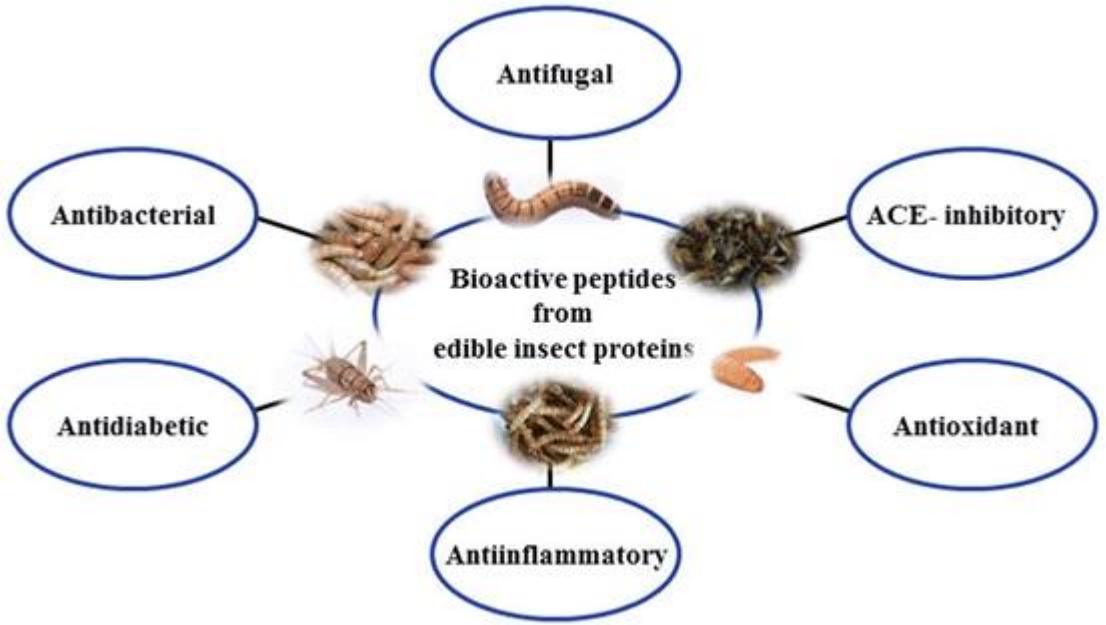


Insects: feed & bioactive compounds

GASCO L.

Department of Agricultural, Forest and Food Sciences

laura.gasco@unito.it

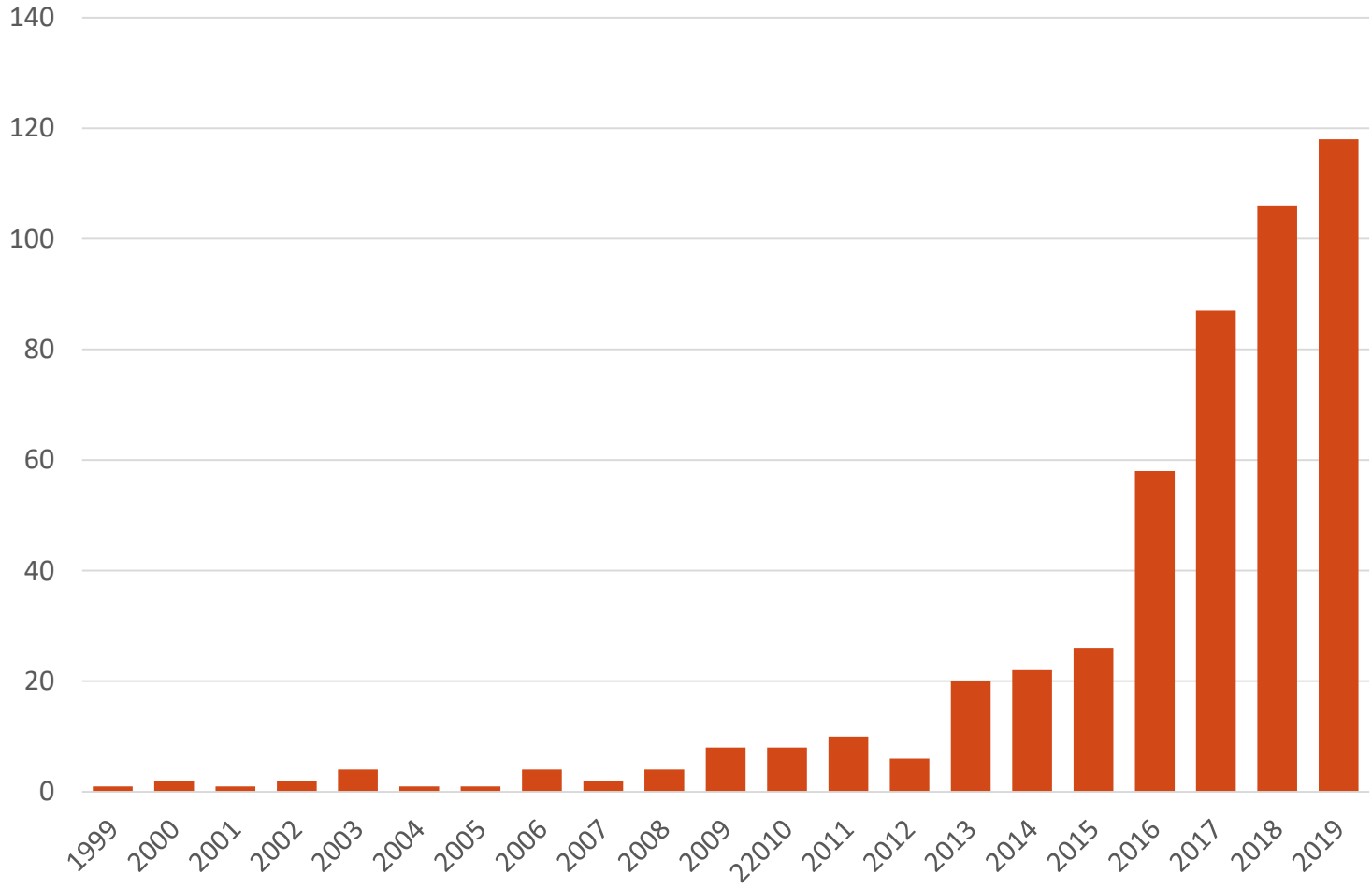
Journal of Animal and Feed Sciences, 26, 2017, 87–99 *https://doi.org/10.22358/jafs/69998/2017*
The Kielanowski Institute of Animal Physiology and Nutrition, Polish Academy of Sciences, Jabłonna

Insect proteins as a potential source of antimicrobial peptides in livestock production. A review

A. Józefiak[1,3] and R.M. Engberg[2]

[1] Poznań University of Life Sciences, Institute of Veterinary Sciences
Wołyńska 35, 60-637 Poznań, Poland
[2] Aarhus University, Department of Animal Science
Blichers Allé 20, 8830 Tjele, Denmark

Insects: increasing interest



WOS «edible insects»


SATISFACTION
100%
GUARANTEED

PESTS


Time to say goodbye
to uninvited guests!

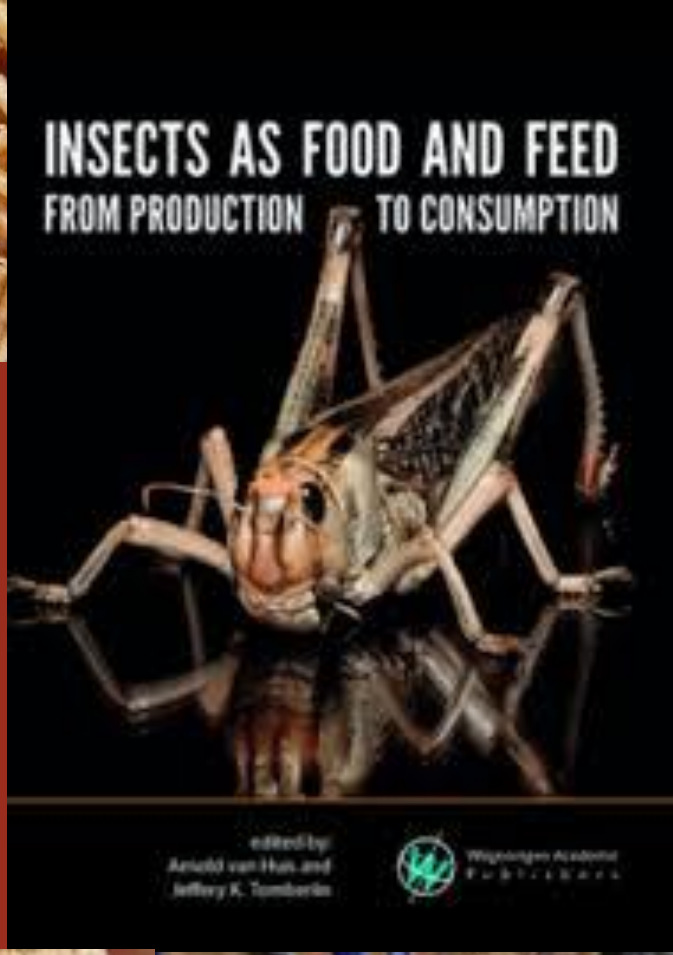

Say Good bye to those
Annoying Pests
We carefully evaluate your home's unique
problem & create a plan of action to make
your home a safe place to be




RESOURCE




FOOD



FEED

New feedstuff for animal feeds

High nutritional value

- Proteins (AA)
- Lipids (En – FA)

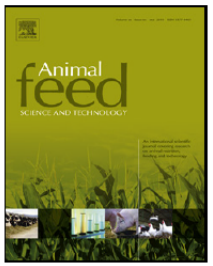
Sustainable (??)

Animal Feed Science and Technology 203 (2015) 1–22

Contents lists available at ScienceDirect

Animal Feed Science and Technology

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



Review

Review on the use of insects in the diet of farmed fish: Past and future

M. Henry[a,*], L. Gasco[b], G. Piccolo[c], E. Fountoulaki[a]

insect meals - fats

REVIEWS IN Aquaculture

Reviews in Aquaculture, 1–24

doi: 10.1111/raq.12281

Insect meals in fish nutrition

Silvia Nogales-Mérida[1], Paola Gobbi[1], Damian Józefiak[2], Jan Mazurkiewicz[3], Krzysztof Dudek[1], Mateusz Rawski[3], Bartosz Kierończyk[2] and Agata Józefiak[4]

insect meals - fats

Ann. Anim. Sci., Vol. 16, No. 2 (2016) 297–313 *DOI:10.1515/aoas-2016-0010*

DE GRUYTER OPEN

INSECTS – A NATURAL NUTRIENT SOURCE FOR POULTRY – A REVIEW*

Damian Józefiak[1♦], Agata Józefiak[3], Bartosz Kierończyk[1], Mateusz Rawski[1], Sylwester Świątkiewicz[4], Jakub Długosz[1], Ricarda Margarete Engberg[2]

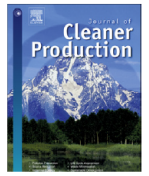
eaner Production 171 (2018) 403–412

lists available at ScienceDirect

Journal of Cleaner Production

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

ELSEVIER



Insect as feed: An emergy assessment of insect meal as a sustainable protein source for the Brazilian poultry industry

Gabriela Allegretti [a,*], Edson Talamini [a], Verônica Schmidt [a], Paulo Cesar Bogorni [b], Enrique Ortega [c]

Animal, page 1 of 8 © The Animal Consortium 2018
doi:10.1017/S1751731117003743

Black soldier fly larva fat inclusion in finisher broiler chicken diet as an alternative fat source

A. Schiavone[1,5], S. Dabbou[1], M. De Marco[1], M. Cullere[2], I. Biasato[1], E. Biasibetti[1], M. T. Capucchio[1], S. Bergagna[3], D. Dezzutto[3], M. Meneguz[4], F. Gai[5], A. Dalle Zotte[2†] and L. Gasco[4,5]

Insect4Feed

Insects: a protein-rich feed ingredient in pig and poultry diets

Teun Veldkamp,* and Guido Bosch†

Biasato et al. Journal of Animal Science and Biotechnology (2019) 10:12
https://doi.org/10.1186/s40104-019-0325-x

Journal of Animal Science and Biotechnology

RESEARCH Open Access

Partially defatted black soldier fly larva meal inclusion in piglet diets: effects on the growth performance, nutrient digestibility, blood profile, gut morphology and histological features

Ilaria Biasato[1], Manuela Renna[2], Francesco Gai[3], Sihem Dabbou[2], Marco Meneguz[1], Giovanni Perona[4], Silvia Martinez[5], Ana Cristina Barroeta Lajusticia[6], Stefania Bergagna[7], Luca Sardi[8], Maria Teresa Capucchio[2], Enrico Bressan[1], Andrea Dama[1], Achille Schiavone[2,3*] and Laura Gasco[1]

Open Access
Asian-Australas J Anim Sci
Vol. 32, No. 3:387-394 March 2019
https://doi.org/10.5713/ajas.18.0647
pISSN 1011-2367 eISSN 1976-5517

Asian-Australasian Journal of Animal Sciences

Nutrient ileal digestibility evaluation of dried mealworm (*Tenebrio molitor*) larvae compared to three animal protein by-products in growing pigs

J. S. Yoo[1,a], K. H. Cho[1,a], J. S. Hong[2], H. S. Jang[3], Y. H. Chung[3], G. T. Kwon[4], D. G. Shin[4], and Y. Y. Kim[2,*]

Animal, page 1 of 9 © The Animal Consortium 2019
doi:10.1017/S1751731119001873

animal

Review: Insect meal: a future source of protein feed for pigs?

