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Centro Tecnológico Nacional de la Conserva y Alimentación

Murcia, Spain
5/7 February 2020

Algae in animal feed and its environmental impact.

Algas en alimentación animal y su impacto ambiental.

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- *Some experiences with algae in animal feed and its environmental impact*
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- *Research group presentation*

NUTRICIÓN Y BROMATOLOGÍA
HUMAN NUTRITION & FOOD SCIENCE
1992
G.I. E098-02 - FACULTAD DE VETERINARIA - UNIVERSIDAD DE MURCIA

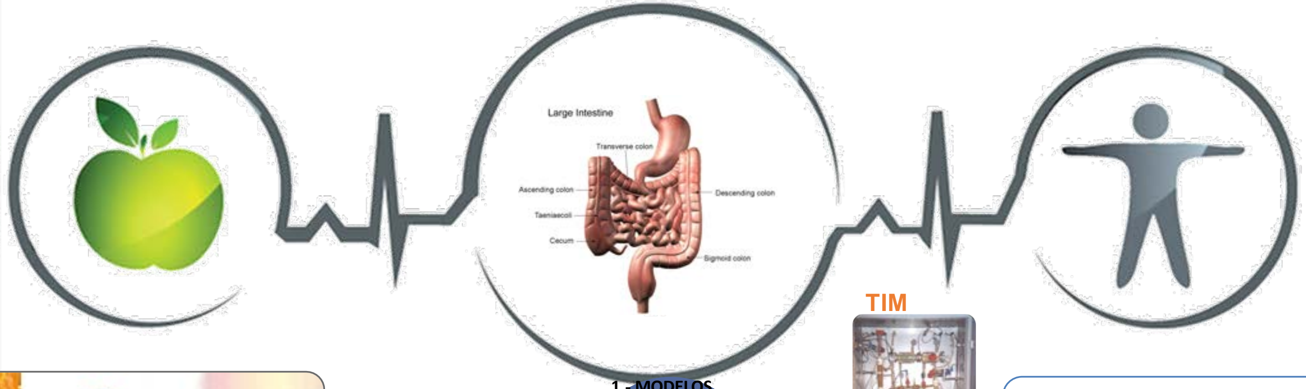
CENTUM CAMPUS MARE NOSTRUM

MURCIA

UNIVERSIDAD DE MURCIA

GOOF SCIENCE	HUMAN NUTRITION

Food *Bioavailablity* *Health*



aecosan

Encuesta Nacional de Ingesta Dietética Española

Distribución de la ingesta habitual de energía en la población española entre 18 y 64 años (**ENIDE 2011**)

PYMES

1.- MODELOS ESTÁTICOS Y DINÁMICOS
- Modelo estático MIM
- Modelo dinámico TIM
SHIME

-Solubilidad
-Diálisis
-Accesibilidad

2.- ESTUDIO IN VITRO CON LÍNEAS CELULARES
- Caco2
- Hep29

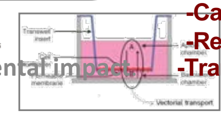
3.- ANIMALES DE EXPERIMENTACIÓN PRECLÍNICOS
- Roedores
- Lechones

-Biodisponiblidad
-Bioeficacia
-Biotransformación
-Distribución
-Genéticos

TIM

SHIME

Línea celular Caco-2
-Captación
-Retención
-Transporte



Instituto de Nutrición Infantil Hero Baby
Arrixaca Hospital Universitario "Virgen de la Arrixaca"
Pediatría

-Biodisponiblidad
-Bioeficacia
-Biotransformación
-Funcionalidad
-Genéticos

Nutrition, diet, functional food & wellbeing.

cost 99

(1995-1999)

Folate Func Health

(1999-2004)

FIFTH FRAMEWORK PROGRAMME

http://www.ifr.ac.uk/folate/

EuroFIR

www.eurofir.net

bedca

Base de Datos Española de Composición de Alimentos

(2005-current)

CDTI CIEN

PROYECTO:

RESEARCH AND EXPERIMENTAL DEVELOPMENT IN NEW HEALTHY FOODS AND ADVANCED CONTAINERS

(AVANZA-S)

cost

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

FA Food and Agriculture

Mineral Improved Crop Production COST 0905

INFOGEST

COST ACTION FA 1005

TRACEL 2011

may 2011 | murcia | spain

Tracel 2011 3rd international symposium on trace elements & health

WG1 Food Structure and Nutrient Bioavailability

WG2 Models of Gastrointestinal Digestion

WG3 Effect of Food on Health

DAIRY FRUITS & VEGETABLES EGGS - MEAT CEREALS

LYCOCARD®

(2007-2011)

SIXTH FRAMEWORK PROGRAMME

http://www.lycocard.com/

Satin

Satiety Innovation

(2012-2016)

SEVENTH FRAMEWORK PROGRAMME

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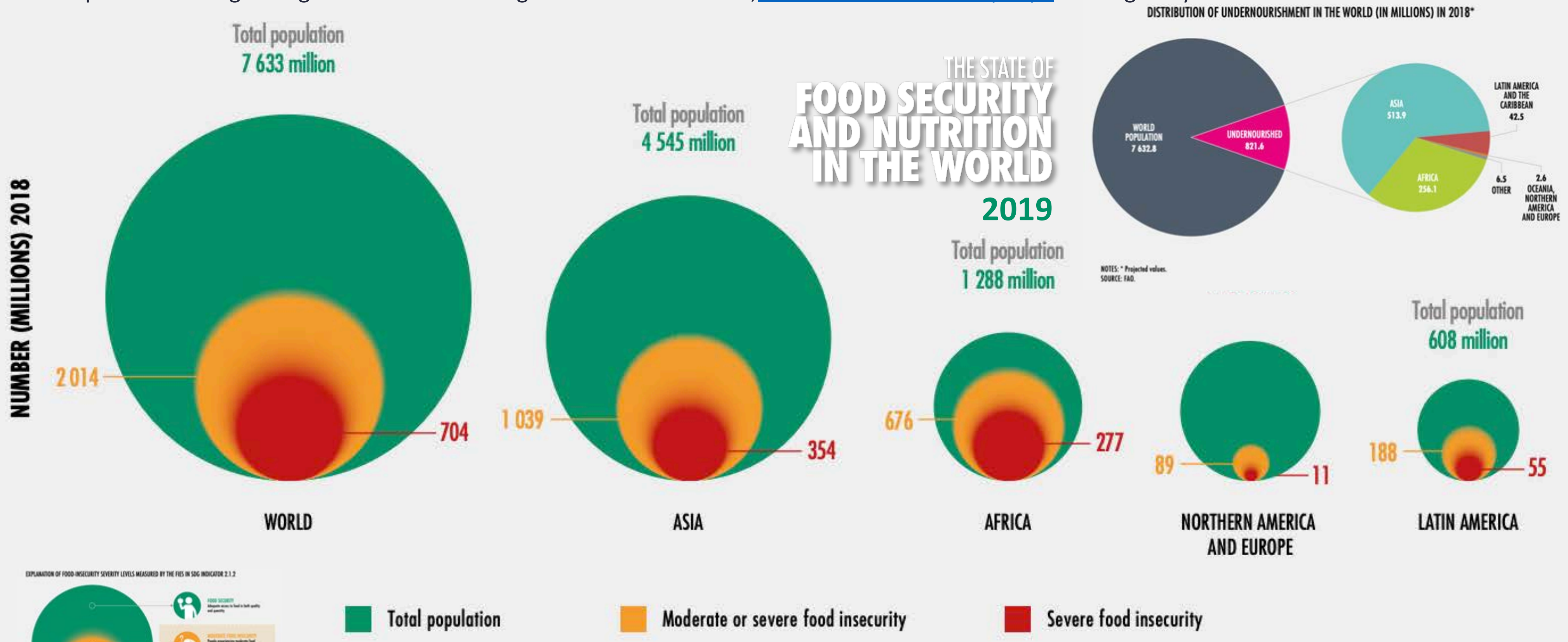
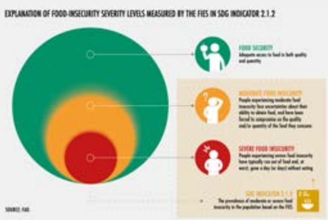
• *Challenges for human food security and nutrition in the world*

- Our planet faces a growing food crisis. According to the United Nations, more than 800 million people are regularly undernourished.





