The ALG-AD Project: *Creating value from waste nutrients by integrating algal and anaerobic digestion technology*

Fleuriane Fernandes

BIOREFINE CLUSTER EUROPE

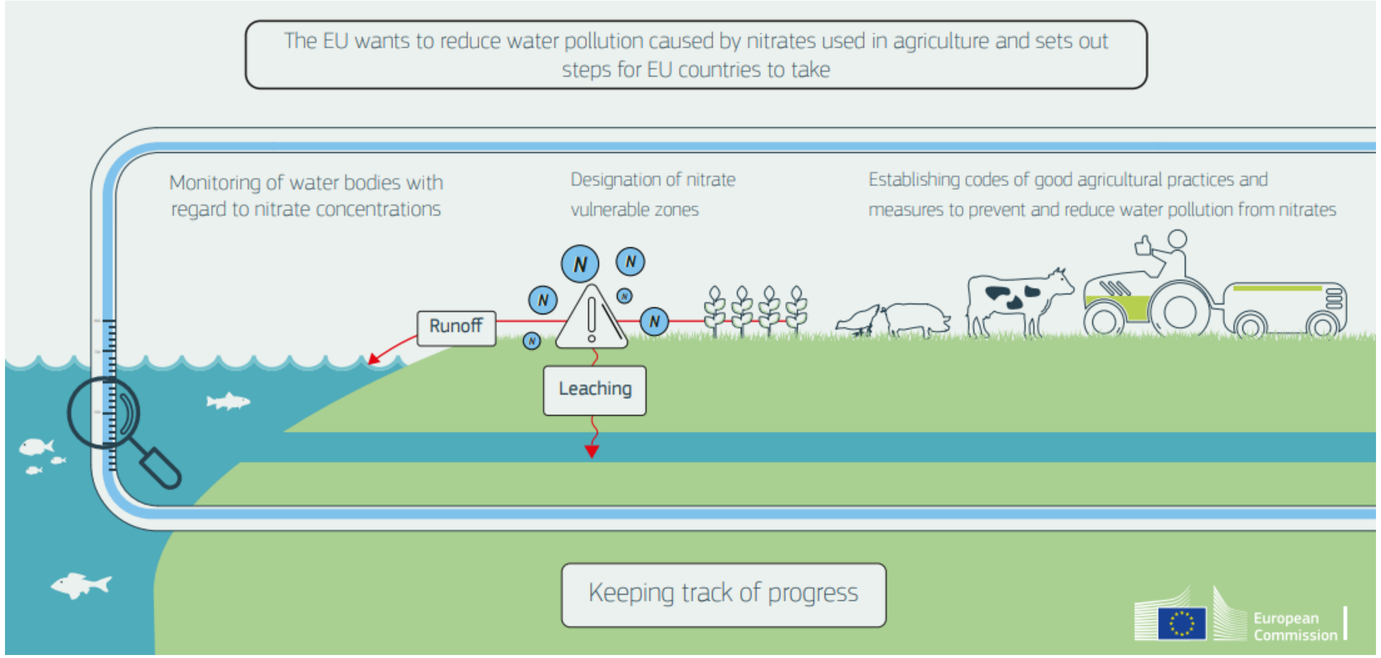
Interreg North-West Europe ALG-AD

European Regional Development Fund

EUROPEAN UNION

29th of March 2022

The ALG-AD project Rationale: The European Nitrate Directive



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LANGAGE AD ANAEROBIC DIGESTION