K. DiGiacomo† and B. J. Leury

Gasco *et al. Journal of Animal Science and Biotechnology* (2019) 10:4
https://doi.org/10.1186/s40104-018-0309-2

Journal of Animal Science and Biotechnology

RESEARCH Open Access

Effect of dietary supplementation with insect fats on growth performance, digestive efficiency and health of rabbits

Laura Gasco[1], Sihem Dabbou[2], Angela Trocino[3], Gerolamo Xiccato[4], Maria Teresa Capucchio[2], Ilaria Biasato[1], Daniela Dezzutto[5], Marco Birolo[4], Marco Meneguz[1], Achille Schiavone[2,6,7*] and Francesco Gai[6]

insect fat

Meat Science 146 (2018) 50–58

Contents lists available at ScienceDirect

Meat Science

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

Incorporation of Black Soldier Fly (*Hermetia illucens* L.) larvae fat or extruded linseed in diets of growing rabbits and their effects on meat quality traits including detailed fatty acid composition

Antonella Dalle Zotte[a], Marco Cullere[a], Cátia Martins[b], Susana P. Alves[c], João P.B. Freire[b], Luísa Falcão-e-Cunha[b], Rui J.B. Bessa[c,*]

animals

MDPI

Review

Animals Fed Insect-Based Diets: State-of-the-Art on Digestibility, Performance and Product Quality

Laura Gasco [1,*], Ilaria Biasato [1], Sihem Dabbou [2], Achille Schiavone [2] and Francesco Gai [3]

Performances
Digestibility
Product quality

Histology
Gut morphology

Nutrition Bulletin

REVIEW

DOI: 10.1111/nbu.12291

Opportunities and hurdles of edible insects for food and feed

D. Dobermann*[†], J. A. Swift[†] and L. M. Field*

sustainability

Article

The Introduction of Insect Meal into Fish Diet: The First Economic Analysis on European Sea Bass Farming

Brunella Arru [1,*], Roberto Furesi [1], Laura Gasco [2], Fabio A. Madau [1,*] and Pietro Pulina [1]

Blood parameters
Microbiota

Consumer attitude
Economic
Safety

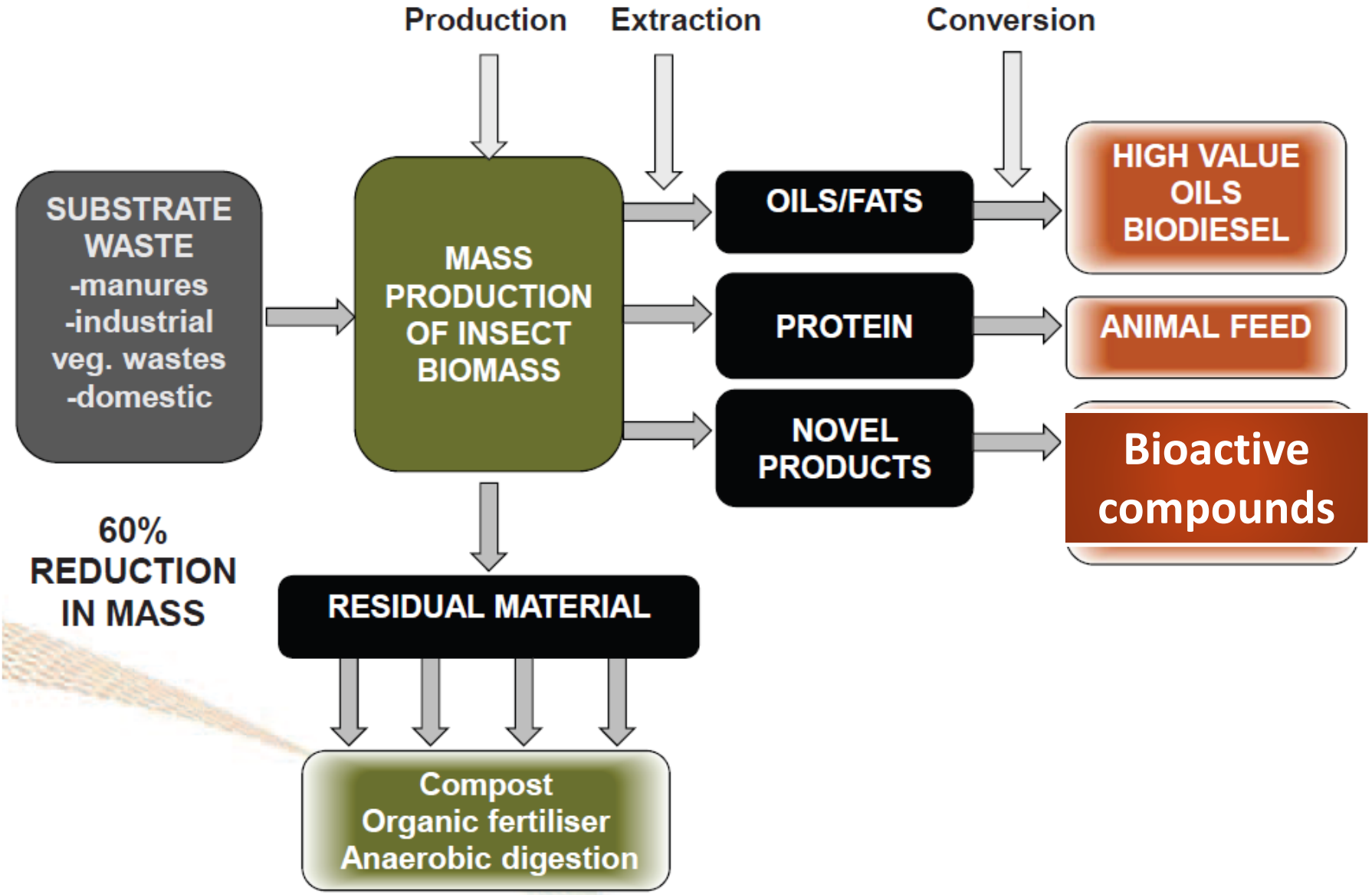
animals

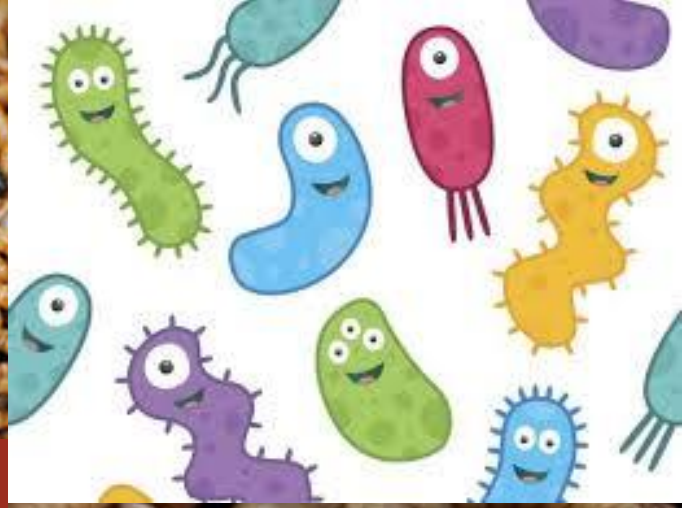
MDPI

Review

The Potential Role of Insects as Feed: A Multi-Perspective Review

Giovanni Sogari [1,2,*], Mario Amato [3], Ilaria Biasato [4], Silvana Chiesa [1] and Laura Gasco [4]


Production
Extraction
Conversion
SUBSTRATE WASTE
-manures
-industrial veg. wastes
-domestic
MASS PRODUCTION OF INSECT BIOMASS
OILS/FATS
PROTEIN
NOVEL PRODUCTS
HIGH VALUE OILS BIODIESEL
ANIMAL FEED
Bioactive compounds
60% REDUCTION IN MASS
RESIDUAL MATERIAL
Compost
Organic fertiliser
Anaerobic digestion

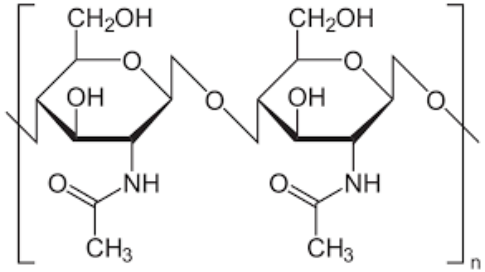


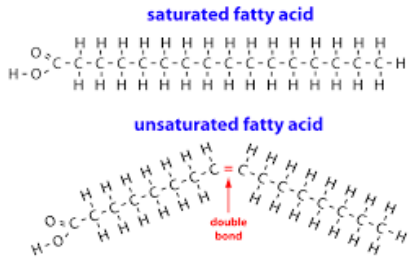
HEALTH

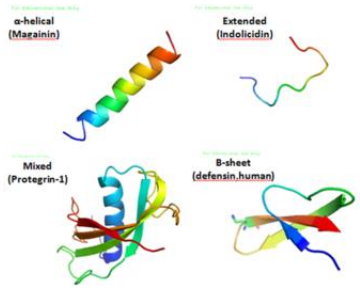
Consuming insects: are there health benefits?

Journal of Insects as Food and Feed, 2017; 3(4): 225-229

N. Roos[1] and A. van Huis[2*]







Can diets containing insects promote animal health?

Journal of Insects as Food and Feed, 2018; 4(1): 1-4

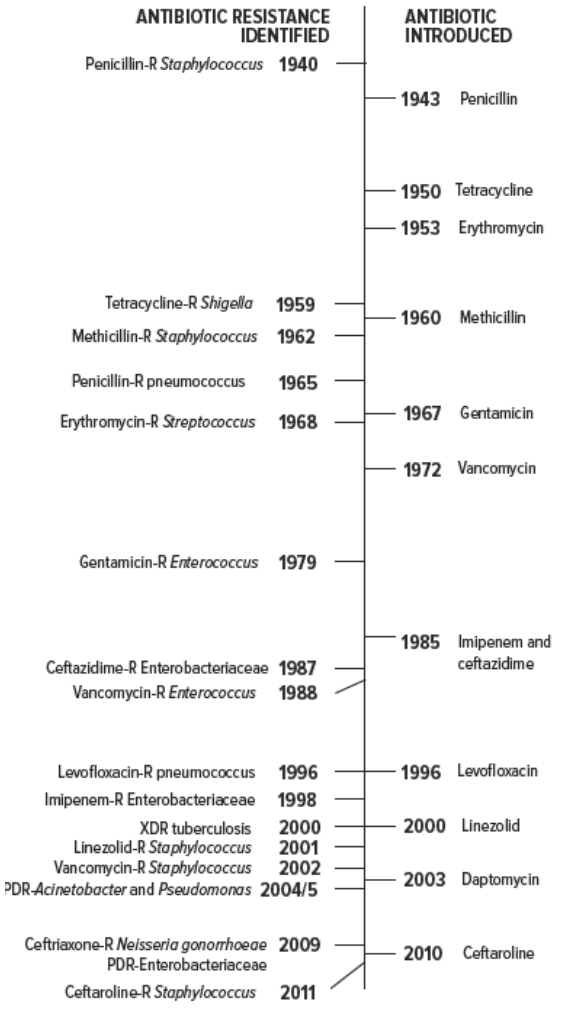
L. Gasco[1], M. Finke[2] and A. van Huis[3]

Bioactive compounds

- Anti-microbial peptides
- Chitin
- Fatty acids

- antimicrobial effects
- strengthen immune system
- microbiota modulation

Figure 1 Developing Antibiotic Resistance: A Timeline of Key Events[5]



PDR = pan-drug-resistant; R = resistant; XDR = extensively drug-resistant

Dates are based upon early reports of resistance in the literature. In the case of pan-drug-resistant *Acinetobacter* and *Pseudomonas*, the date is based upon reports of health care transmission or outbreaks. Note: penicillin was in limited use prior to widespread population usage in 1943.

