# Conversion of organic side-streams into multiple marketable products – BBI-InDIRECT project

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BIO-BASED INDUSTRIES
Bio-based Industries Consortium
Horizon 2020
European Union Funding
for Research & Innovation

# Fact sheet InDIRECT

**Title**:

Direct and indirect biorefinery technologies for conversion of organic side-streams into multiple marketable products

**Acronym**: InDIRECT

**Project partners:** 2 research partners; 7 industrial partners (5 SMEs)
from 4 countries: Italy, France, The Netherlands, Belgium

**Funding scheme:** Research & Innovation Action (H2020)

BBI.R10-2015-call on 'Innovative efficient biorefinery technologies'

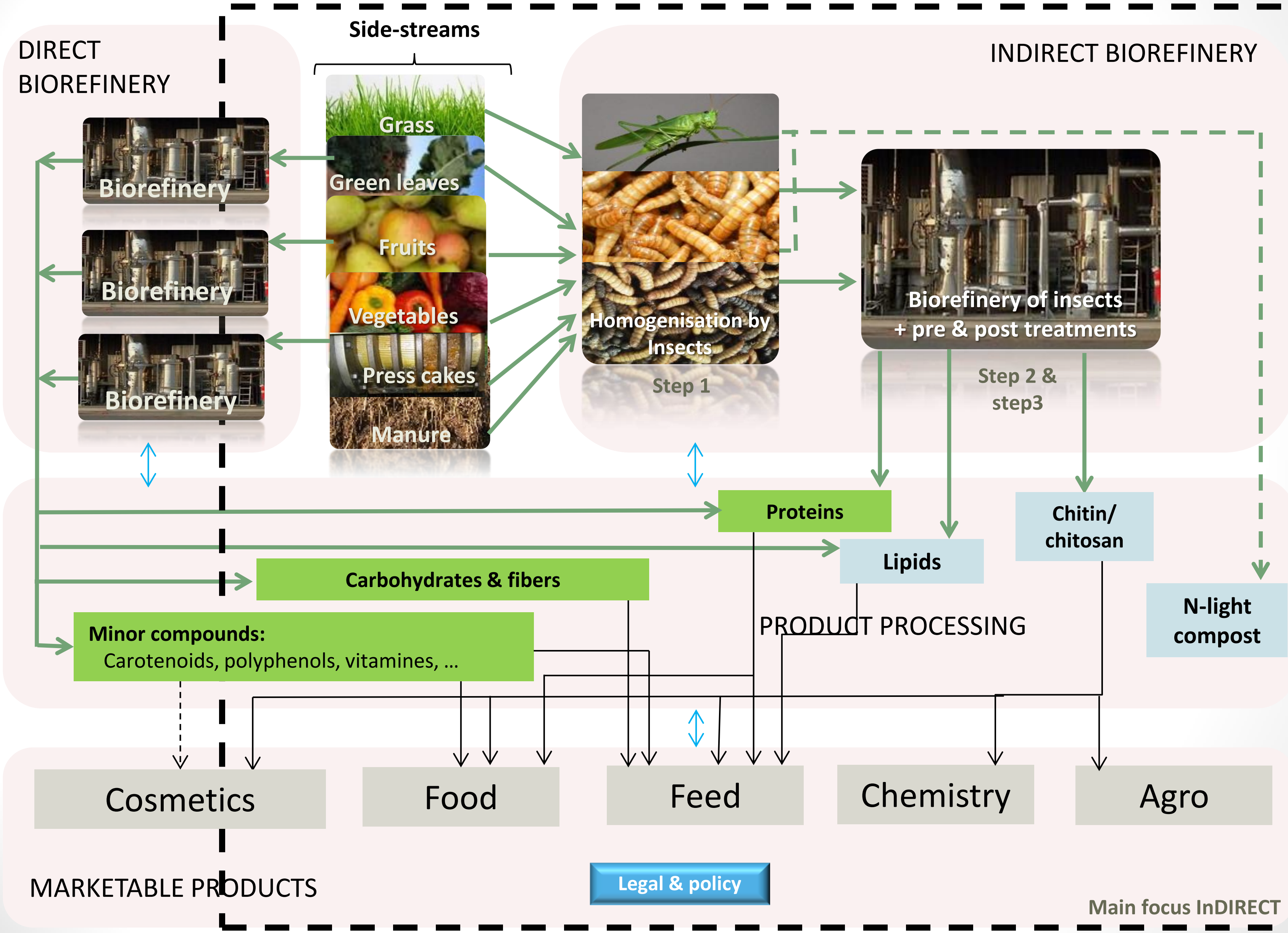
Total project costs: 2,089,670 euro

Grant: 1,347,948 euro

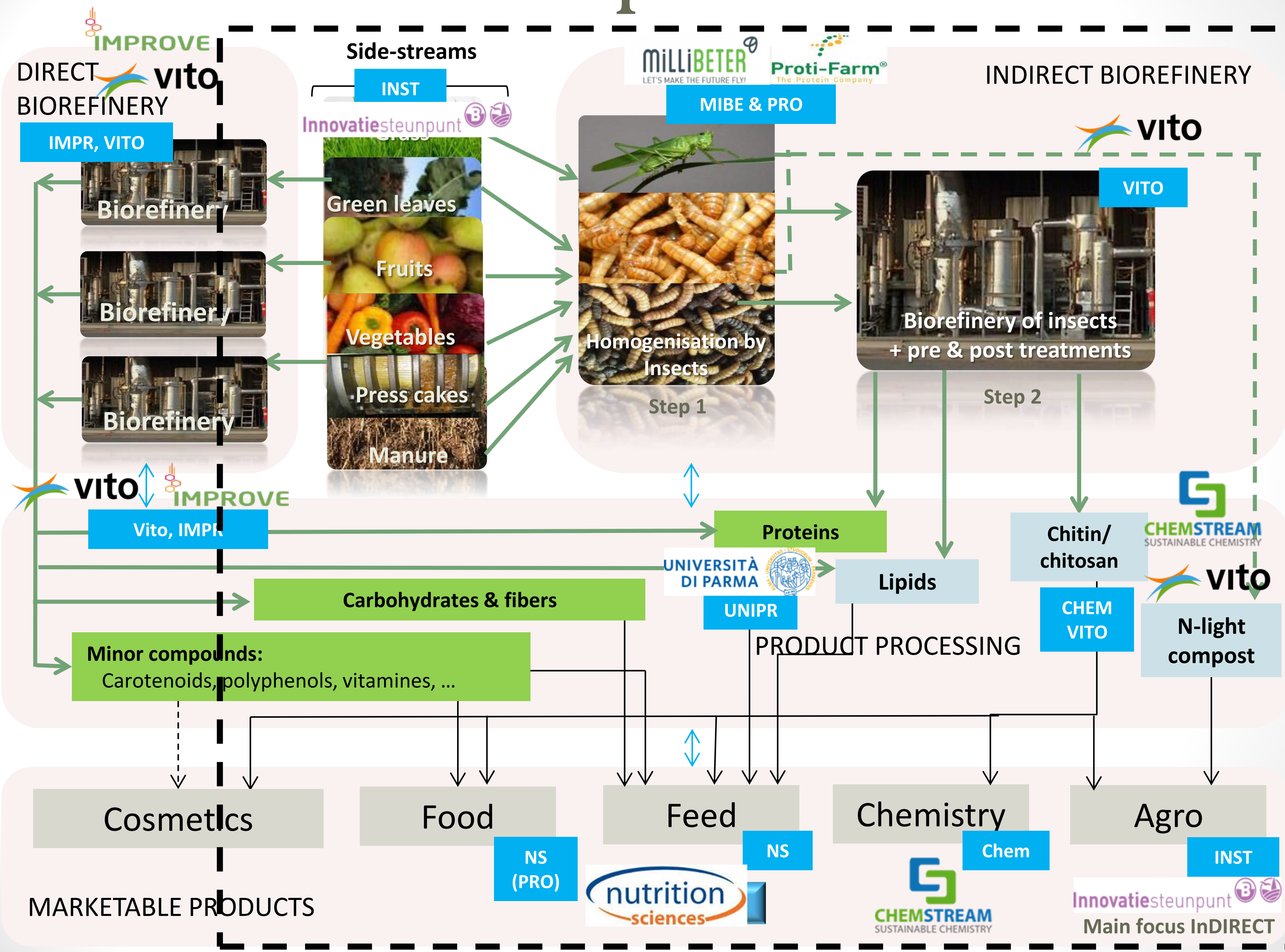
**Duration:** 36 months (official start 1/11/2016)

**Coordination:** VITO (Belgium)

# Scope InDIRECT project



# Role of Indirect partners



# General Objectives of InDIRECT

InDIRECT

- Development of indirect cascading biorefinery processes for converting a variety of underspent **side streams/residues** into useful **marketable products** via:
  - Step 1: Homogenisation of the side-streams with insects
  - Step 2: Fractionation of the insect biomass into crude extracts
  - Step 3: Purification & conversion of compounds
- Development of direct biorefinery processes for a selection of underspent side streams/residues, for comparison with the indirect approach.
- Optimisation of the biorefinery processes to increase the **conversion efficiency** (product/ton biomass input) and maximise the **values** of the feedstock (euro/ton biomass input).
- Exploration of application areas of the extracted compounds for use in different sectors like feed, chemistry and food.
- Hereby taking into account the whole value chain and the associated economic, environmental, legal and practical aspects – lab to pilot.

