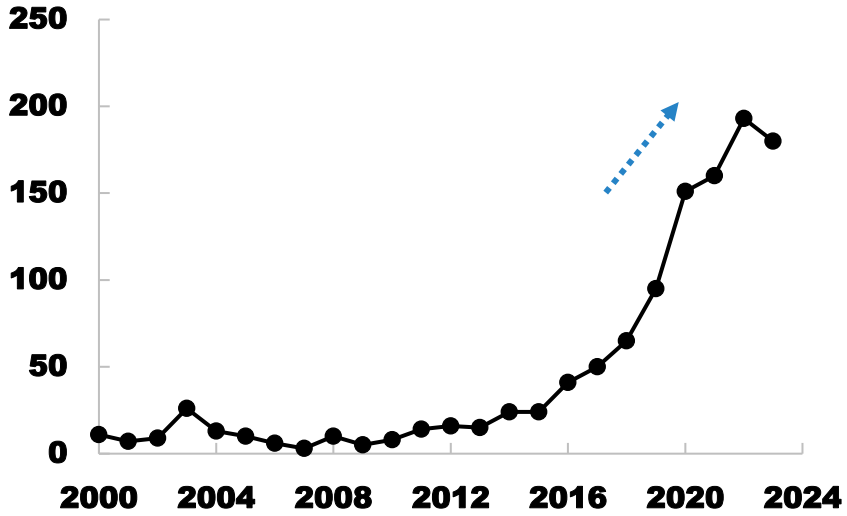
Insect-food protein market perspectives to 2029 (data from 2022)





Insect food and feed markets are going to be expanded for achievement of many SDGs and protect food security in the world

Publications of Insect food and feed are expected to be increasing



Research field

- Nutrients
- Safety
- Function
- Food processing
- Raising insect for food and feed

Insect foods in the world from the past and future

Japan

Due to an aversiveness to insect foods for most people, high-processing is necessary in Japanese markets

Thailand

Simply cooked (fried, heated with taste) is general as well as chicken and shrimp in Thailand street markets

European countries

- ○ Green: Authorized (whole and processed)
- ○ Yellow: Authorized (limited)
- ○ Purple: Authorized (non-EU)
- × Orange: Not approved

Data from IPIFF (2021)

Different responses for each country

Important issues for the development of insect-foods and feed

1. Aversiveness to insects as food (and feed)
2. Safety (food-related allergens, etc.) and function
3. Recognized and authorized as a novel food in Japan
4. Raising insects and manufacturing processed insect foods and feed for sustainability
5. Labeling of insect nutrients (e.g., protein or chitin) for foods and feed markets
6. Education on the use of insects as food and feed for population

Trends in Food Science & Technology 88 (2019) 505–512

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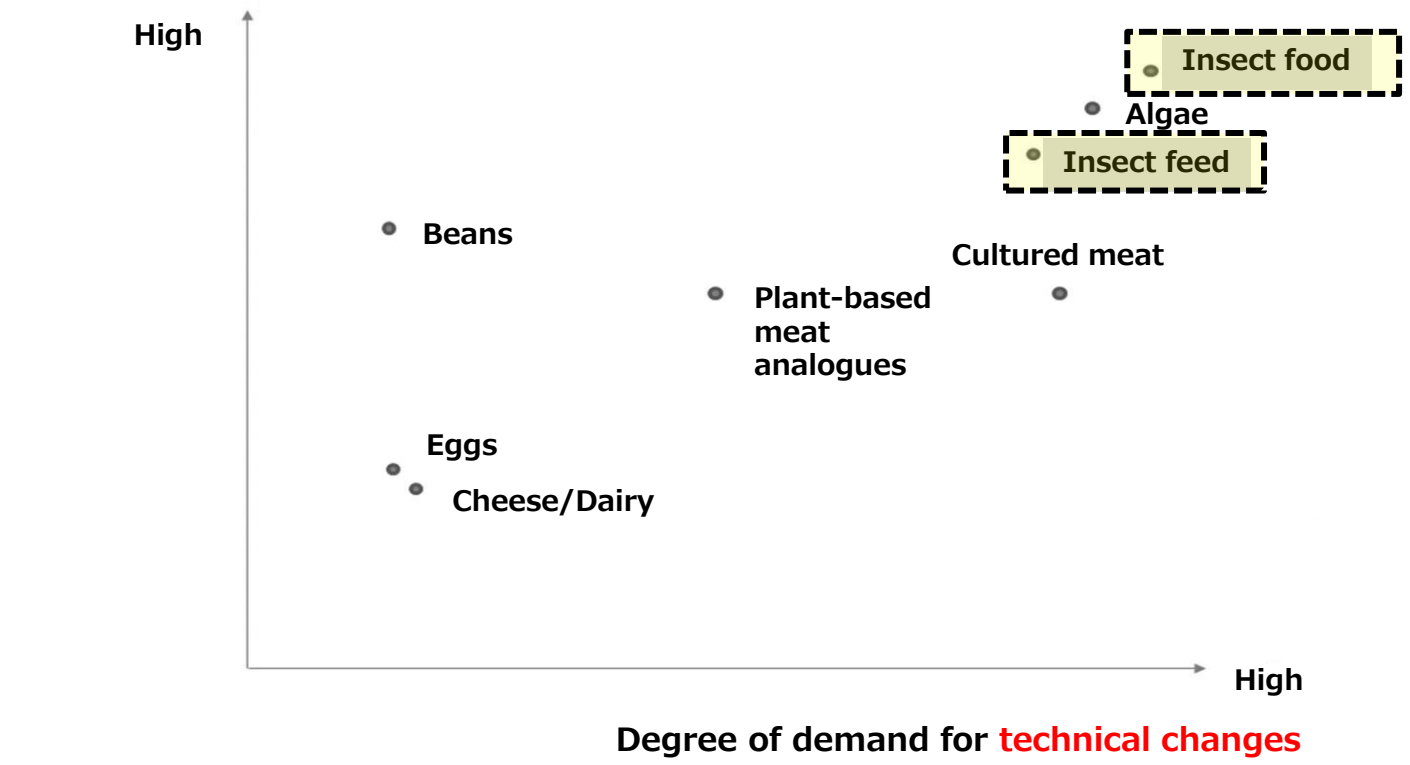
journal homepage: www.elsevier.com/locate/tifs

Review

Meat alternatives: an integrative comparison

Cor van der Weele[a,*], Peter Feindt[b], Atze Jan van der Goot[c], Barbara van Mierlo[a], Martinus van Boekel[c]

High demand for social institutional and technological changes to insect foods and feeds



Summary / Conclusion

- **Nutritional abundance (protein, lipids / fat, dietary fiber)**

  α-Linolenic acid is contained as phospholipids and triglyceride forms

  Protein amounts are well, but their amino acid balance is not good

  Dietary fiber chitin are contained at about 10% in the insect powder

- **Nutritional physiological functions**

  Lowering LDL-lipid levels in blood are expected in rats

  Suppressing lipid absorption and liver lipid synthesis are expected in rats

➢ **Some important issues for the development of insects for food and feed**

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Thank you for your kind attention

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