Global **over-use** of **drugs treatments** in human and animal nutrition to treat diseases (or as growth promoters)

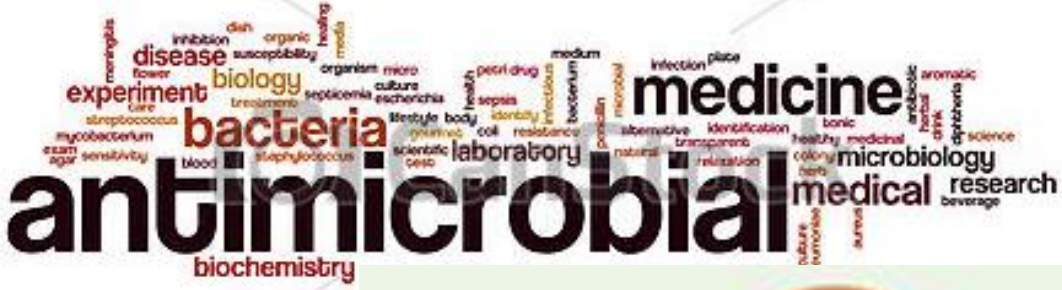
↓

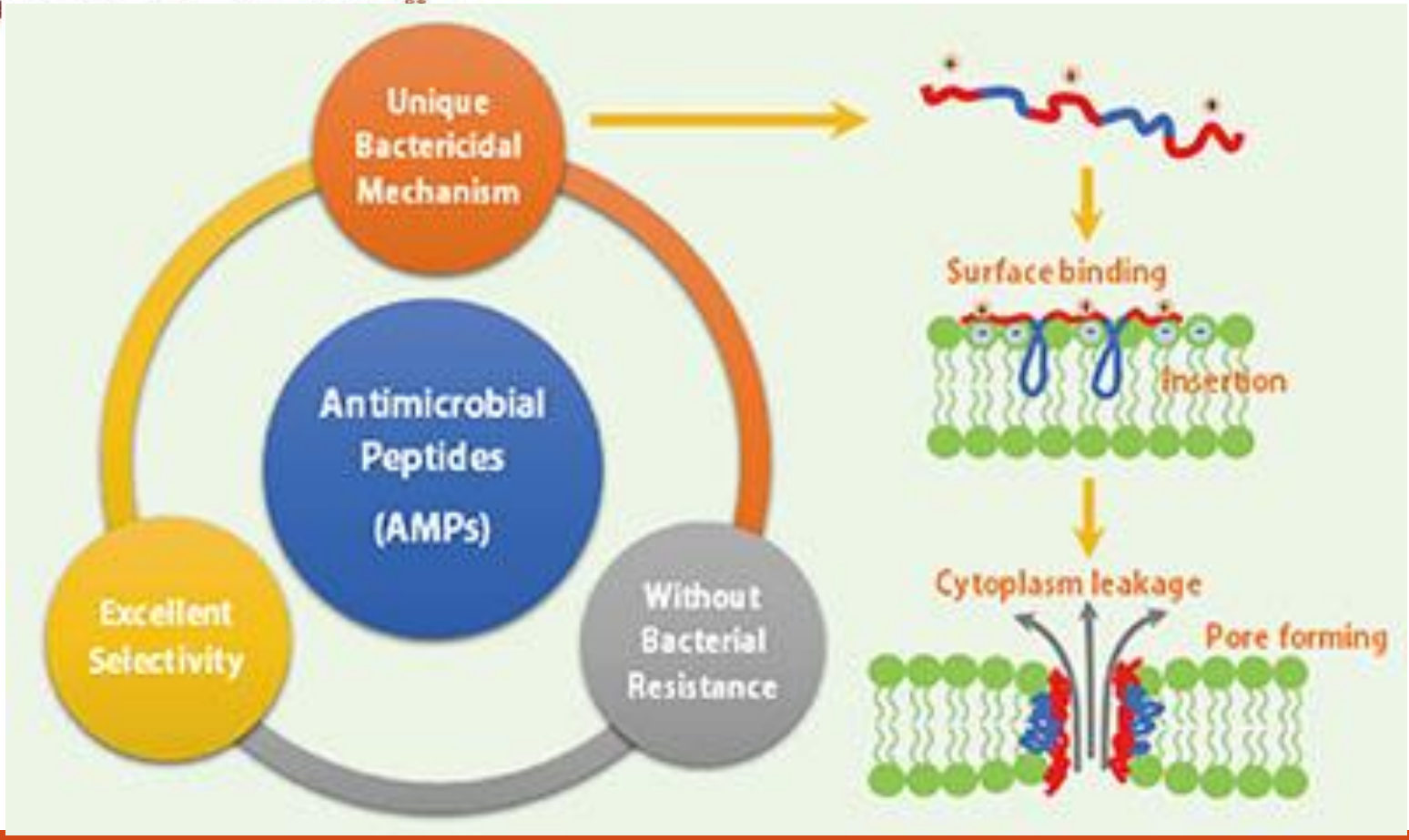
microbial resistance

- Animals: associated with decrease in performances, high morbidity & mortality

Antimicrobial resistance is one of the biggest threats to global health, food security, and development today

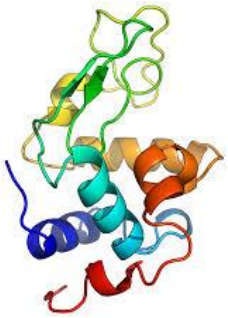
Ventola, 2015. P&T, 40:277-283


antimicrobial
bacteria
medicine
disease
biology
experiment
laboratory
microbiology
medical
research
biochemistry

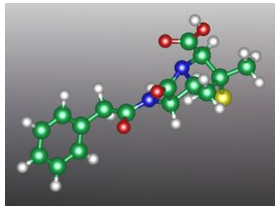

Unique Bactericidal Mechanism
Antimicrobial Peptides (AMPs)
Excellent Selectivity
Without Bacterial Resistance
Surface binding
Insertion
Cytoplasm leakage
Pore forming

AMPs

1922: A. Fleming



1928: penicillin



- 1940s: therapeutic use of penicillin
- 1945: Nobel Prize for Medicine

Golden Age of antibiotics

Loss of interest in the therapeutic potential of natural AMPs

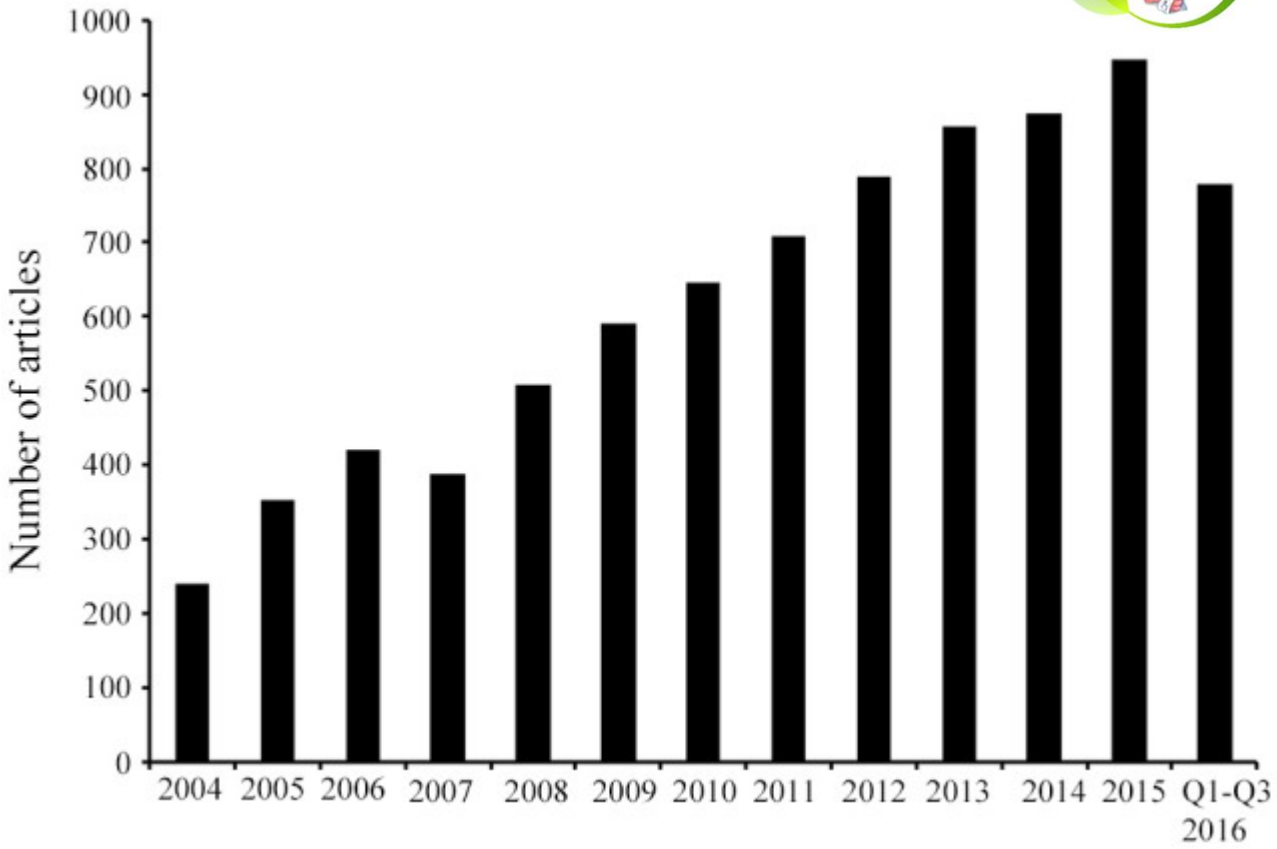
‘60s

Antimicrobial resistance

Renewed interest

- 5000 AMPs have been deposited in the Antimicrobial Peptide Database
- only a small fraction of gene-encoded antibiotic proteins produced in nature

Published research on AMPs identified from 2004 until September 2016.