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algae wales

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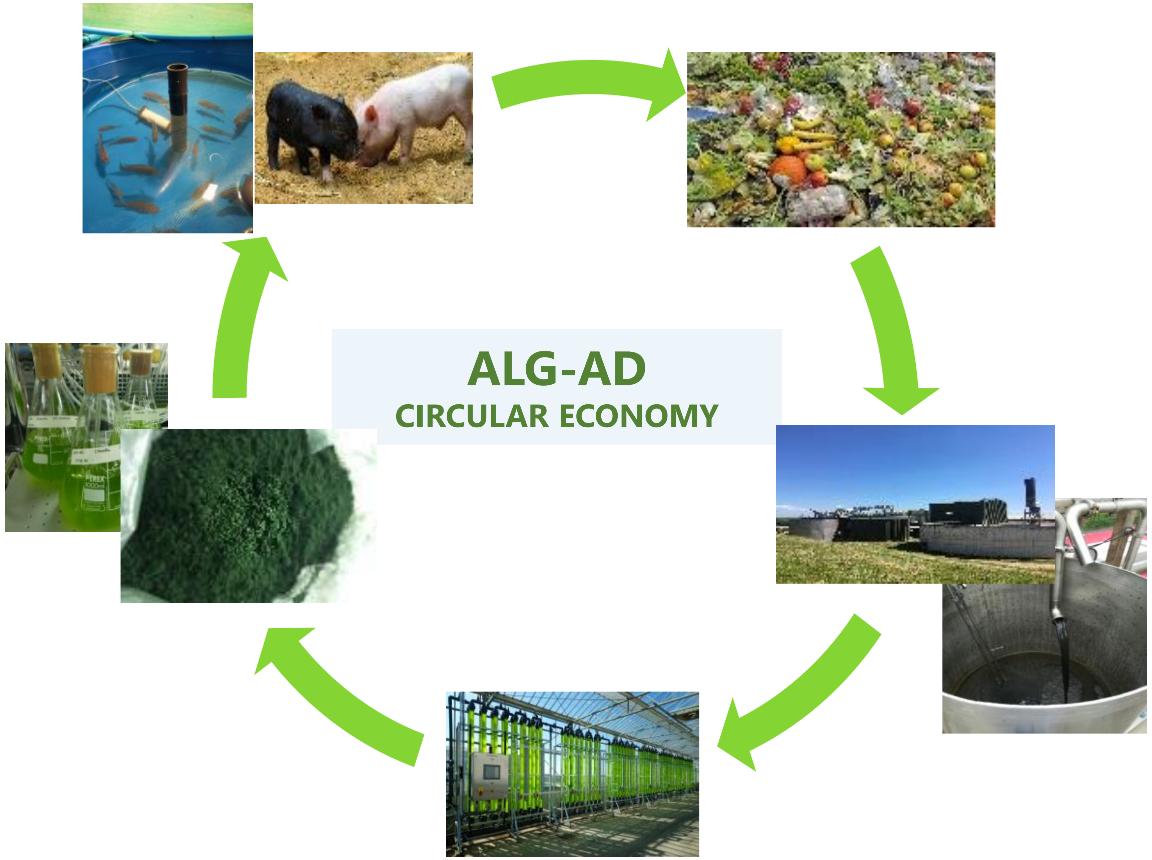
AGRICULTURES & TERRITOIRES CHAMBRES D'AGRICULTURE ARC ATLANTIQUE

The ALG-AD Project: the circular economy concept



ALG-AD combines algal and AD technology to reduce excess nutrients in liquid digestate

ALG-AD converts nutrients to create algal biomass for sustainable animal feeds

Three 4 tonne pilot facilities to implement and test the technology in real life conditions

11 partners from North West Europe (NWE) including the UK, France, Belgium and Germany

The biomass produced has been used to conduct piglet and fish feeding trials

Information collated has enabled the development of Decision Support Tools

DIGESTATE TREATMENT FOR MICROALGAE CULTIVATION

Digestate

- Dark Colour
- High dry weight – Particles
- N & P concentration -> to be tailored to microalgal needs

Membrane filtration was efficient at separating liquid and solid fractions of NRD and at recovering nearly 95% of both N and P

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Valorising nutrient-rich digestate: Dilution, settlement and membrane filtration processing for optimisation as a waste-based media for microalgal cultivation

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Chlorella vulgaris
Pilot-scale

ABSTRACT

Digestate produced from the anaerobic digestion of food and farm waste is primarily returned to land as a biofertiliser for crops, with its potential to generate value through alternative processing methods at present under explored. In this work, valorisation of a digestate resulting from the treatment of kitchen and food waste was investigated, using dilution, settlement and membrane processing technology. Processed digestate was subsequently tested as a nutrient source for the cultivation of *Chlorella vulgaris*, up to pilot-scale (800L). Dilution of digestate down to 2.5% increased settlement rate and induced release of valuable compounds for fertiliser usage such as nitrogen and phosphorus. Settlement, as a partial processing of digestate offered a physical separation of liquid and solid fractions at a low cost. Membrane filtration demonstrated efficient segregation of nutrients, with micro-filtration recovering 92.38% of phosphorus and the combination of micro-filtration, ultra-filtration, and nano-filtration recovering a total of 94.35% of nitrogen from digestate. Nano-filtered and micro-filtered digestates at low concentrations were suitable substrates to support growth of *Chlorella vulgaris*. At pilot-scale, the microalgae grew successfully for 28 days with a maximum growth rate of 0.62 day^{-1} and dry weight of 0.86 $g \cdot L^{-1}$. Decline in culture growth beyond 28 days was presumably linked to ammonium and heavy metal accumulation in the cultivation medium. Processed digestate provided a suitable nutrient source for successful microalgal cultivation at pilot-scale, evidencing potential to convert excess nutrients into biomass, generating value from excess digestate and providing additional markets to the anaerobic digestion sector.