# Needs & challenges to address

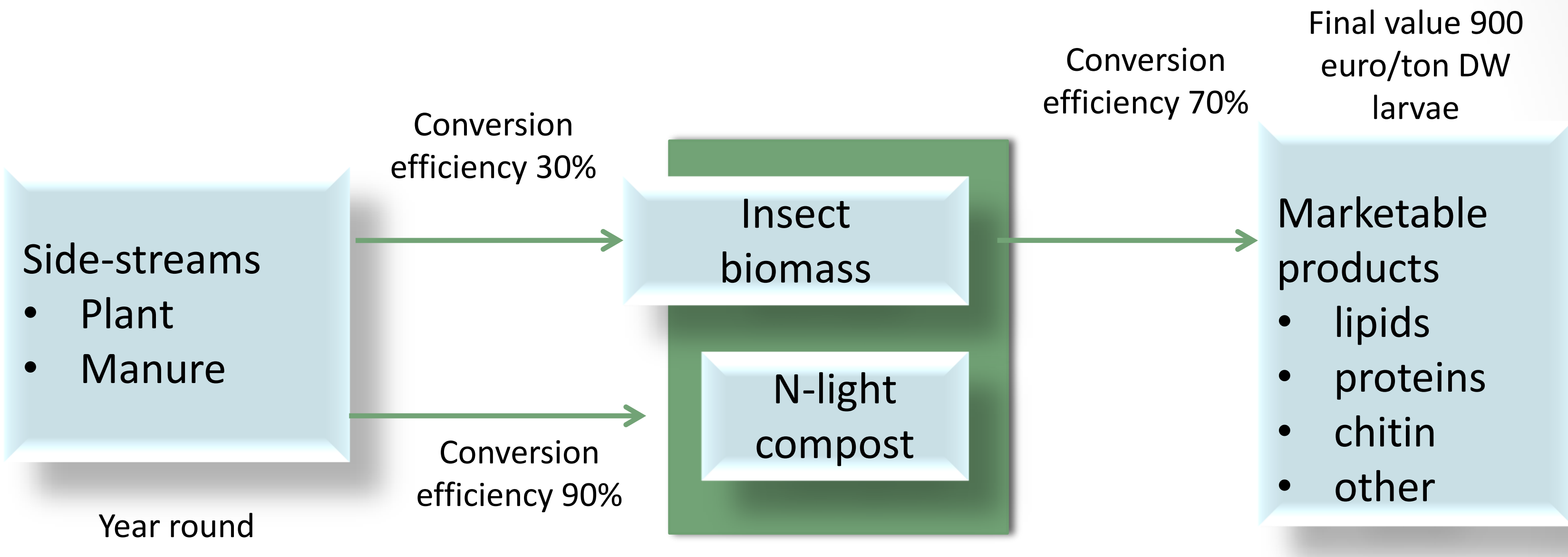
- ‘Management of waste as a resource’ (EU COM 2011/571)

- ‘ accelerating innovation and market uptake of bio-based products’ (BBI vision paper)
  - Biorefineries important role BUT to be developed
  - Stable & economically interesting compounds needed
  - Consumers preferences - change needed?
  - Availability of sufficient feedstock all-round
  - New value chains
  - ‘A shorter time to market with ten new bio-based values chains by 2020’ KPI2

- Alternative source for proteins
- Alternatives for antibiotics

- Reduce dependency of European economy on non-European countries

# Specific objectives – indirect biorefinery




At least 50% improvement

Year round biorefinery

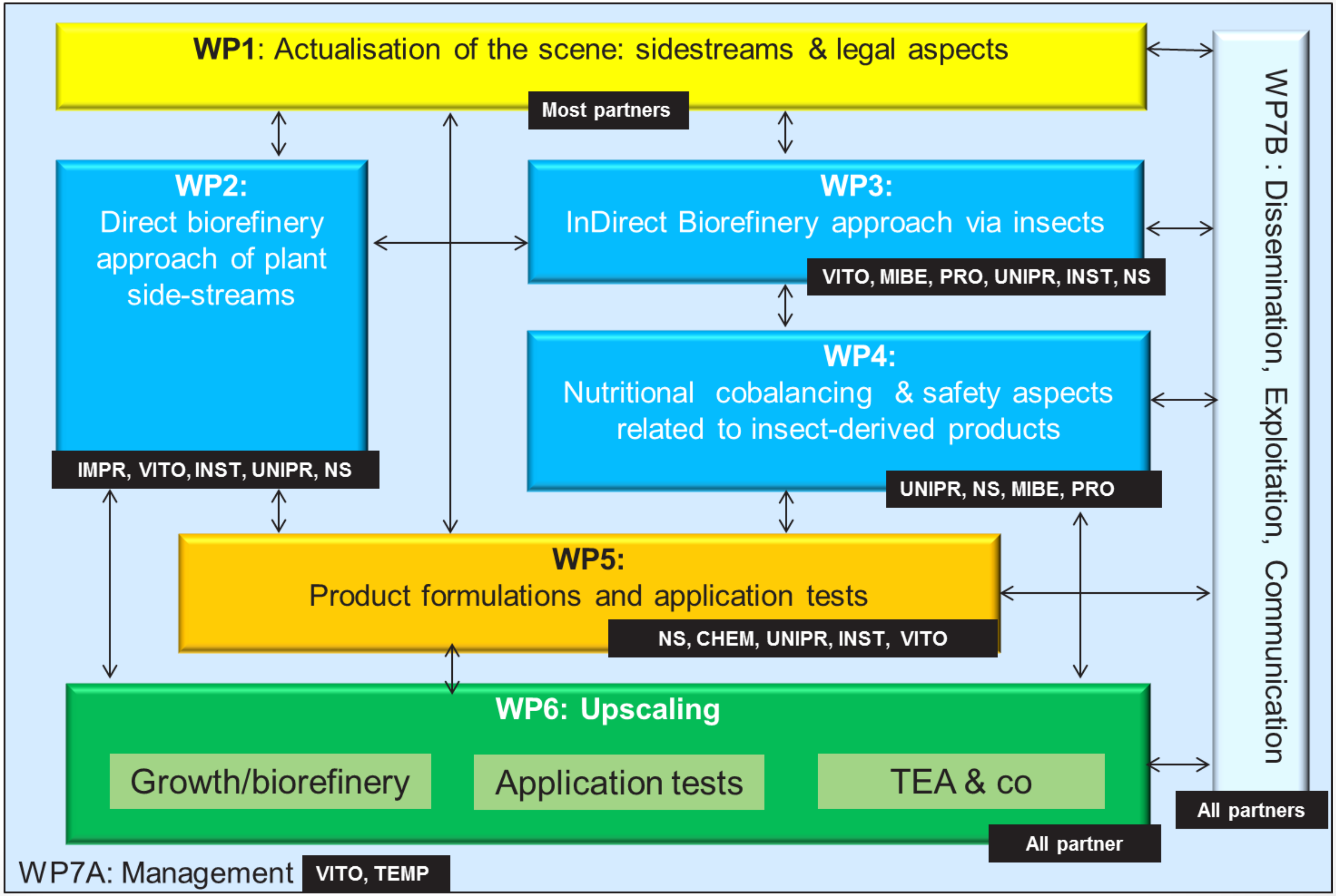
Commercial availability of chitin/chitosan oligomers