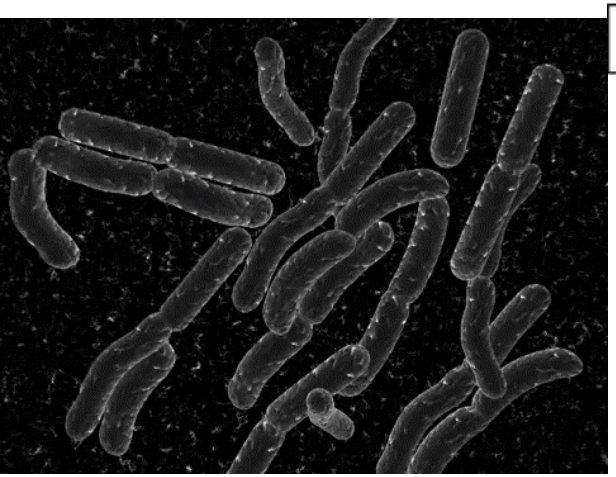


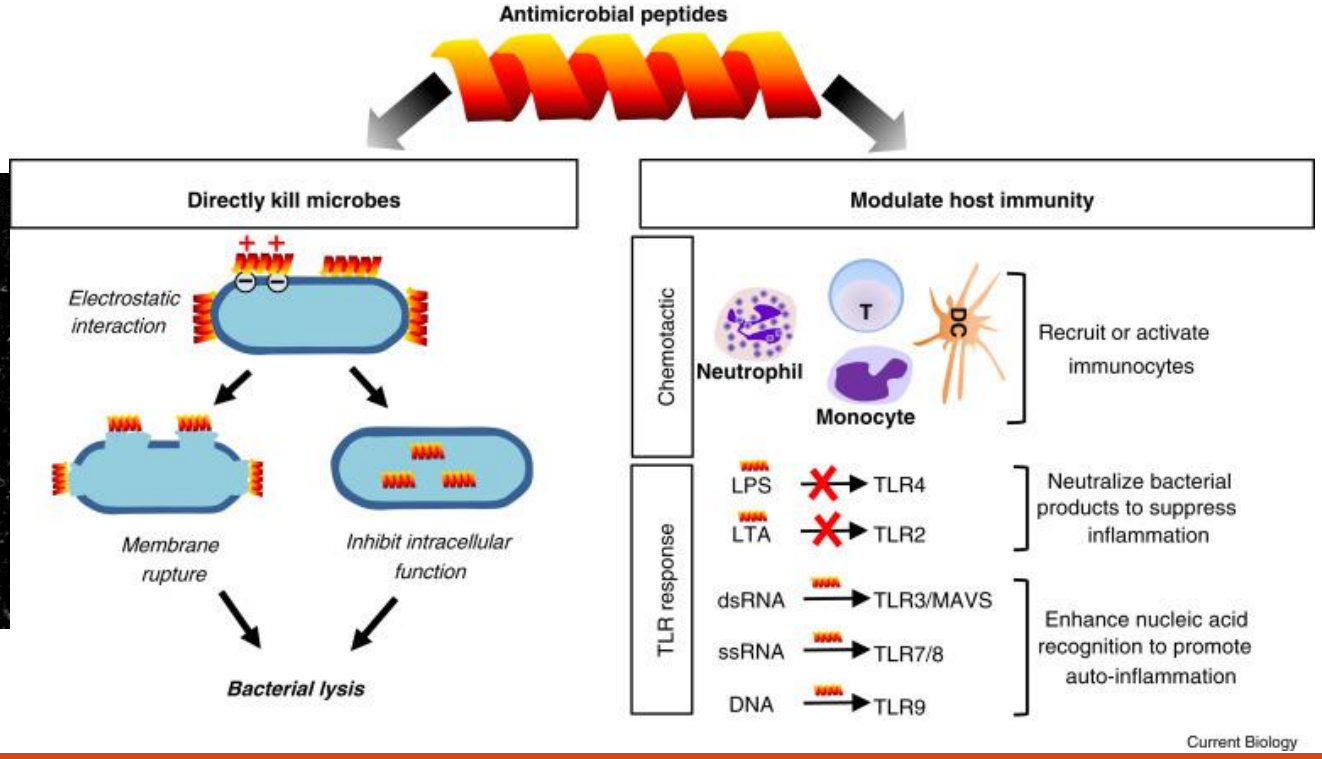
PubMed key words = antimicrobial peptides, AMPs, and/or host defense peptides.

In the last decade the AMP research field has progressively expanded

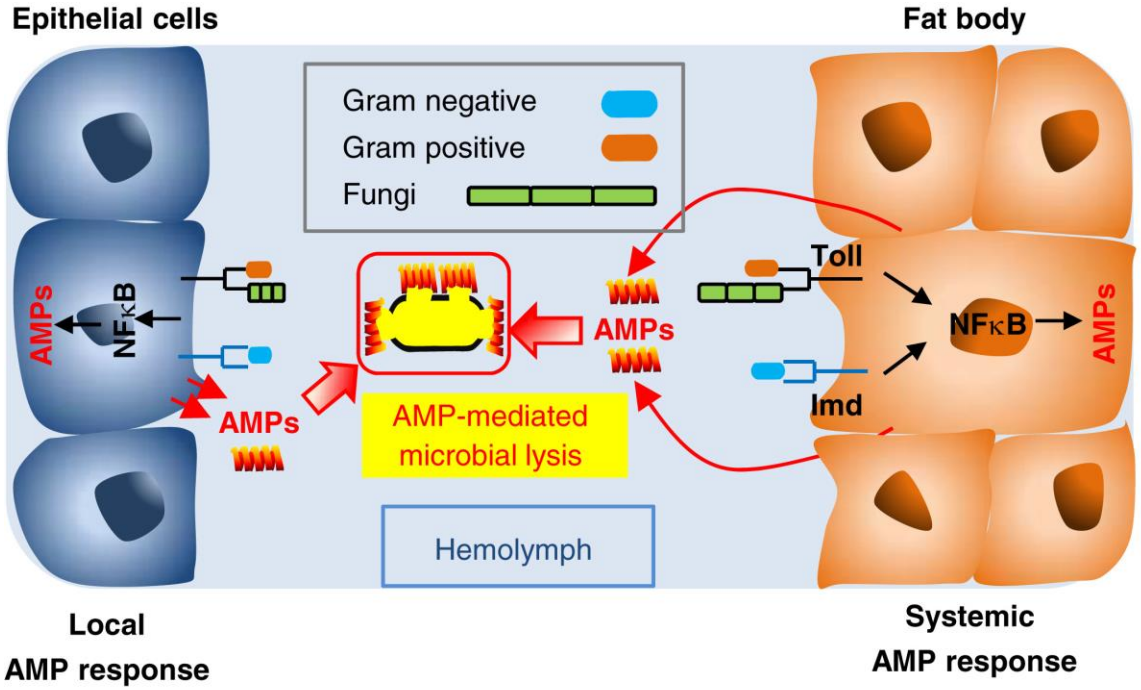
AMPs

- = small cationic proteins that exhibit activity against bacteria, fungi, parasites & virus
- AMPs
  - directly kill microbes
  - boost host specific innate immune response and exert selective immunomodulatory effects
- AMPs activity does not lead to natural bacteria resistance (or very low)





- Insects are a primary source of AMPs



Antimicrobial activity	Peptide names
Gram-positive bacteria	Defensins Andropin
Gram-negative bacteria	Cecropins Attacins Diptericins Drosocin
Fungi	Drosomycin Metchnikowin

Current Biology

Figure 3. Local and systemic AMP response in *Drosophila*.
Drosophila produces AMPs in response to microbial infection, either locally by epithelial cells or systemically by the fat body which secretes AMPs into hemolymph. Activation of the Toll pathway by Gram-positive bacteria or fungi, or the Imd pathway by Gram-negative bacteria, triggers NFκB activation followed by induction of AMPs, the effector molecules that mediate microbial lysis. The table on the right lists the main AMPs and their antimicrobial targets in *Drosophila*.

- 1,5 – 3 million insect species

great potential to be use in animal nutrition

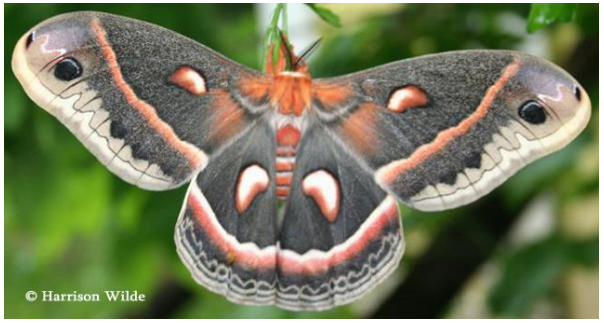
- 1st insect AMP: cecropin: extracted from *Hyalaphora cecropia* pupae

Sequence and specificity of two antibacterial proteins involved in insect immunity

H. Steiner, D. Hultmark, Å. Engström, H. Bennich & H. G. Boman

Nature **292**, 246–248 (1981)

giant silkmoth *Hyalaphora cecropia*



Zhang & Gallo, 2016. Current Biology, 26(1), 14-19

- **about 150 insect AMPs have been identified**

Journal of Animal and Feed Sciences, 26, 2017, 87–99 https
The Kielanowski Institute of Animal Physiology and Nutrition, Polis

SCIENTIFIC REPORTS

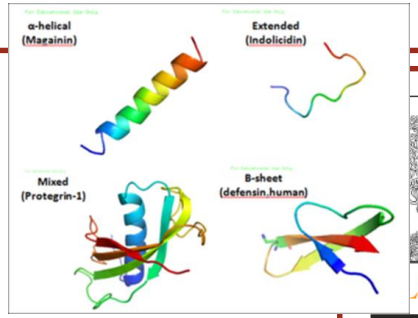
OPEN

ved: 15 May 2017
pted: 15 August 2017
shed online: 21 September 2017

Antibacterial and immunomodulatory activities of insect defensins-DLP2 and DLP4 against multidrug-resistant *Staphylococcus aureus*

Zhanzhan Li[1,2], Ruoyu Mao[1,2], Da Teng[1,2], Ya Hao[1,2], Huixian Chen[1,2], Xiumin Wang[1,2], Xiao Wang[1,2], Na Yang[1,2] & Jianhua Wang[1,2]

Insect proteins as a potential source of antimicrobial peptides in livestock production. A review



Contents lists available at ScienceDirect

Peptides

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

Review

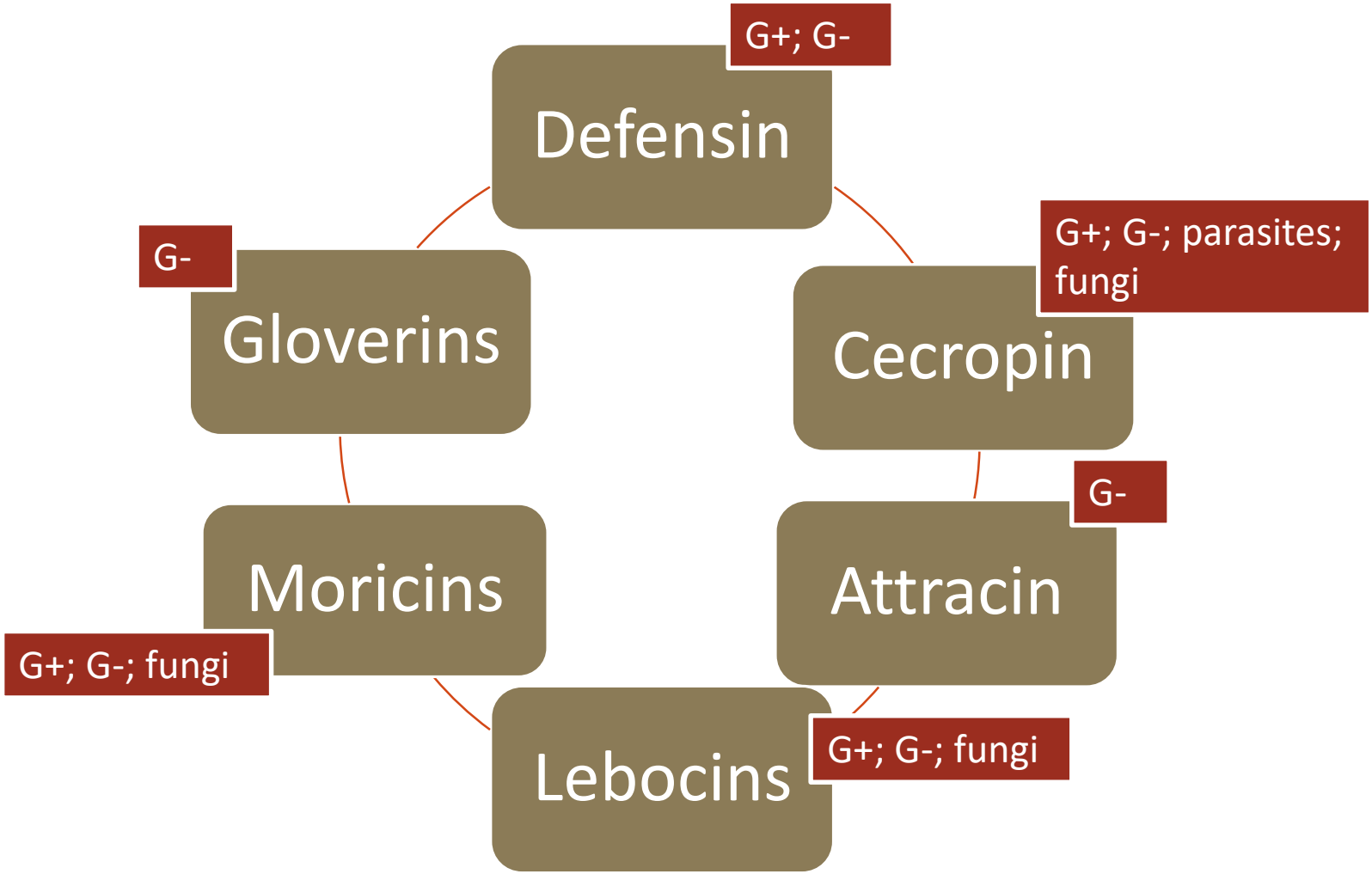
An overview of antifungal peptides derived from insect

Mohammad Omer Faruck[a], Faridah Yusof[a,*], Silvia Chowdhury[b]

Faruk et al., 2016. Peptides, 80:80-88; Józefiak & Engberg, 2017. J Anim & Feed Sci, 26:87-99; Li et al., 2017. Scientific Reports, 7:12124

AMPs

- No general consensus on the classification
- Structure – amino acid sequence



Yi et al., 2014. Appl Microbiol Biotechnol., 98, 5807–5822 - Wu et al., 2018. Toxins, 10, 416

Insect defensins: inducible antibacterial peptides*

Jules A. Hoffmann and Charles Hetru

In response to bacterial challenge or trauma, insects produce a battery of bactericidal or bacteriostatic molecules with a broad spectrum of activity against Gram-positive and/or Gram-negative bacteria; most are small-sized cationic peptides. This review focuses on insect defensins, a large group of inducible antibacterial peptides that are present both in ancient and recent insect orders. This immune response of insects shares many of the characteristics of the mammalian acute phase response.