1. Introduction

Anaerobic digestion (AD) is commonly used in Europe for the treatment of food and farm waste. The AD process is a biological mechanism during which bacterial and archaeal communities convert carbon-rich organic waste into biogases, primarily methane and carbon dioxide (Doble and Kumar, 2005). Another by-product of the AD process is a nutrient-rich digestate (NRD). NRD is rich in carbon, nitrogen (N), phosphorus (P) and other macro and micronutrients (Papadimitriou et al, 2008; Tambone et al, 2017). NRD is primarily used as organic fertiliser and is directly applied onto farmland (Fuchs and Drosg, 2013). However, the use of digestate as a soil fertiliser increases the risk of nutrient runoff and penetration of groundwater resources, leading to soil and water eutrophication (Guilayn et al., 2019). Consequently, Nitrate Vulnerable Zones (NVZs) have been designated under the European Nitrate Directive 91/676/CEE that limits the annual load of nitrogen applied onto farmland. NVZs are on the increase across North West Europe, resulting in the accumulation of approximately 10 million tons of excess digestate (Fuchs and Drosg, 2013).

Alternatives to farmland spreading have been investigated, such as using solid digestate for energy production or conversion into added-value products (char or activated carbon) (Monlau et al., 2015), however valorisation of digestate has been underexplored and solutions have yet to be firmly established to create value from this excess NRD. The present study focused on mechanical and biological treatments of digestate to increase its value and marketability. The partial processing of digestate was investigated first, by establishing methods for the separation of liquid and solid fractions of digestate using simple low-cost techniques. This approach

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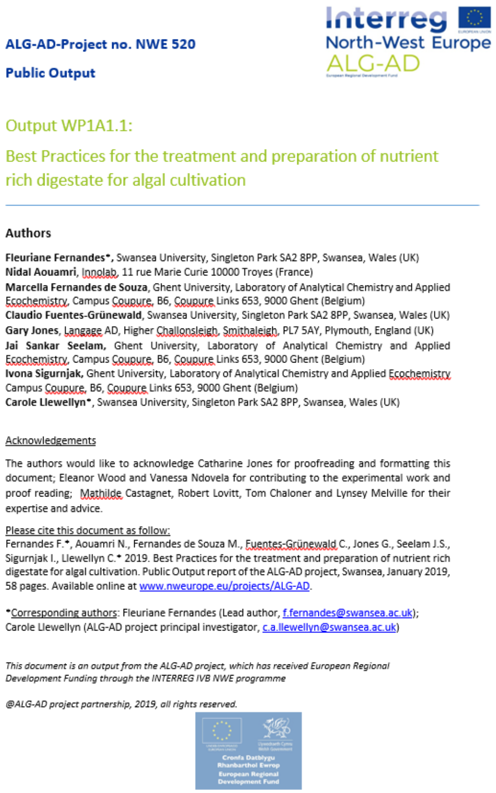

ALG-AD-Project no. NWE 520

Public Output

Interreg North-West Europe ALG-AD

Output WP1A1.1:

Best Practices for the treatment and preparation of nutrient rich digestate for algal cultivation

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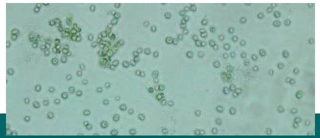
Cronfa Datblygu Rhanbarthol Ewrop
European Regional Development Fund

ALG-AD CULTIVATION PILOTS

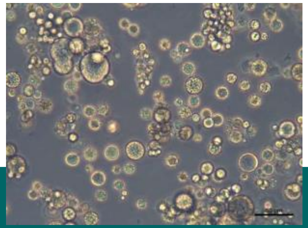
Langage AD, Plymouth

5T photobioreactor
Chlorella sp. and *Scenedesmus sp.*
2.5% of micro-filtered digestate (origin: kitchen waste)



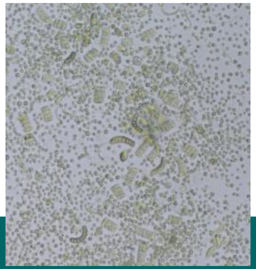
Cooperl, Lamballe

2T photobioreactor
Auriantochitrium mangrovei
80% of centrifuged digestate (origin: pig manure)