10Mtonnes/y stable production of recycled proteins

Lab → Pilot

Expected impact

# InDIRECT WP-Structure



# Time line InDIRECT

| WPs | Year 1 | Year 2 | Year 3 |
|---|---|---|---|
| **WP1: Actualisation of the scene** | | | |
| T1.1 – Side-streams | | | |
| T1.2 – legal aspects | | | |
| **WP2: Direct Biorefinery of plant biomass** | | | |
| T2.1 – Composition screening | | | |
| T2.2 – Biorefinery | | | |
| T2.3 – Product characterisation | | | |
| T2.4 – Preservation approaches | | | |
| **WP3: Indirect biorefinery via insects** | | | |
| T3.1 – Breeding of Black soldier fly | | | |
| T3.2 – Breeding of mealworm & co | | | |
| T3.3 – Biorefinery of insects | | | |
| **WP4: Nutritional cobalancing & safety aspects** | | | |
| T4.1 – Nutritional cobalancing | | | |
| T4.2 – Safety aspects | | | |
| **WP5: Product formulations & application tests** | | | |
| T5.1 – Feed application | | | |
| T5.2 – Chemical applications | | | |
| T5.3 – Others applications | | | |
| **WP6: Upscaling & ETEA** | | | |
| T6.1 – Upscaling biorefinery | | | |
| T6.2 – Larger scale application tests | | | |
| T6.3 – Techno-economic & environmental assessment | | | |
| **WP7 : Management, dissemination & exploitation & communication** | | | |
| **WP8 : Ethical aspects** | | | |

# Side-streams considered- WP1

- Selection criteria:
  - Availability in EU (Tonnes/Y);
  - Seasonallity;
  - Composition & dry matter content (suitable as insect food)
  - Under-spent → lower cost-price

- Some selected side-streams


Apple pomace


Leek


Sugar beet leaves
Sugar beet pulp


Rapeseed meal


DDGS

Others: Olive pomace, onions, carrots, corn gluten feed, ricebran, … (fresh & fermented)

# Direct biorefinery – WP2

**Selection side-streams & characterization:**

- Selection:
  - Leek (10 months/Y)
  - Sugar beet leaves (autumn only)
  - Alfalfa  (references – 4 cuts/Y);
- Characterisation:
  - Composition
  - Seasonal variability

**Biorefinery**

- Focus on proteins
- Maximal valoriation of biomass (at least 2 compounds targets from same biomass → cascading biorefinery)

**Preservation of side-streams before use**

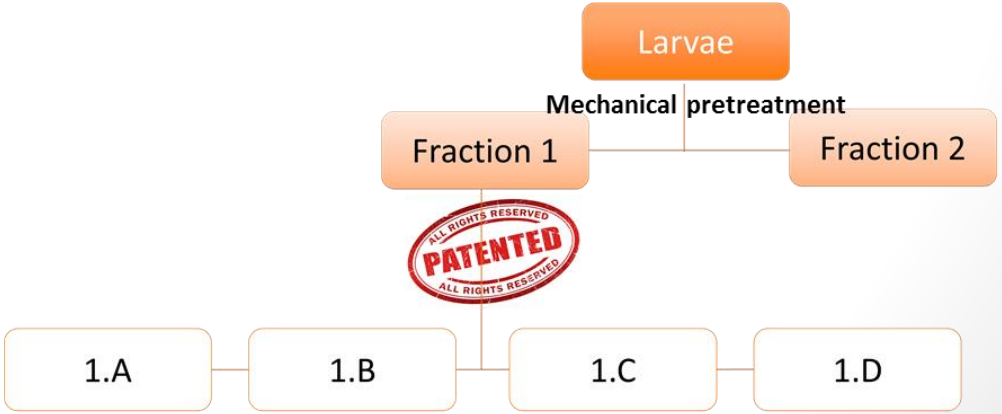
- Impact of cooling, freezing, freezedrying on quality of the side-stream
  - Monitoring in time
- Ensiling

# Indirect biorefinery – WP3

Aim:

1) Recycling biomass side-streams by growth of insects
   - Suitable side-stream for supporting growth (plants & manure)?
   - Impact of side-stream on composition larvae?