Diversity, evolution and medical applications of insect antimicrobial peptides

Eleftherios Mylonakis[1], Lars Podsiadlowski[2], Maged Muhammed[1] and Andreas Vilcinskas[3,4]

Antimicrobial peptides (AMPs) are short proteins with antimicrobial activity. A large portion of known AMPs originate from insects, and the number and diversity of these molecules in different species varies considerably. Insect AMPs represent a potential source of alternative antibiotics to address the limitation of current antibiotics, which has been caused by the emergence and spread of multidrug-resistant pathogens. To get more insight into AMPs,

Cellular & Molecular Immunology

Article

Purification and Molecular Identification of an Antifungal Peptide from the Hemolymph of *Musca domestica* (housefly)

Ping Fu[1],

ARTHROPOD/HOST INTERACTION, IMMUNITY

Purification and Characterization of an Antimicrobial Peptide, Insect Defensin, From Immunized House Fly (Diptera: Muscidae)

X. L. DANG,[1,2] Y. S. WANG,[1] Y. D. HUANG,[3] X. Q. YU,[4] AND W. Q. ZHANG[1,5]

Contents lists available at ScienceDirect

Developmental and Comparative Immunology

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

Purification and characterization of a novel antibacterial peptide from black soldier fly (*Hermetia illucens*) larvae

Soon-Ik Park [a], Jong-Wan Kim [b,c], Sung Moon Yoe [a,*]

Journal of Food Protection, Vol. 67, No. 4, 2004, Pages 685–690
Copyright ©, International Association for Food Protection

Reduction of *Escherichia coli* O157:H7 and *Salmonella enterica* Serovar Enteritidis in Chicken Manure by Larvae of the Black Soldier Fly

MARILYN C. ERICKSON,[1]* MAHBUB ISLAM,[1] CRAIG SHEPPARD,[2] JEAN LIAO,[1] AND MICHAEL P. DOYLE[1]

- decrease in *E. coli* O157:H7
- decrease in *Salmonella enterica*

OPEN ACCESS Freely available online

PLOS ONE

Dietary Nisin Modulates the Gastrointestinal Microbial Ecology and Enhances Growth Performance of the Broiler Chickens

Damian Józefiak[1*], Bartosz Kierończyk[1], Jerzy Juśkiewicz[2], Zenon Zduńczyk[2], Mateusz Rawski[1], Jakub Długosz[1], Anna Sip[3], Ole Højberg[4]

- Neg. ctrl
- Pos ctrl (Salinomycin = cocciodiostat)
- 4 levels of Nisin (AMP) (Lactococcus lactis)

- improved performances
- decrease in *Bacteroides* and *Enterobacteriacae* in ileal digesta of broilers

Dose / response effect

Journal of Animal and Feed Sciences, 25, 2016, 309–316 *https://doi.org/10.22358/jafs/67802/2016*
The Kielanowski Institute of Animal Physiology and Nutrition, Polish Academy of Sciences, Jabłonna

The nisin improves broiler chicken growth performance and interacts with salinomycin in terms of gastrointestinal tract microbiota composition

B. Kierończyk[1], E. Pruszyńska-Oszmałek[2], S. Świątkiewicz[3], M. Rawski[1], J. Długosz[1], R.M. Engberg[4] and D. Józefiak[1,5]

- Neg. ctrl
- Pos ctrl (Salinomycin = cocciodiostat)
- 1 level of Nisin (AMP)

- improved BW
- Improved FI – FCR (1st period)

- Salinomycin
- Nisin
- Nisin + Salinomycin

decrease

- TBC
- *Enterobacteriaceae*
- *Clostridium perfringens*
- *Lactobacillus* spp
- *Enterococcus* spp

Synergic action

Animal Feed Science and Technology 177 (2012) 98–107

Contents lists available at SciVerse ScienceDirect

Animal Feed Science and Technology

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

Effects of dietary supplementation of antimicrobial peptide-A3 on growth performance, nutrient digestibility, intestinal and fecal microflora and intestinal morphology in weanling pigs

J.H. Yoon[a], S.L. Ingale[a], J.S. Kim[a], K.H. Kim[a], S.H. Lee[a], Y.K. Park[b], I.K. Kwon[a], B.J. Chae[a,*]

Apramycin
AMP-A3 L1
AMP-A3 L2
AM-A3 L3

- dietary supplementation of AMP-A3 (3 levels) to weaning pigs (*vs* apramycin)
  - growth performance
  - CTTAD nutrients
  - Serum immunoglobulins
  - Intestinal / fecal microflora
  - Intestinal morphology

+ results

Linear increase with AMP-A3 increase

Dose / response effect

Livestock Science 159 (2014) 53–60

Contents lists available at ScienceDirect

Livestock Science

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

Effects of dietary supplementation of synthetic antimicrobial peptide-A3 and P5 on growth performance, apparent total tract digestibility of nutrients, fecal and intestinal microflora and intestinal morphology in weanling pigs

J.H. Yoon [a], S.L. Ingale [a], J.S. Kim [a], K.H. Kim [a], S.H. Lee [a], Y.K. Park [b], S.C. Lee [c], I.K. Kwon [a], B.J. Chae [a,*]

NC
PC (avilamycin)
AMP-A3
AMP-P5

- dietary supplementation of synthetic AMP-A3 and AMP-P5
  - improved
    - growth performance
    - ATTCD nutrients
    - Fecal / intestinal microflora
    - intestinal morphology

} + results similar to PC

Induction of maggot antimicrobial peptides and treatment effect in *Salmonella pullorum*-infected chickens

Gang Zhou,*[1] Jungang Wang,†[1] Xiaoqi Zhu,* Yufei Wu,* Mingming Gao,* and Hong Shen*[2]

- Used inactivated *Salmonella pullorum* to stimulate **AMP generation by MD**

  mesured antibacterial activity of AMP (compare to antibiotics)

  - ***S. pullorum***
  - ***Stap. aureus***
  - ***E. coli***

- Artificially infected birds with *S. pullorum* & treated with AMP extracts
  - Increased survival rate
  - Blood indicators
  - Intestinal bacteria changes

Positive results

Contents lists available at ScienceDirect

Journal of Ethnopharmacology

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

Research paper

Anti-tumor and immunomodulatory activity of peptide fraction from the larvae of *Musca domestica*

Hong-Xiang Sun [a,*], Li-Qing Chen [a], Juan Zhang [a], Feng-Yang Chen [a,b]

MD

- mice inoculated with sarcoma S180 cell
- dietary administration of peptide fraction of MD larvae (3 doses, 10 days)

Results: MDPF could significantly not only inhibit the growth of mouse transplanted S180 sarcoma, but also promote splenocytes proliferation, NK cell and CTL activity from splenocytes, and enhance serum antigen-specific IgG, IgG2a and IgG2b antibody levels in S180-bearing mice. MDPF also significantly promoted the production of IFN-γ and up-regulated the mRNA expression levels of IFN-γ and Th1 transcription factors T-bet and STAT-4 in splenocytes from the S180-bearing mice. However, Th2 cytokine IL-10 and transcription factors GATA-3 and STAT-6 were not significantly changed both at transcriptional and protein levels following MDPF treatment.

peptide fraction of MD larvae act as antitumor agent with immunomodulatory activity

Appl Microbiol Biotechnol (2016) 100:7397–7405
DOI 10.1007/s00253-016-7718-y

MINI-REVIEW

Insect antimicrobial peptides: potential tools for the prevention of skin cancer

Miray Tonk[1] · Andreas Vilcinskas[1,2] · Mohammad Rahnamaeian[1]

effective synthetic of recombinant peptides, particularly short AMPs without disulfide bonds. AMPs provide a promising source of new drugs for the prevention and treatment of skin cancer because they are highly suitable for topical application and can be formulated as creams and ointments, which are suitable for self-administration or for parents to apply to their children.

1 **Isolation and Purification of Active Antimicrobial Peptides from**

2 ***Hermetia illucens* L., and Its Effects on CNE2 Cells**

3 ---- anticancer effect of antimicrobial peptides

4

5 **Zhong Tian[#], Qun Feng[#], Hongxia Sun, Ye Liao, Lianfeng Du, Rui Yang, Xiaofei Li,**

6 **Yufeng Yang, Qiang Xia[*]**

BSF

- Isolation and purification of an active antimicrobial peptide HI-3 (5th instar)
- antibacterial activity
  - *Staphylococcus aureus*
  - *Bacillus subtilis*
  - *Escherichia coli*
  - *Enterobacter aerogenes*
- inhibitory activity on the proliferation of CNE2 cells (nasopharyngeal carcinoma cells)

Potential antitumoral drug

Tian et al., 2018. bioRxiv doi.org/10.1101/353367

AMPs

- positive action against bacteria, fungi, parasites, virus
- immune modulators
- support of animal growth and health

alternative to antibiotics

- positive results against cancer

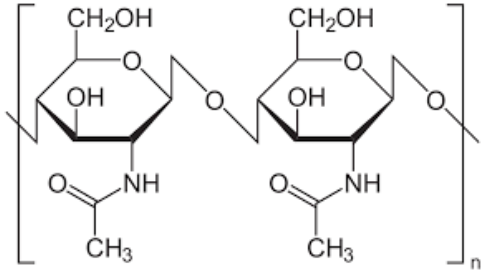
- several **applications** in different fields:
  - agricultural science
  - biology
  - **human and veterinary medicine**
  - **food and feed industries**

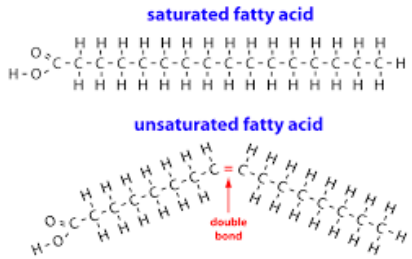
Currently, no insect derived AMPs have been introduced on the market yet

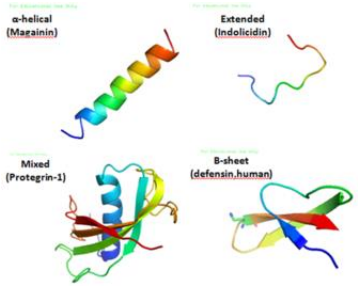
Consuming insects: are there health benefits?

Journal of Insects as Food and Feed, 2017; 3(4): 225-229

N. Roos[1] and A. van Huis[2*]







Bioactive compounds

Can diets containing insects promote animal health?

Journal of Insects as Food and Feed, 2018; 4(1): 1-4

L. Gasco[1], M. Finke[2] and A. van Huis[3]

- Anti-microbial peptides
- **Chitin**
- Fatty acids

- antimicrobial effects
- strengthen immune system
- microbiota modulation

Chitin

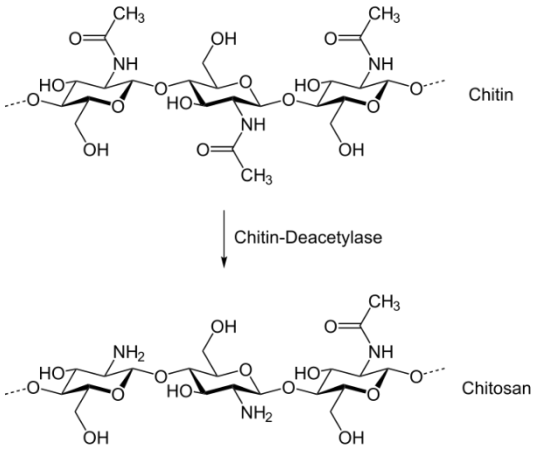

cuticle made
of chitin

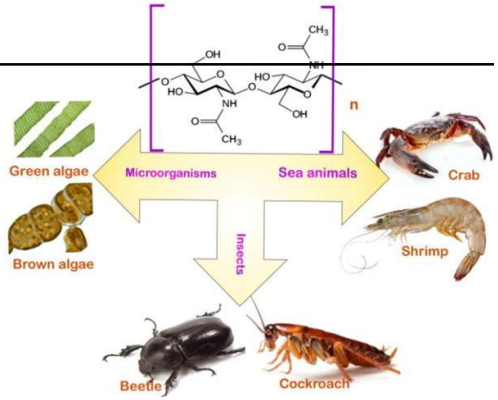

Sources of Chitin


Exoskeleton
Chitin is a major component of the exoskeleton of insects that helps in protecting their delicate soft tissues.