Innolab, Ghent

2T photobioreactor
Consortium of Chlorella sp. and Desmodesmus sp.
5% of filtered digestate (origin: plant and food waste)



ALG-AD CULTIVATION PILOTS – Biomass production

2.5% digestate (80 mg/L $NH4^+$)

7 days of cultivation

10 g/L glucose in mixo phase

14 g/L final biomass

20 mg/L/day N uptake

2.5% digestate (70 mg/L $NH4^+$)

2 days of cultivation

20 g/L glucose, 2 g/L yeast extract, 2 g/L peptone

4 g/L final biomass

35 mg/L/day N uptake

2.5% digestate (50 mg/L $NH4^+$)

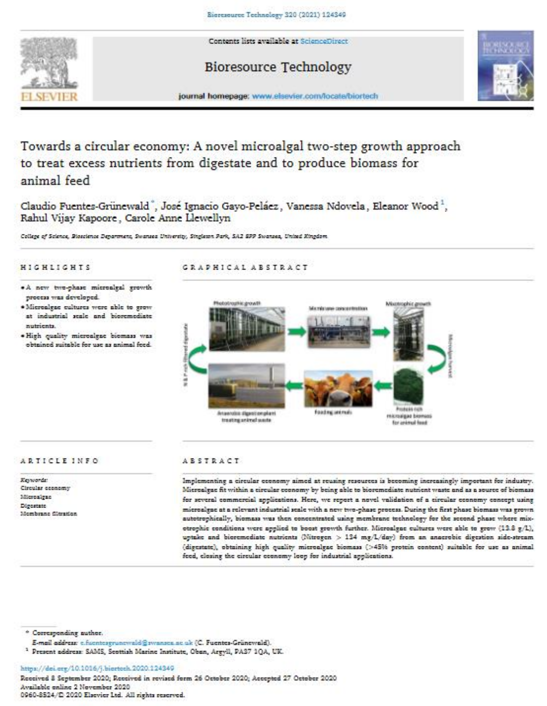
7 days of cultivation

No external nutrients

1.7 g/L final biomass

20 mg/L/day N uptake

25 kg of concentrated biomass (10g/L) produced by pilots



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Towards a circular economy: A novel microalgal two-step growth approach to treat excess nutrients from digestate and to produce biomass for animal feed

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HIGHLIGHTS

- A new two-phase microalgal growth process was developed.
- Microalgae cultures were able to grow at industrial scale and bioremediate nutrients.
- High quality microalgae biomass was obtained suitable for use as animal feed.

GRAPHICAL ABSTRACT

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Digestate
Membrane filtration

ABSTRACT

Implementing a circular economy aimed at reusing resources is becoming increasingly important for industry. Microalgae fit within a circular economy by being able to bioremediate nutrient waste and as a source of biomass for several commercial applications. Here, we report a novel validation of a circular economy concept using microalgae at a relevant industrial scale with a new two-phase process. During the first phase biomass was grown autotrophically, biomass was then concentrated using membrane technology for the second phase where mixotrophic conditions were applied to boost growth further. Microalgae cultures were able to grow (13.8 g/L), uptake and bioremediate nutrients (Nitrogen > 134 mg/L/day) from an anaerobic digestion side-stream (digestate), obtaining high quality microalgae biomass (>45% protein content) suitable for use as animal feed, closing the circular economy loop for industrial applications.

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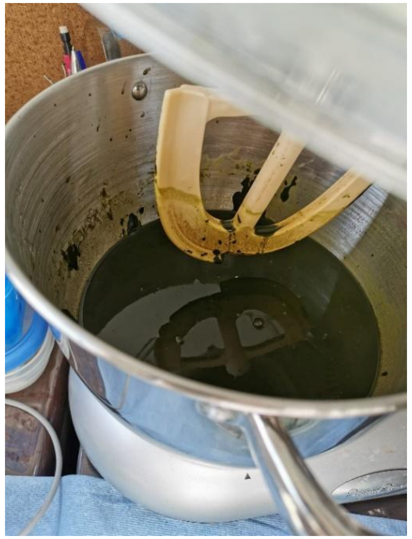
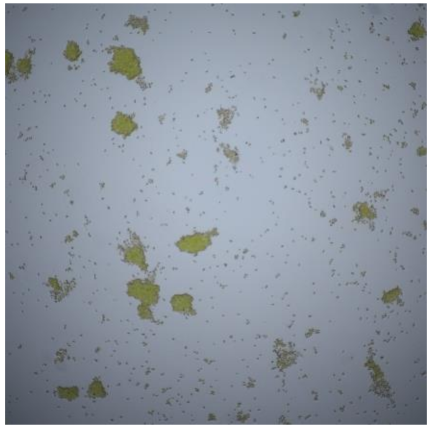
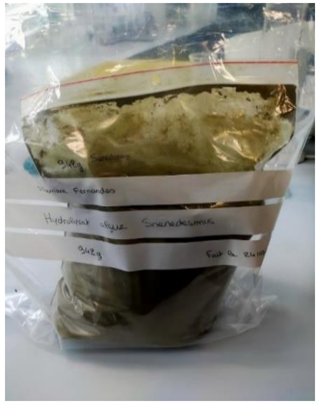
BIOMASS PROCESSING - Hydrolysis