2) Sustainable biorefinery of insects in proteins, fats and chitin
   - Cascading biorefinery
   - Preservation of functionality during biorefinery



# Insect species considered – WP3

## Black soldier fly larvae -> 'Wet' side-stream (30% DM)

- Chemical applications
- Feed applications
- Technical applications

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## Lesser mealworm larvae → Dry side-stream

- Towards food & feed applications

Proti-Farm®
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## (House cricket)

- Extrapolation case

Proti-Farm®
The Protein Company

InDIRECT

# Cobalancing feed & safety aspects – WP4

**Objectives:**

(1) Cobalancing feed for insects:

- Unravelling some principles behind the needs of insects related to feed and
- applying this principles for cobalancing insect feed that is composed of side-streams.
- increasing the conversion efficiency of the insects
- tuning the composition of the insect towards specific applications;

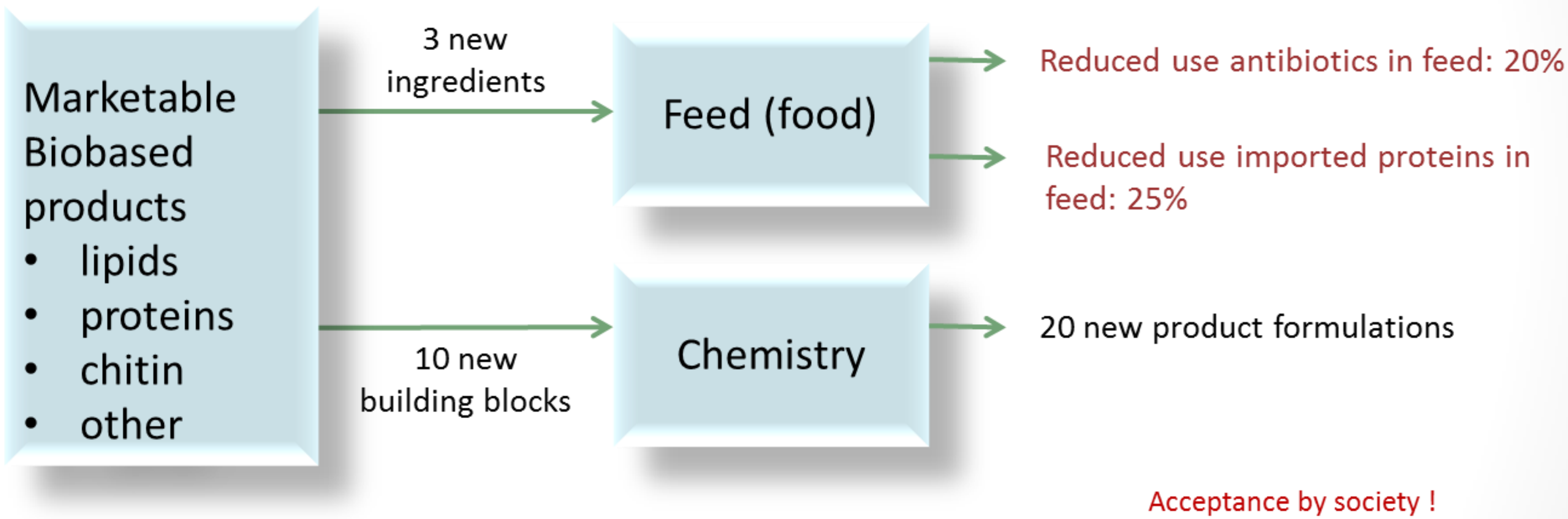
(2) Evaluating aspects related to safety of insect-derived products

- Mycotoxines, metals, pesticides, allergens, antibiotics, pathogens

# Application tests & formulations – WP5

***Objectives***

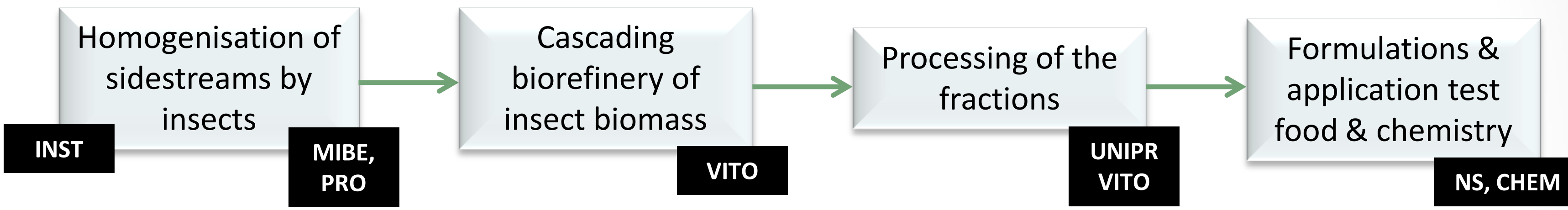
*1*) To formulate the recycled compounds from WP2 & WP3 into:




2) To evaluate their applicability at small scale.

# Upscaling – WP6

**Objective:** To evaluate at a larger scale the different elements of the proposed new InDIRECT value chain for converting side streams into marketable products.