Chitin

chiton





- structural polysaccharide that contains nitrogen
- polymer of N-acetylglucosamine
- major element in the exoskeleton of insects

crustacean chitin

- antioxidant
- anti-inflammatory
- anticoagulant
- antitumoral & anticancer
- **antibacterial**
- antihypertensive
- **immunostimulant**
- hypocholestorolemic

medicinal & pharmaceutical applications

drug delivery
tissue engineering
production of functional foods
food preservation
biocatalysis immobilization
wastewater treatment
molecular imprinting
production of metal nanocomposites

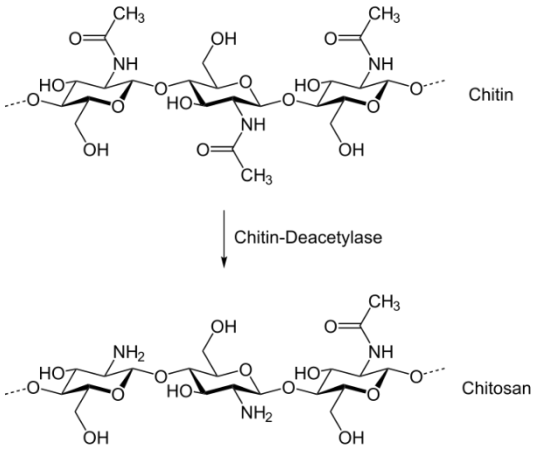
Advances in Food and Nutrition Research, Volume 73
ISSN 1043-4526
http://dx.doi.org/10.1016/B978-0-12-800268-1.00002-0

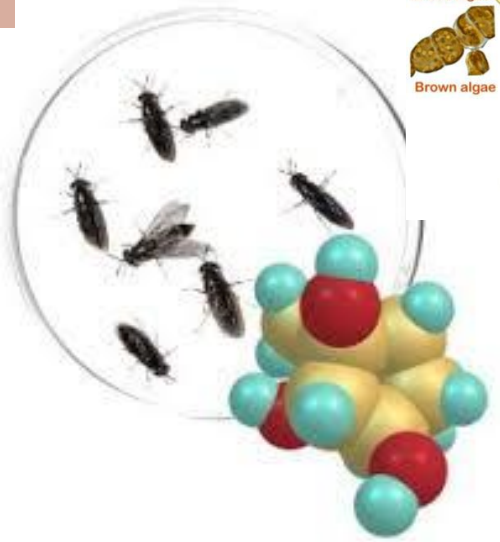
Ngo & Kim, 2014

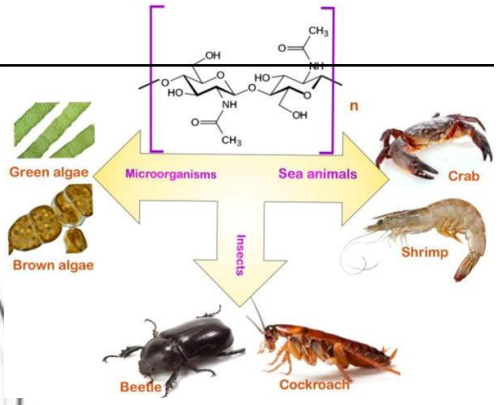
Wásko et al., 2016
International Journal of Biological Macromolecules 92, 316–320

Chitin

chiton







- antioxidant
- anti-inflammatory
- anticoagulant
- antitumoral & anticancer
- antibacterial
- antihypertensive
- immunostimulant
- hypocholestorolemic

Insect chitin???

- particles size?
  - small size = anti-inflammatory
- chitin structure? α – β - γ
- chitin composition?
  - insect chitin: matrix of protein, lipids + other compounds
  - crustacean chitin: matrix of protein & minerals

Ngo & Kim, 2014

Advances in Food and Nutrition Research, Volume 73
ISSN 1043-4526
http://dx.doi.org/10.1016/B978-0-12-800268-1.00002-0

Immunostimulation

TM: 0%, 9%, 18%, 27%

in fish fed 18% TM

TM

- decrease in plasma MDA content + increase in plasma SOD activity
- increase in plasma
  - lysozyme activity
  - IgM levels
- up-regulation of immune related genes (MHC II, IL-1, CypA, Img, HE)

- increase of survival rate after **challenged** with ***Edwardsiella ictaluri***

TM could **improve immune response & bacterial resistance**

Su et al., 2017. Fish & Shellfish immunology, 69:59-66

Immunostimulation

DOI: 10.1111/are.13611

ORIGINAL ARTICLE

WILEY Aquaculture Research

Effects of black soldier fly (*Hermetia illucens*) larvae meal protein as a fishmeal replacement on the growth and immune index of yellow catfish (*Pelteobagrus fulvidraco*)

BSF

Yellow catfish fed **10.8%** or **22.3%**, BSF larvae meal

- Increased weight (+29.1%)
- Lowest FCR: 0.9
- Lysozyme activity (+ 31.9%)

- Increased weight (+21.7%)
- Lysozyme activity (+ 6.8%)

BSF had **positive effects** on growth performance & **immune indexes**

Immunostimulation

Does dietary insect meal affect the fish immune system? The case of mealworm, *Tenebrio molitor* on European sea bass, *Dicentrarchus labrax*

M.A. Henry [a,*], L. Gasco [b], S. Chatzifotis [c], G. Piccolo [d]

TM

fish fed 25 & 50% of full fat TM larva meal

- improved lysozyme activity (tendance)
- increased anti-protease activity

↓

correlated with anti-parasitic activity of fish immune system

similarities between the composition of insects and parasites exoskeleton

↓

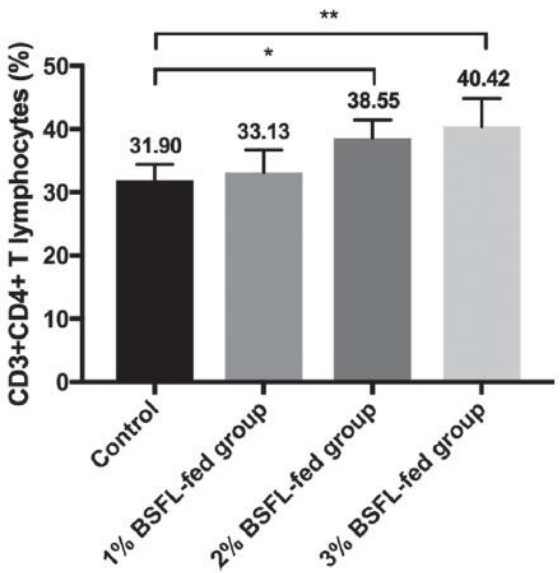
Immunostimulant effect

Immunostimulation

Black soldier fly (*Hermetia illucens*) larvae enhances immune activities and increases survivability of broiler chicks against experimental infection of *Salmonella* Gallinarum

BSF

Birds fed low levels of BSF larvae meal (1%, 2%, 3%)



increase of:

- performances
- frequency of CD4+ T lymphocyte
- serum lysozyme activity
- spleen lymphocyte proliferation

- survival rate of broiler challenged with ***Salmonella* Gallinarum**

BSF: positive effect on growth + **stimulate non specific immune response**

Antibacterial effect

Characterization of chitosan extracted from Mealworm Beetle (*Tenebrio molitor, Zophobas morio*) and Rhinoceros Beetle (*Allomyrina dichotoma*) and their antibacterial activities

Chae-Shim Shin [a], Do-Yeong Kim [b], Weon-Sun Shin [a,*]

- Chitin isolation
- Chitosan characterization: similar to commercial chitosan
- Antibacterial activity

  - *Bacillus cereus*
  - *Listeria monocytogenes*
  - *E. coli*

Shin et al., 2019. International Journal of Biological Macromolecules 125, 72–77

Antibacterial effect

TM

Article

Replacement of Fish Meal by Defatted Yellow Mealworm (*Tenebrio molitor*) Larvae in Diet Improves Growth Performance and Disease Resistance in Red Seabream (*Pargus major*)

growth trial

↓

25 – 40 – 65% TM

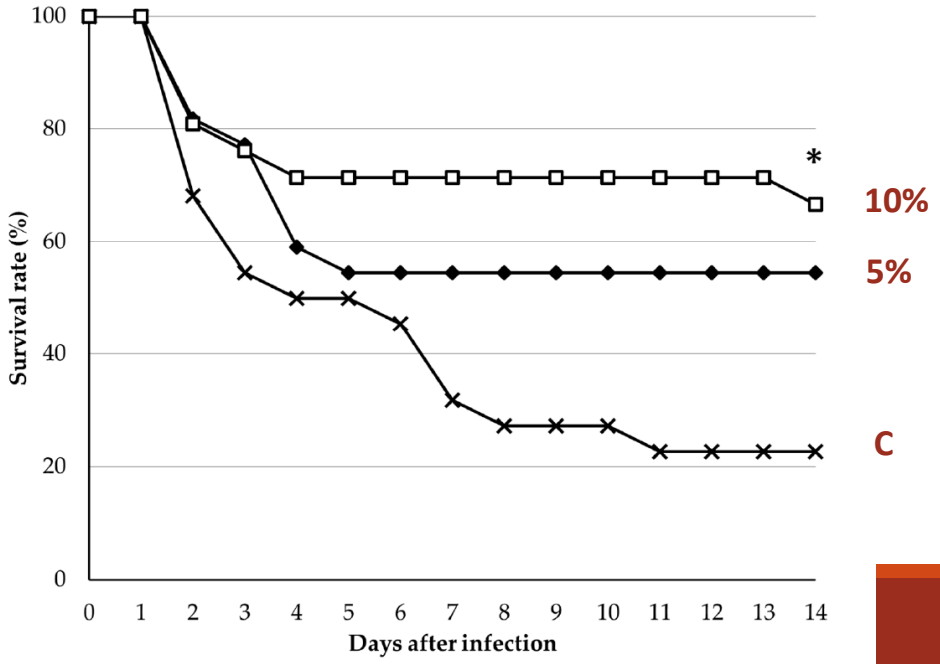
↓

increased performances

challenge test

↓

5 – 10% TM

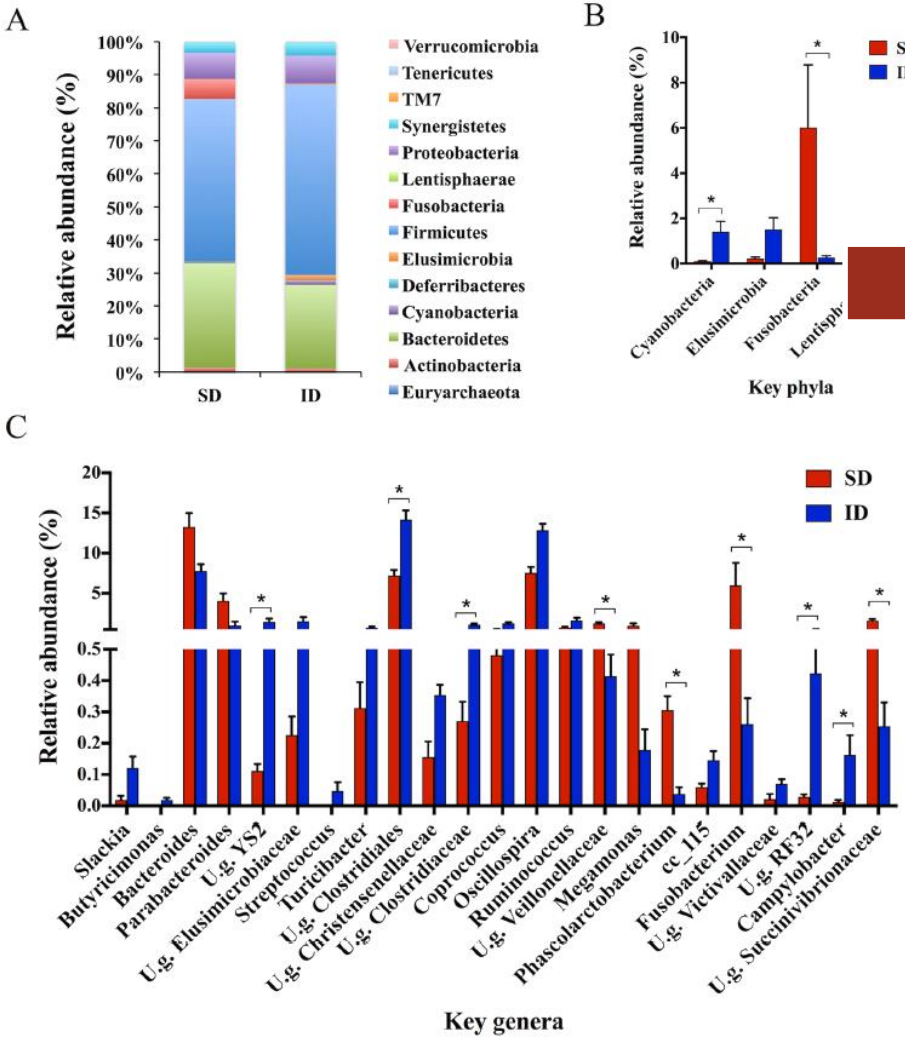


increased protection against ***Erdwardsiella tarda***

TM chitin or AMP or other bioactive compounds?