Specific hydrolysis process : enzymatic cocktails tailored to the different types of biomass

Breaking down of proteins and other molecules into peptides and amino acids and other metabolites of interest for feed trials







Cheaper than extraction methods

Better incorporation into feed formulation and better absorption by animals

ANIMAL FEED TRIALS

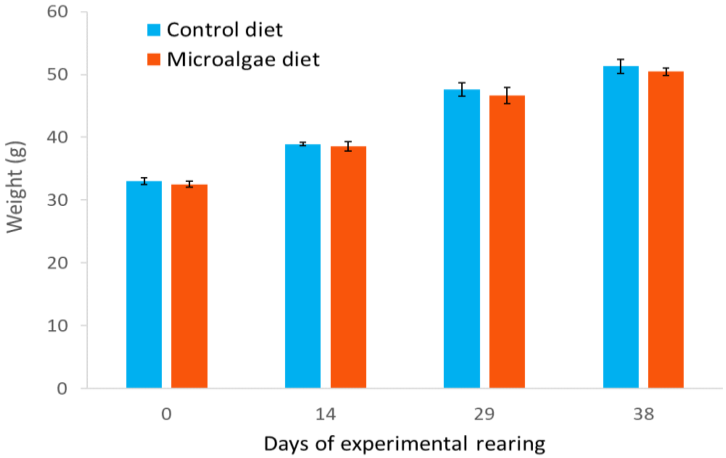
Seabass Trials

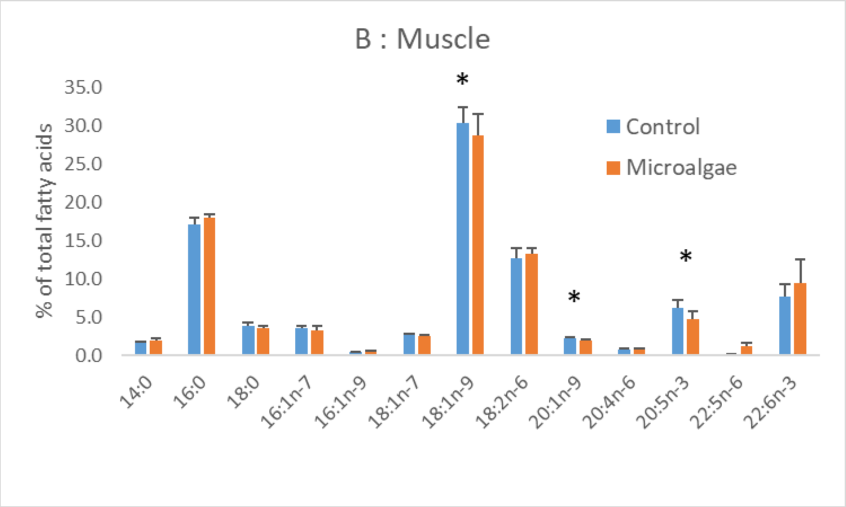
- *Aurantiochytrium mangrovei* used to replace 15% of a standard feed for Seabass Juvenile and larvae
- Objective : Increase DHA supply and DHA/EPA ratio with microalgae biomass inclusion