**Upscaling of growth & promising biorefinery concepts**

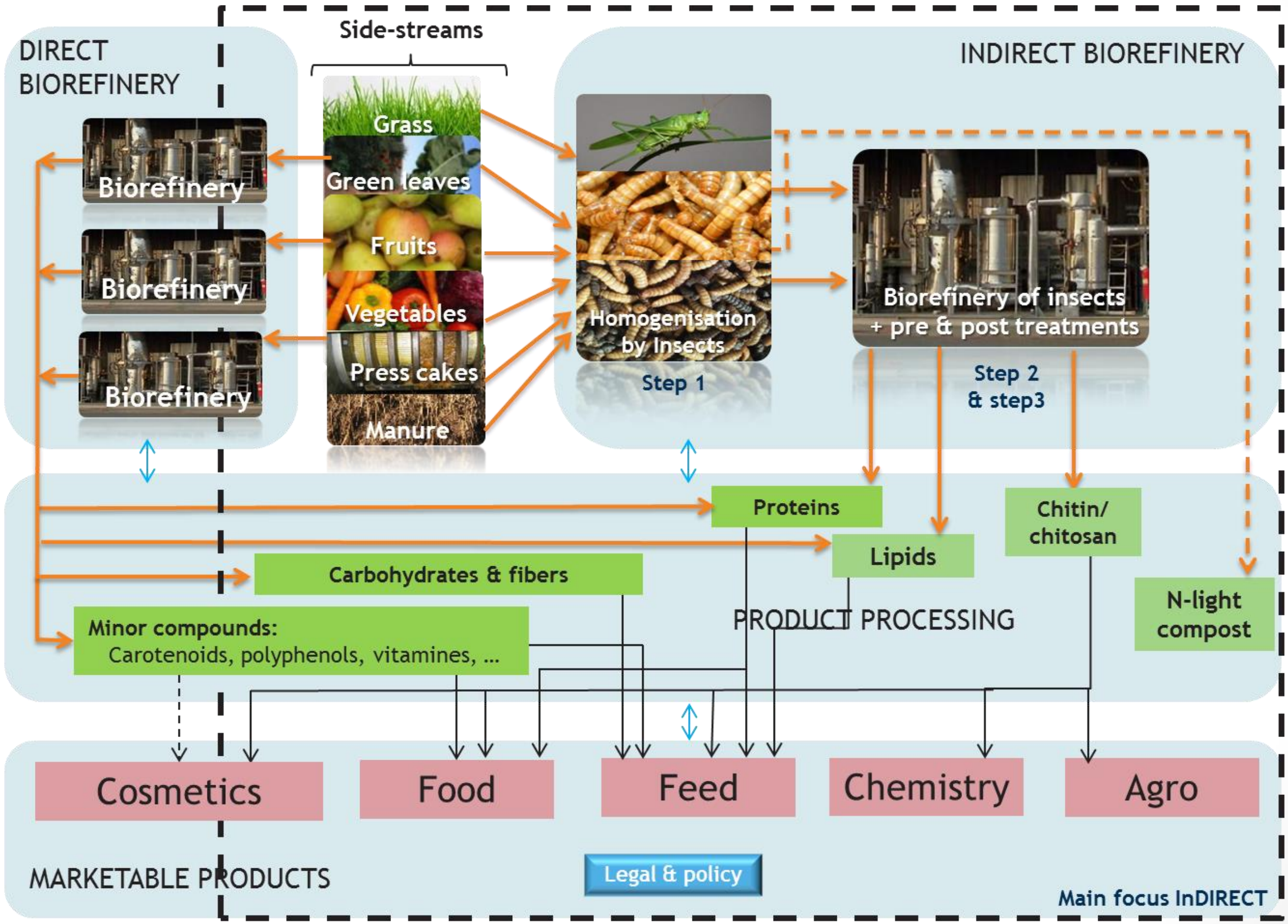
- Black soldier fly
- Lesser mealworm

**Upscaling of product formulations and application tests**

- Feed applications
- Chitin/chitosan and their corresponding formulations

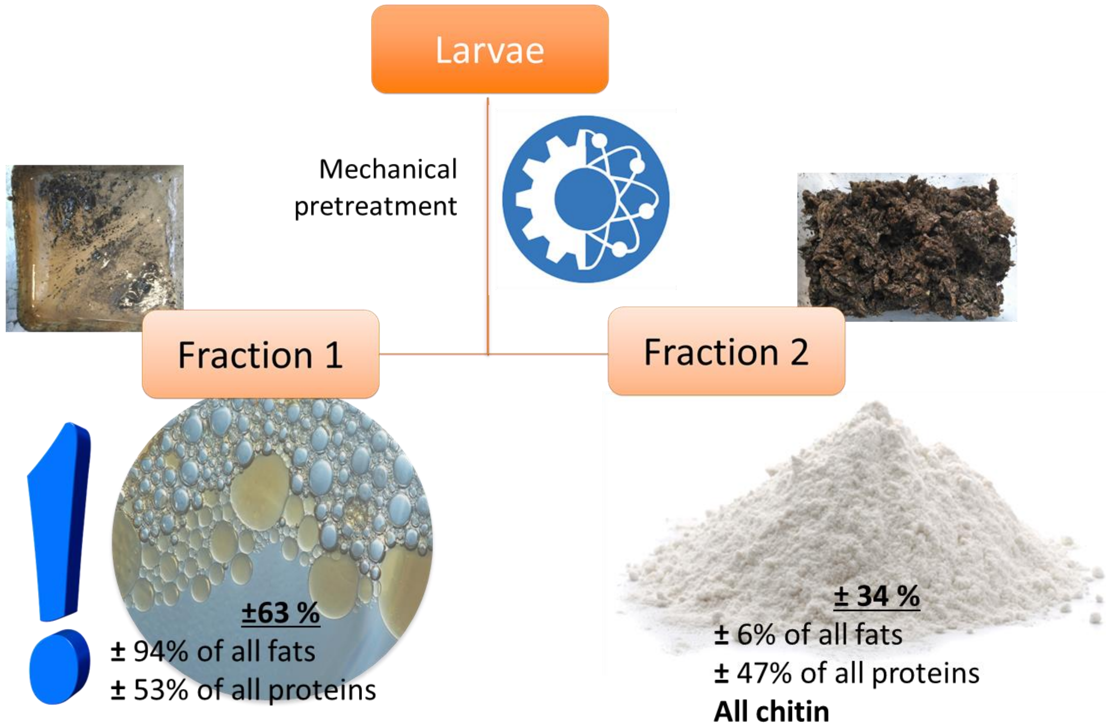
**Techno-economic and environmental analyses**