SOURCE: FAO.

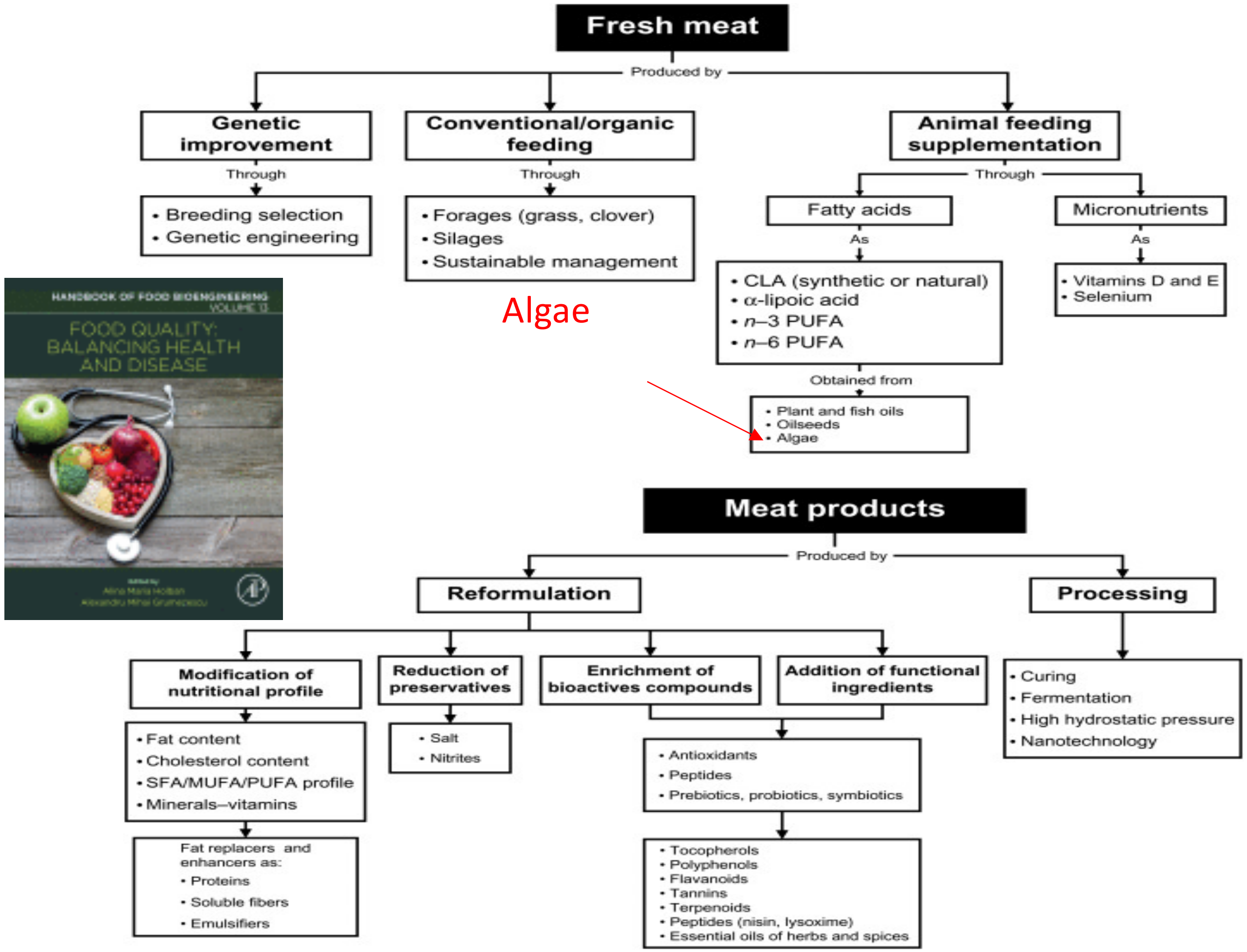
- By 2050, an additional 2 to 3 billion new guests will join the planetary dinner table.