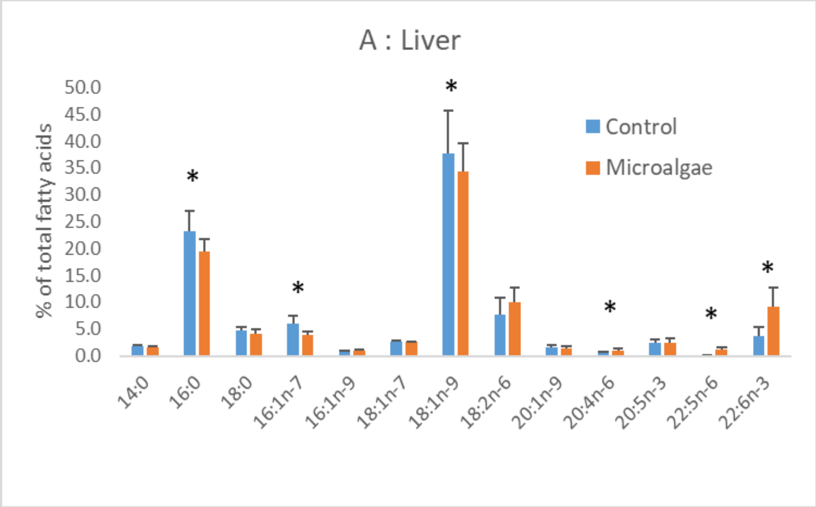
Tilapia Trials

- *Scenedesmus obliquus* used to replace 10% of a standard feed for Tilapia juveniles
- Objective : decrease reliance on fish meal proteins by replacing them with SO as a high source of proteins