# Schematic representation of InDIRECT



# Fractionation of BSF

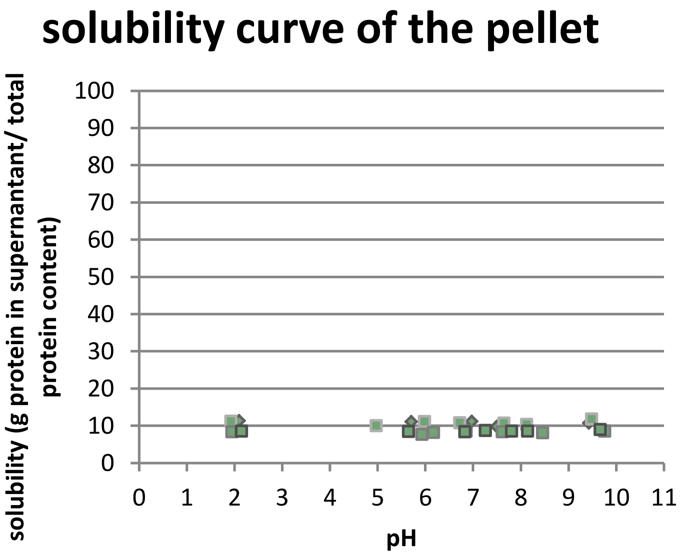
- Goal: all insect fractions are valuable but not always in same ratios of the whole insect (e.g. too much fat; digestibility of chitin)




Conclusion: all chitin in one fraction

# Insect fractionation

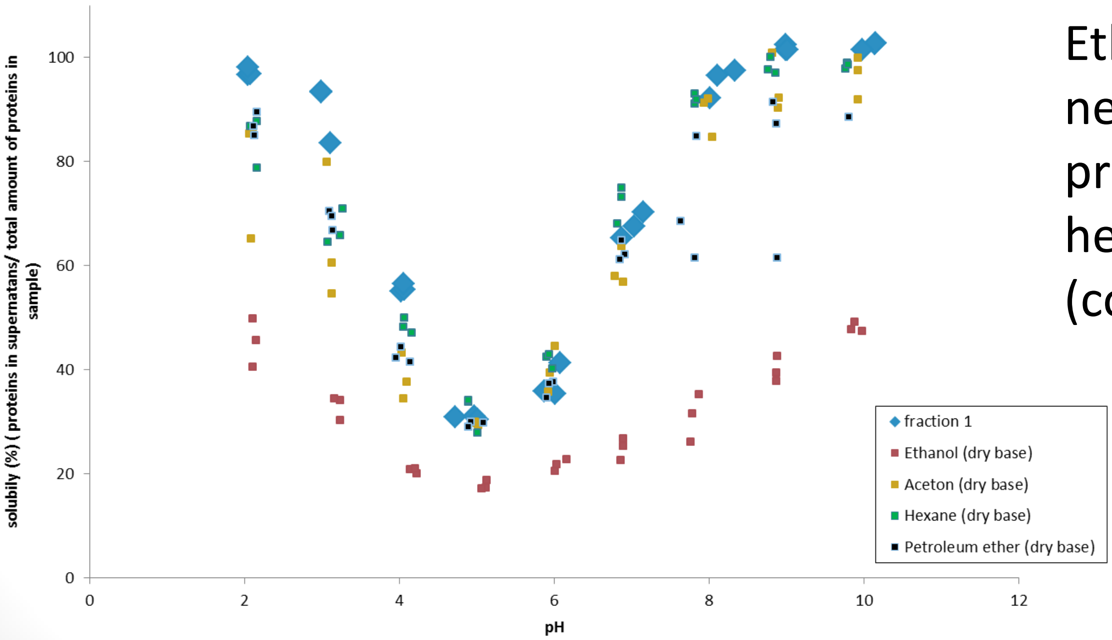
- Rendering = separation of fat from animal residues (e.g. fish oil) by using high T → protein hydrolysate fraction with nutritional value but no functionality
- Rendering in lab (boiling)




**Conclusion:**
- Pure lipid fraction (96%)
- A lot of fat (46%) in the protein pellet
- Proteins are denatured: solubility of 10% at pH 2-10

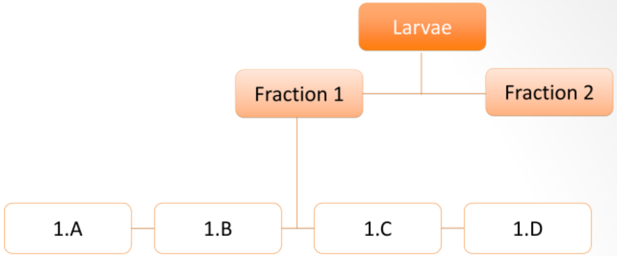
# Insect fractionation

- Organic solvents (e.g. hexane,…)
- Hexane is most efficient for fat recovery from dried insects, compared to petroleum ether, ethanol and acetone (data not shown)