Ido et al., 2019. Animals, 9, 100

Microbiota modulation



SCIENTIFIC REPORTS

OPEN

Insect-based diet, a promising nutritional source, modulates gut microbiota composition and SCFAs production in laying hens

BSF

Ceacal microbiota modulation

development of bacteria having a chitin degradation activity

connected with SCFAs production

Probiotic effect of BSF

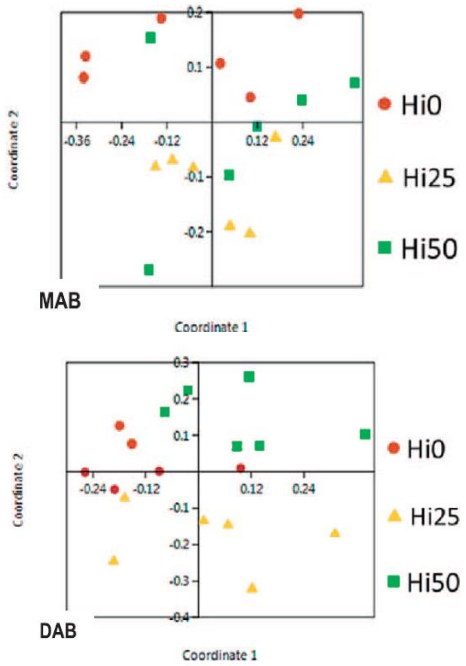
Microbiota modulation

Characterisation of the intestinal microbial communities of rainbow trout (*Oncorhynchus mykiss*) fed with *Hermetia illucens* (black soldier fly) partially defatted larva meal as partial dietary protein source

Leonardo Bruni[a], Roberta Pastorelli[b], Carlo Viti[c], Laura Gasco[d], Giuliana Parisi[a,*]

BSF

Mucosa- (MAB) & Digesta- (DAB) Associated Bacterial community



modulation microbial community

increased incidence of ***Carnobacterium*** genus

- *in vitro* inhibition of pathogens
- stimulate non-specific immune response
- *in vivo* improvement of disease resistance

Bruni et al, 2018. Aquaculture, 487:56-63

Microbiota modulation

Rev Fish Biol Fisheries (2019) 29:465–486
https://doi.org/10.1007/s11160-019-09558-y

ORIGINAL RESEARCH

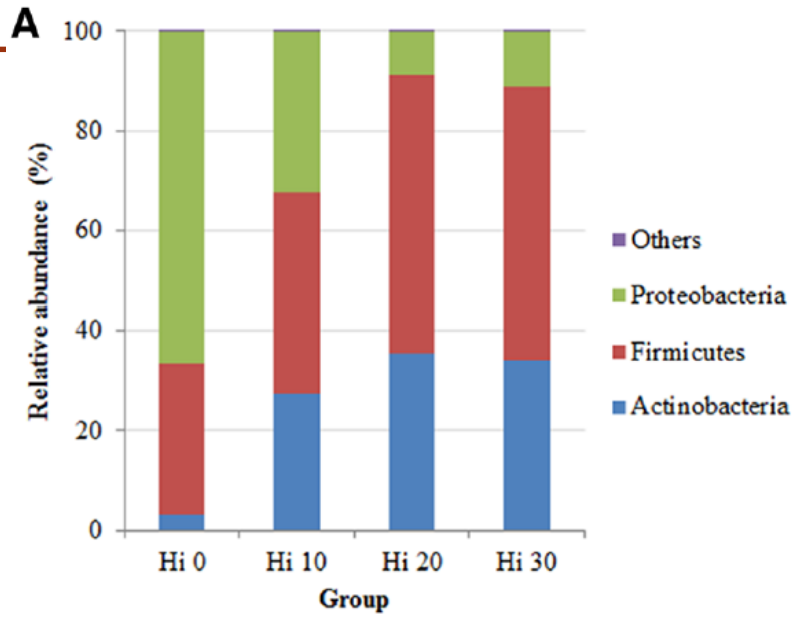
BSF

Rainbow trout (*Oncorhynchus mykiss*) gut microbiota is modulated by insect meal from *Hermetia illucens* prepupae in the diet

Genciana Terova · Simona Rimoldi · Chiara Ascione · Elisabetta Gini · Chiara Ceccotti · Laura Gasco

modulation microbiota

modulation of ***Actinobacteria & Protobacteria***



Hypolipidaemic & hypocholesterolaemic

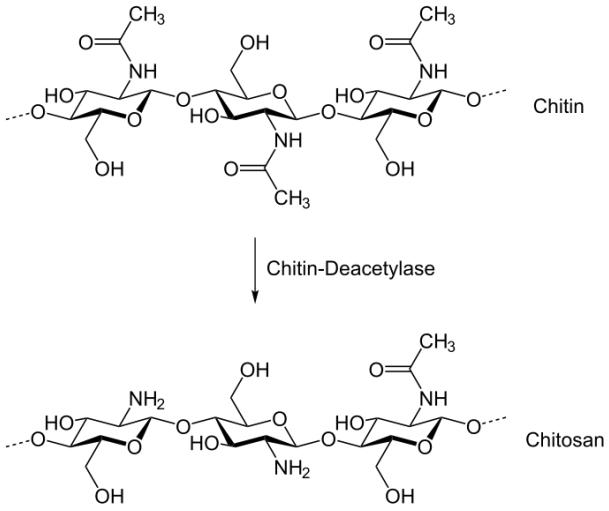
nutrients

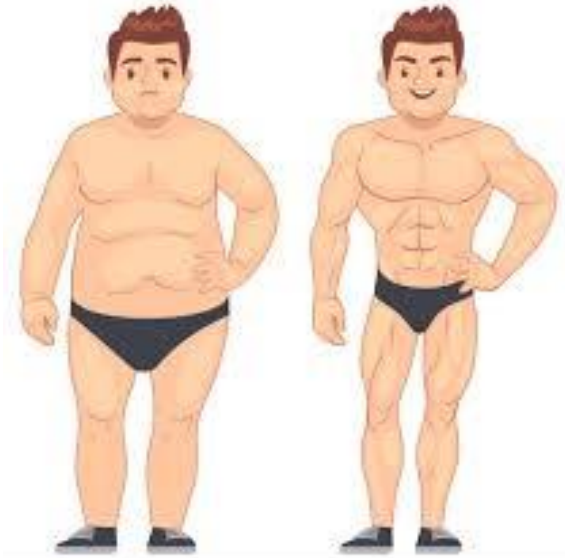
MDPI

Article

Influence of Chitosan Treatment on Surrogate Serum Markers of Cholesterol Metabolism in Obese Subjects

Dieter Lütjohann [1,*], Milka Marinova [2], Karsten Wolter [2], Winfried Willinek [2,3], Norman Bitterlich [4], Martin Coenen [1], Christoph Coch [1] and Frans Stellaard [1]





Nutrients **2018**, *10*, 72; doi:10.3390/nu10010072

Hypolipidaemic & hypocholesterolaemic

rats fed MD meal
- reduction of visceral fat
- reduction of serum LDL cholesterol

MD

promote the efflux of excess cholesterol in the body and inhibit cholesterol re-absorption from the intestine

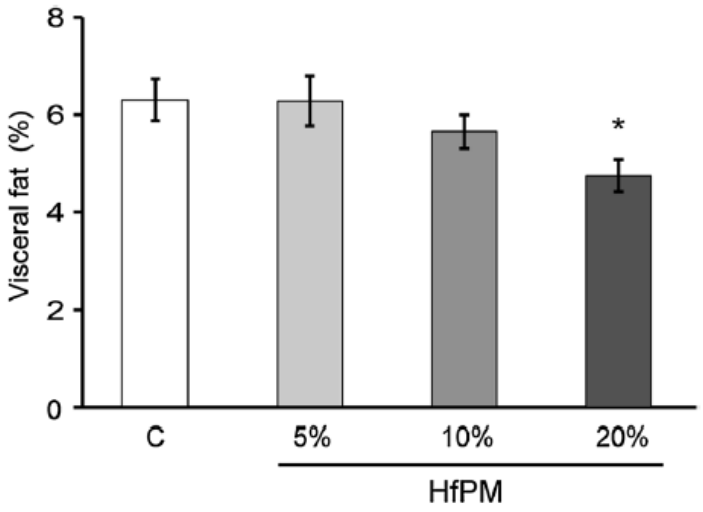


Fig. 6 Visceral fat accumulation in rats fed with the diet containing HfPM for 28 days. Weight of visceral fat depots is expressed as a percentage (visceral fat weight/body weight × 100). Results are given as the mean ± SEM. *$p < 0.05$ against the control is considered to indicate statistical significance (Bonferroni post hoc test)

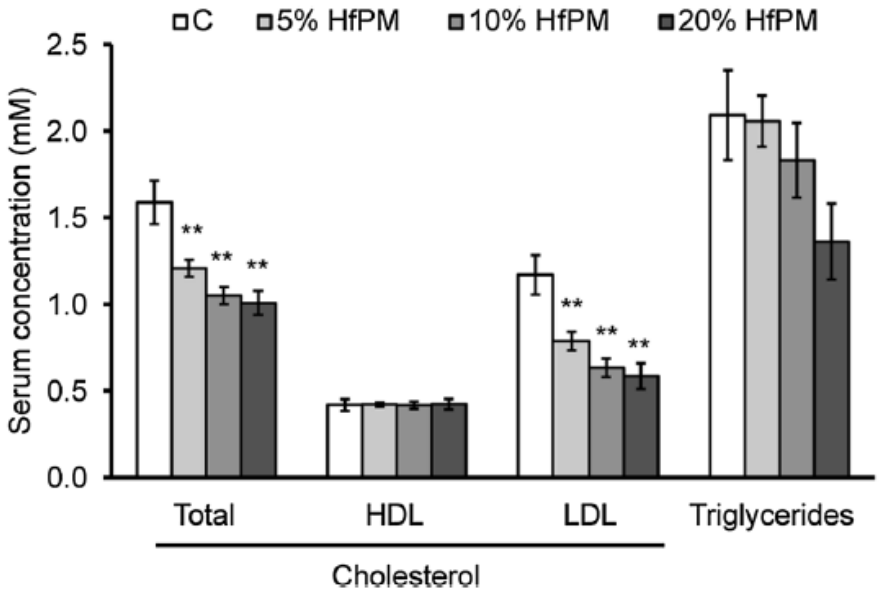


Fig. 7 Serum cholesterol and triglyceride concentrations in rats receiving a diet containing HfPM for 28 days. Results are given as mean ± SEM. **$p < 0.01$ against control is considered to indicate statistical significance (Bonferroni post hoc test)