SEABASS TRIAL MAIN RESULTS

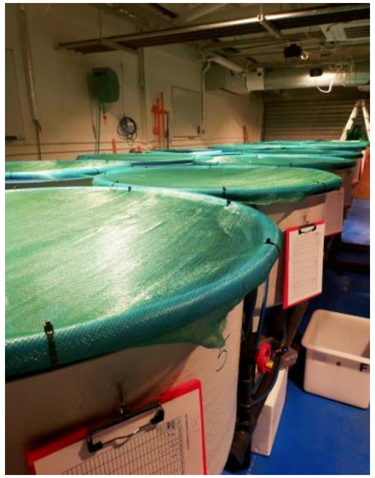






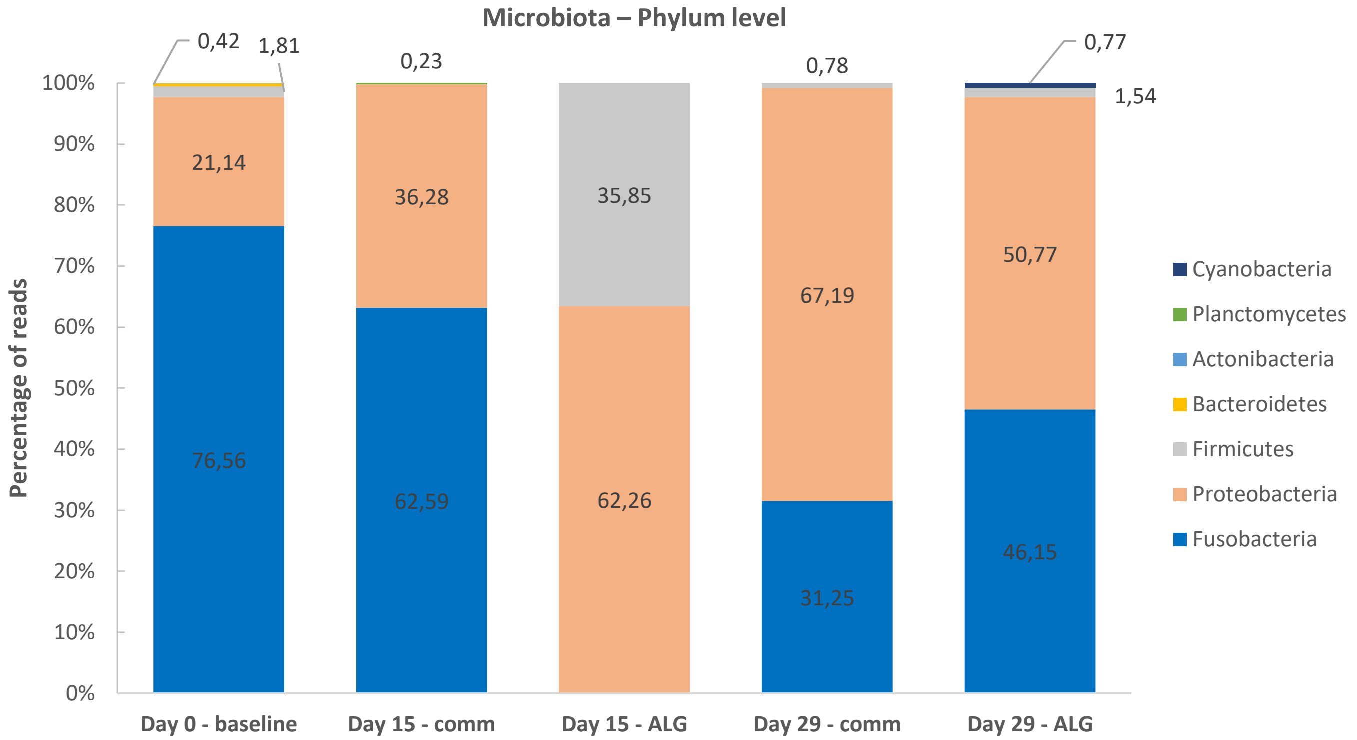
Comparable growth of the fish

DHA increased in liver and in muscle -> added value for aquaculture sector

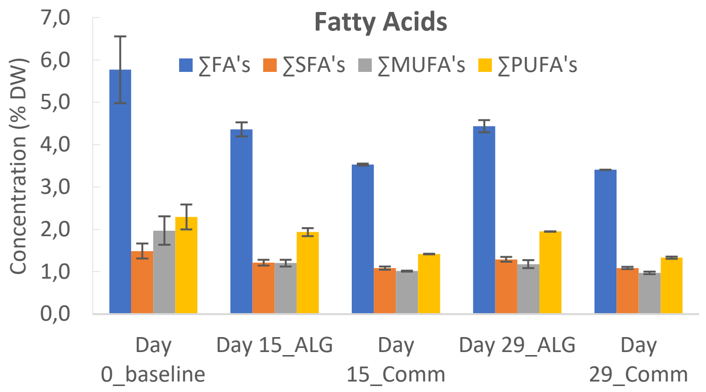


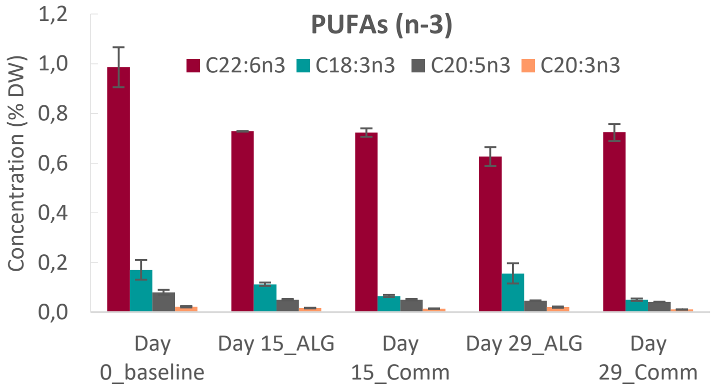
TILAPIA TRIAL MAIN RESULTS

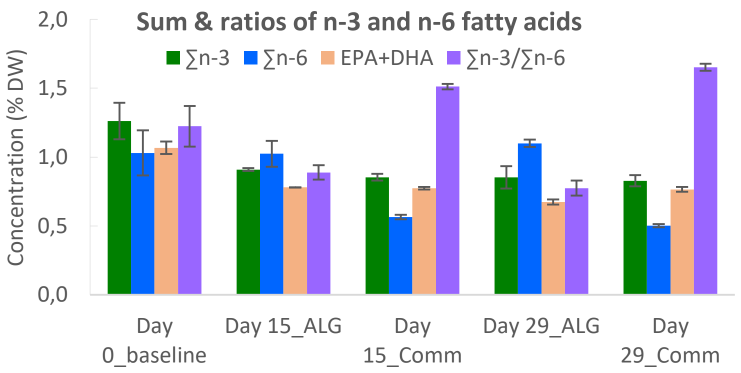
Higher microbial diversity -> better fish health and immunity

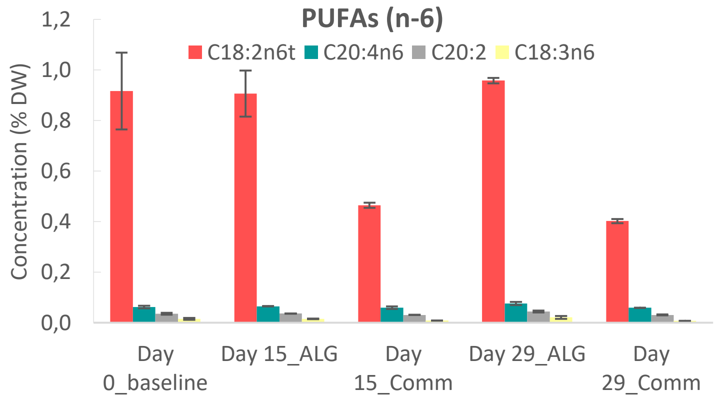


TILAPIA TRIAL MAIN RESULTS









Twenty-two FAs found

Total fatty acids and **PUFAs** were significantly **higher for the ALG-AD feed**.