William Moomaw, Isaac Berzin, and Asaf Tzachor.Industrial Biotechnology.Oct 2017.234-243

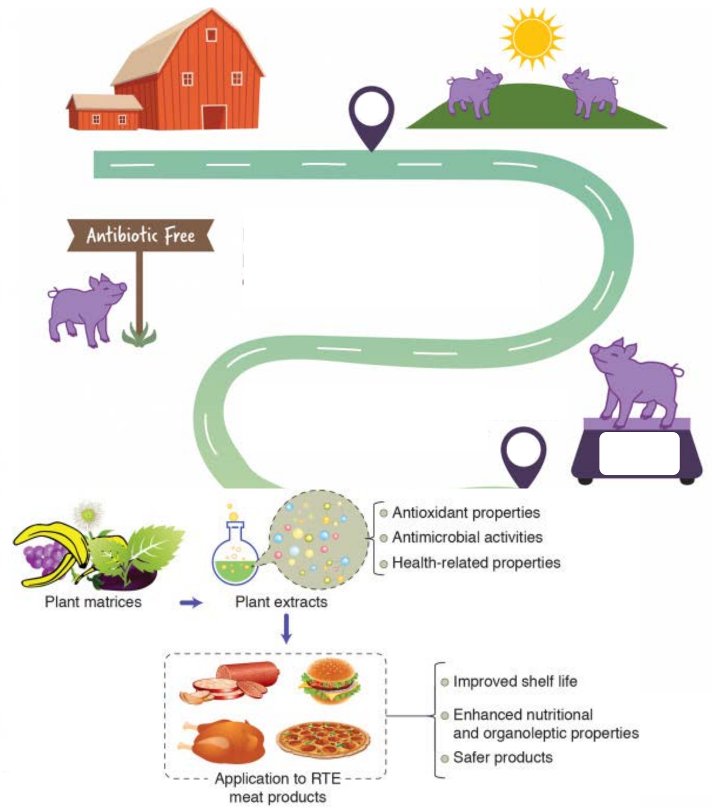
Meeting this challenge involves not only providing sufficient calories for every person, but also assuring a balanced diet that includes the protein and nutrients that are essential to good health.

Marine algae (micro or not) might be a sustainable solution for solving global macro-hunger.