Ido et al., 2015. Appl Entomol Zool, 50:213–221

Hypolipidaemic & hypocholesterolaemic

Aquaculture 477 (2017) 62–70

Contents lists available at ScienceDirect

Aquaculture

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

Defatted black soldier fly (*Hermetia illucens*) larvae meal in diets for juvenile Jian carp (*Cyprinus carpio* var. Jian): Growth performance, antioxidant enzyme activities, digestive enzyme activities, intestine and hepatopancreas histological structure

BSF

Jian carp fed BSF meal (0%, 2.6%, 5.3%, 7.9% & 10.6%)

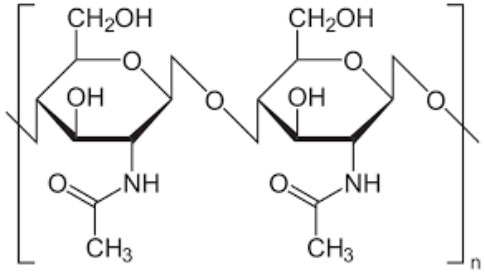
- no differences in growth performances
- reduction of hepatopancreas fat
- reduction of serum cholesterol
- Increase in CAT activity

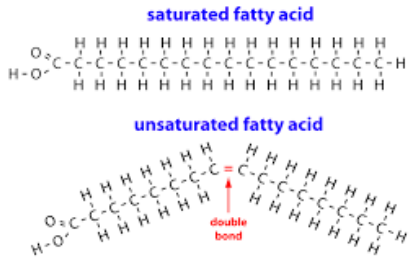
Hypocholesterolaemic effect + bost antioxidant status

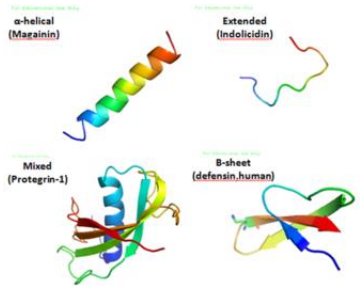
Consuming insects: are there health benefits?

Journal of Insects as Food and Feed, 2017; 3(4): 225-229

N. Roos[1] and A. van Huis[2*]







Bioactive compounds

Can diets containing insects promote animal health?

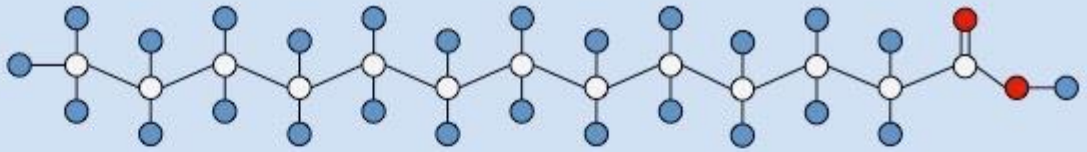
Journal of Insects as Food and Feed, 2018; 4(1): 1-4

L. Gasco[1], M. Finke[2] and A. van Huis[3]

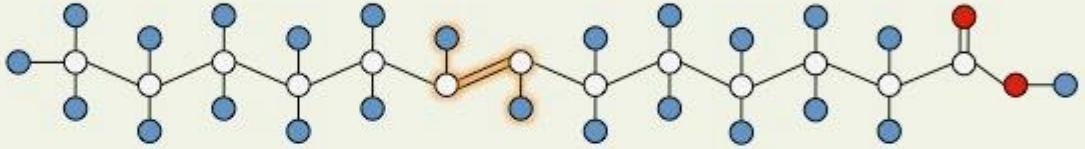
- Anti-microbial peptides
- Chitin
- **Fatty acids**
  - antimicrobial effects
  - strengthen immune system
  - microbiota modulation

Fatty acids

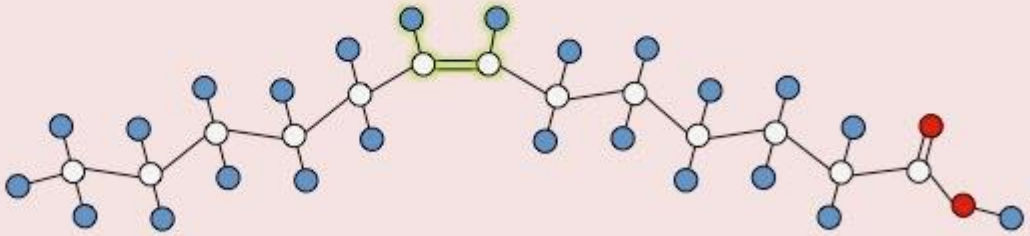
Saturated fatty acid
(***no*** double bonds)



Unsaturated – ***trans***
(H atoms opposite)



Unsaturated – ***cis***
(H atoms same side)
⟹ *bent configuration*



○ = C ● = O ● = H

Insect fatty acid composition

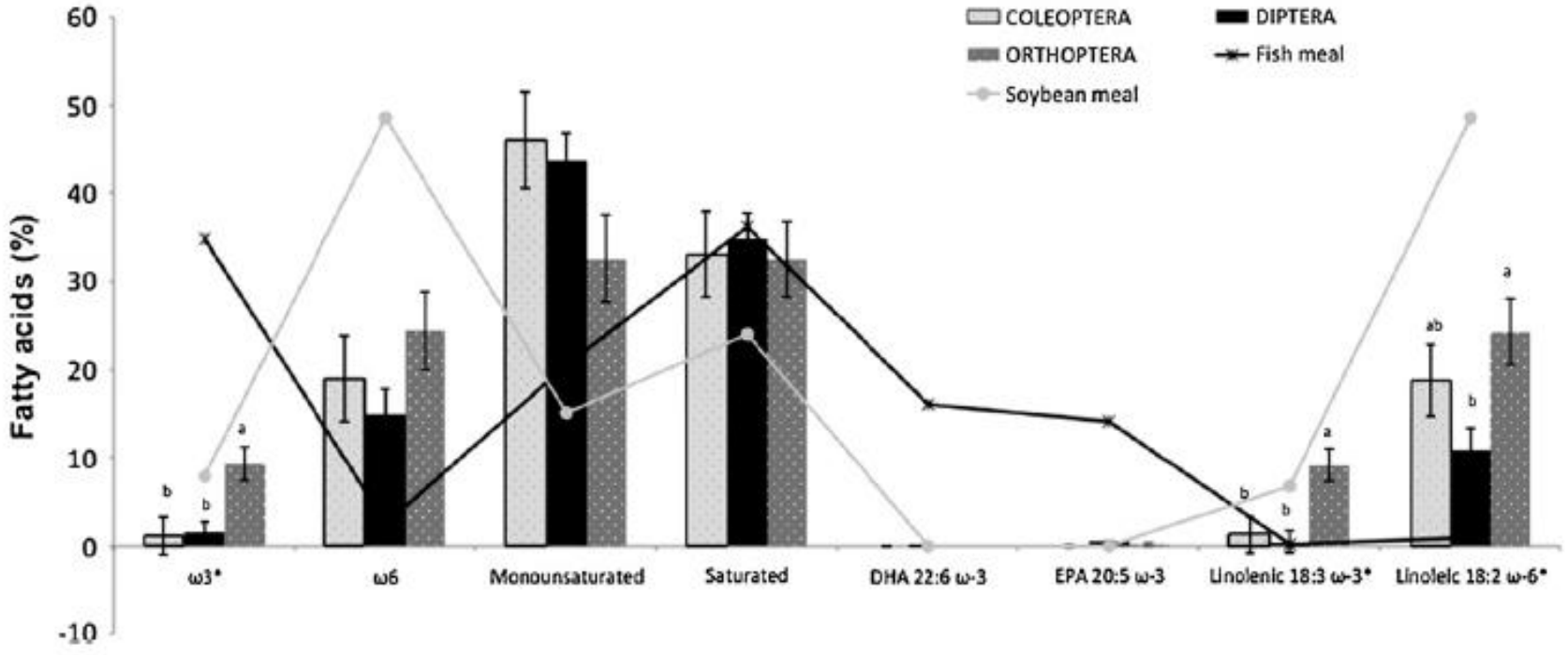


Fig. 3. Differences between insect orders studied in the percentage of fat acids (using fish meal and soybean reference).

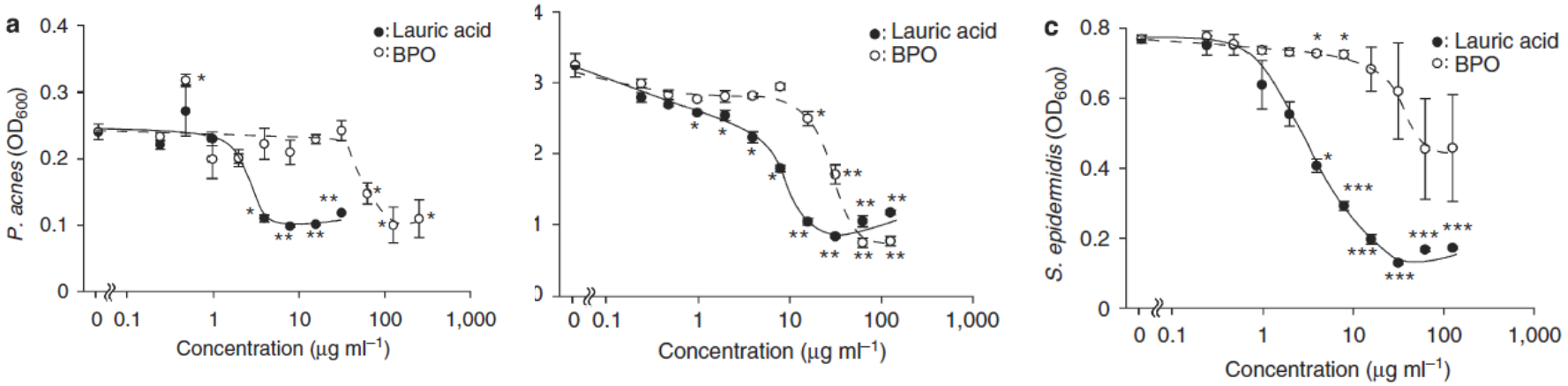
- Fatty acid composition is specie – specific
- Could be manipulated through rearing substrate
- BSF: lauric acid (C12:0)
- TM: Oleic acid (C18:1) – linoleic acid (C18:2)

Barroso et al., 2014

Fatty acids: Lauric acid (MCFAs)

Antimicrobial Property of Lauric Acid Against *Propionibacterium Acnes*: Its Therapeutic Potential for Inflammatory Acne Vulgaris

strong antibacterial properties of C12:0



Nakatsuji et al., 2009. Journal of Investigative Dermatology, 129:2480-2488

Research Article

iMedPub Journals
http://www.imedpub.com/

Annals of Clinical and Laboratory Research
ISSN 2386-5180

2017
Vol.5 No.2:170

DOI: 10.21767/2386-5180.1000170

Antibacterial Activity of Lauric Acid on Some Selected Clinical Isolates

Abbas Abel Anzaku[1], Josiah Ishaku Akyala[2], Adeola Juliet[3] and Ewenighi Chinwe Obianuju[4]

Conclusion and Recommendation

This study establishes the fact that lauric acid has antibacterial effect on Gram positive bacteria more compare to the Gram-negative bacteria. This however recommends that lauric acid beneficially be used in treating some of the microbial infection caused by some Gram-positive bacteria. More studies should be done to ascertain the mechanisms of actions of this acid on the bacterial cell including the non-cellular (viruses) strains.

C12:0: more active against Gram+

could be used in combatting some microbial strains resistant to antibiotics

Fatty acids: Lauric acid (BSF)

Gut antimicrobial effects and nutritional value of black soldier fly (*Hermetia illucens* L.) prepupae for weaned piglets

- *In vitro* trial (0,58g/100 ml):
  - suppressed growth of lactobacilli & D-streptococci

Spranghers et al., 2018. Animal Feed Science and Technology, 235:33-42

Antimicrobial activity of insects' fats

NUCERA[1], D., MENEGUZ[1], M., PIANO[1], S., DABBOU[2], S., BIASATO[1], I., SCHIAVONE[2], A., GASCO[1], L.

[1]DEPARTMENT OF AGRICULTURAL, FOREST AND FOOD SCIENCES. TURIN UNIVERSITY (IT)
[2]DEPARTMENT OF VETERINARY SCIENCES. TURIN UNIVERSITY (IT)

Pure TM oil – BSF fat

against some common rabbit bacteria

God in his wisdom made the fly
And then forgot to tell us why

Ogden Nash