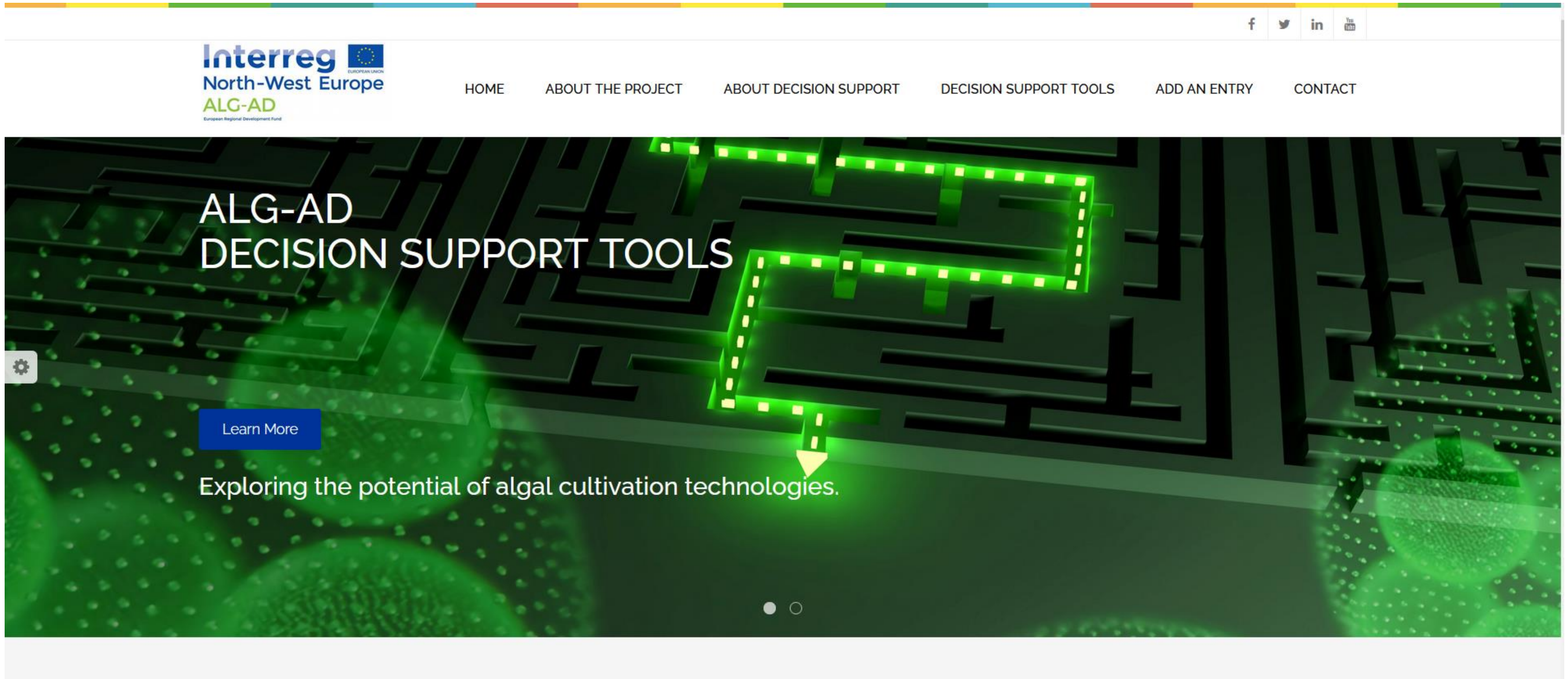
Fatty acid content of fish directly influenced by the **fatty acid composition of the diet** : **Large amounts of alpha-linoleic acid** in *Scenedesmus obliquus* -> metabolised in different lipids

ω-3/ω-6 ratio of nearly 1 -> associated with lower risks of developing allergies, inflammatory and cardio-vascular diseases

Improved flesh quality and consequent added-value for the aquaculture sector

DECISION SUPPORT TOOL

Inform and guide technology developers, businesses, policy makers and researchers.



The tools can provide supporting information that is unique to your location and circumstances. They are flexible and adaptive to enable you to explore various process scenarios.

Release in the next few months

PUBLICLY AVAILABLE OUTPUTS AND DELIVERABLES

Best Practice documents

Decision support tool

Scientific publications

Webinars recordings

All available on the ALG-AD website

Thank you

@ALGADProject

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