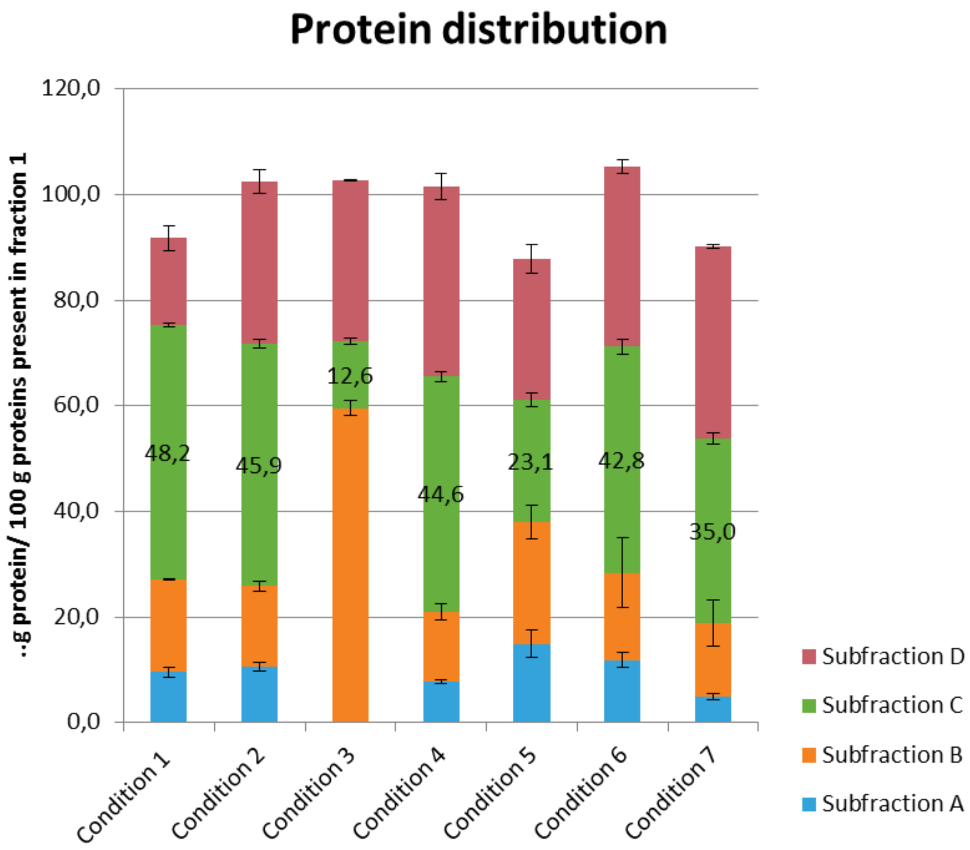



Ethanol has large negative impact on protein solubility; hexane less impact (confirmed by SDS-PAGE)

# Insect fractionation

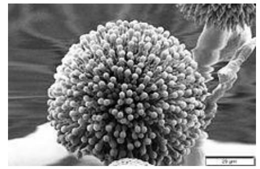



- Alternative procedure:



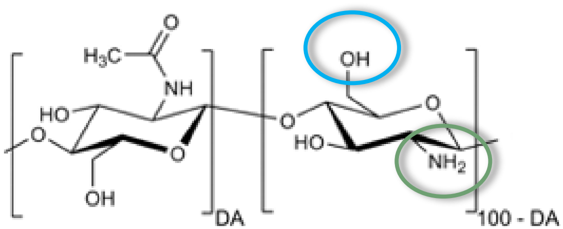

Conclusion:
Fat and proteins are not completely separated over subfractions A to D

# Chitin and chitosan

Sources:   

Industrial processing for chitin:
- acid treatment → $CaCO_3$
- alkaline extraction → proteins
- decolorization → pigments

Chitin —Deacetylation (Chemical: 30-60% NaOH)→ Chitosan —Depolymerisation (Chemical (e.g. HCl) or enzymatic)→ Chitosan oligomers




DA -degree of *N*-acetylation

| | |
|---|---|
| **chitin** | DA > 50% |
| **chitosan** | DA < 50% |

Properties:
- Solubility: chitin is insoluble; chitosan is soluble in acidic aqueous media
- Molecular weight
- Degree of (de)acetylation

Natural polymer of N-acetylglucosamine

Functional groups for (bio)chemistry

# Chitosan properties

- Biopolymer as building block: biodegradability
- Antimicrobial properties (Verlee et al. 2017):
  - type of microorganism (fungi, bacteria)
  - degree of deacetylation ↑ activity ↑: electrostatic interaction between $-NH_3^+$ and negative cell surface
  - molecular weight: LMW (16-190 kDa) activity ↑
  - type of derivatisation
  - environmental effects: pH ↓ and temperature ↑ activity ↑
- Anticholesterol properties: binding of lipids
- Antioxidant properties
- Dietary fiber: not digestible by human

# Chitosan market + applications

- 2015: chitin production 28.000 T ↔ demand 60.000 T
- Market growth: 2 billion USD (2016) to 4,2 billion USD (2021)
- Waste water treatment: flocculant, binding with metals, proteins,…
- Biopharmaceutics: wound healing, anti-cholesterol and weight loss products,…

- Agriculture: biostimulant, biopesticide, seed coating

- Food & feed: dietary fibre, replacement of antibiotics
- Materials: coating, packaging, fiber,…

# InDIRECT consortium

InDIRECT

vito vision on technology

nutrition sciences

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BIO-BASED INDUSTRIES Public-Private Partnership

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Horizon 2020 European Union Funding for Research & Innovation