- *Strategies to improve the nutritional quality of animal origin food products*



Animal Wellbeing

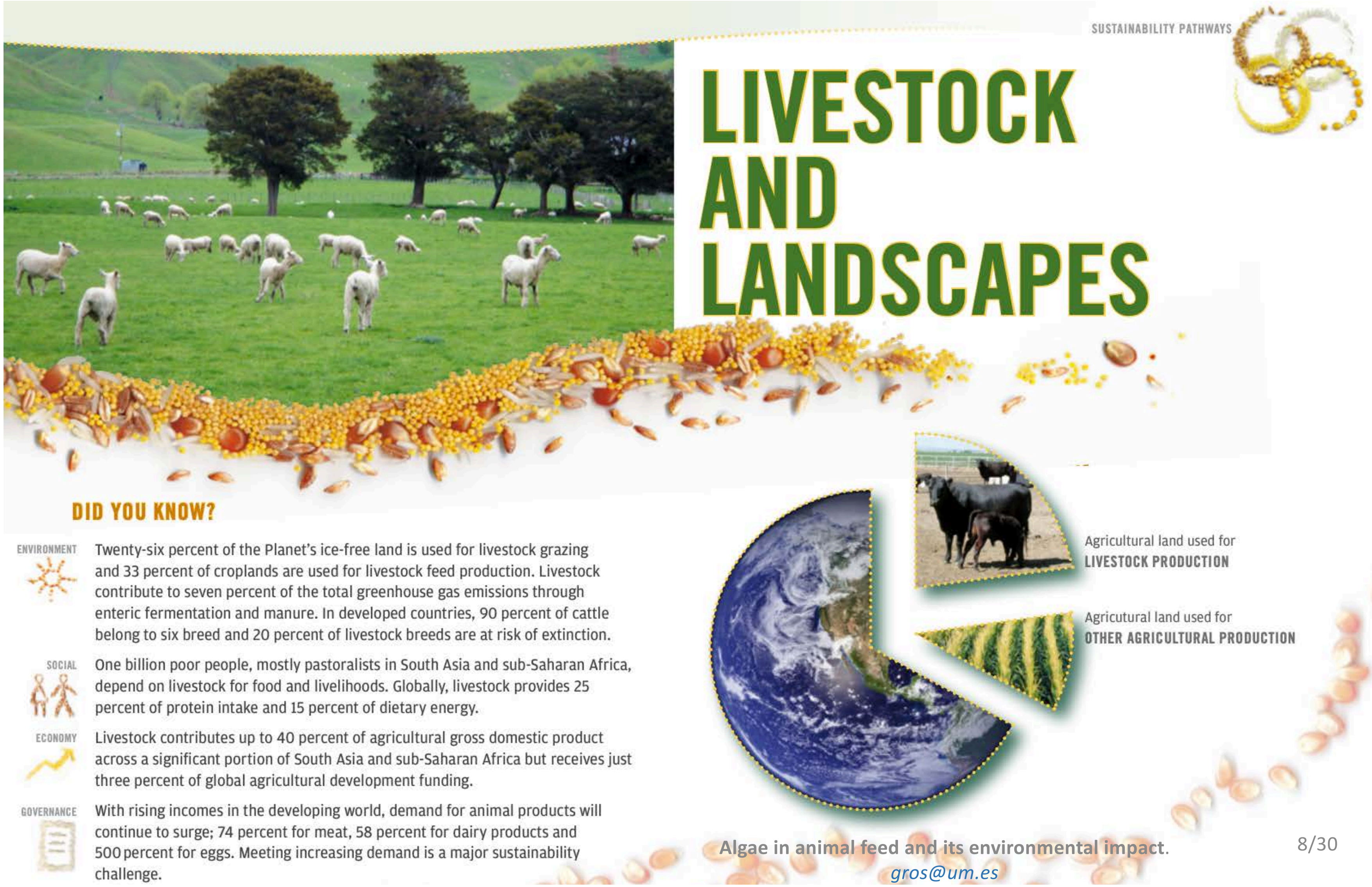


María J.Beriain, Inmaculada Góme, Francisco C. Ibáñez, M. Victoria Sarriés, Ana I.Ordóñez Chapter 1 - Improvement of the Functional and Healthy Properties of Meat Products 2018, Pages 1-74

- *Some problems (potential or not) with current food production systems*

Livestock production is replacing forests with cropland and pastures for meat and animal feed.

Nitrogen and phosphorous fertilizer used to grow feed grain and other crops is degrading soils and creating biological dead zones in some 400 estuaries around the world.


SUSTAINABILITY PATHWAYS

LIVESTOCK AND LANDSCAPES

DID YOU KNOW?

ENVIRONMENT — Twenty-six percent of the Planet's ice-free land is used for livestock grazing and 33 percent of croplands are used for livestock feed production. Livestock contribute to seven percent of the total greenhouse gas emissions through enteric fermentation and manure. In developed countries, 90 percent of cattle belong to six breed and 20 percent of livestock breeds are at risk of extinction.

SOCIAL — One billion poor people, mostly pastoralists in South Asia and sub-Saharan Africa, depend on livestock for food and livelihoods. Globally, livestock provides 25 percent of protein intake and 15 percent of dietary energy.

ECONOMY — Livestock contributes up to 40 percent of agricultural gross domestic product across a significant portion of South Asia and sub-Saharan Africa but receives just three percent of global agricultural development funding.

GOVERNANCE — With rising incomes in the developing world, demand for animal products will continue to surge; 74 percent for meat, 58 percent for dairy products and 500 percent for eggs. Meeting increasing demand is a major sustainability challenge.

Agricultural land used for LIVESTOCK PRODUCTION

Agricutural land used for OTHER AGRICULTURAL PRODUCTION


• *Some problems (potential or not) with current food production systems*
The current Western diet requires vast amounts of land, water and energy, is heavily polluting and is a major contributor to climate change.
Providing nutritious food for an ever-growing global population with increasing per capita demand is pushing our current food production system beyond its limits.
Carbon emissions from agriculture, including meat and dairy, are projected to contribute approximately 70% of the established value for greenhouse gas emissions that would restrict the rise of global temperature to 2 degrees centigrade this century.
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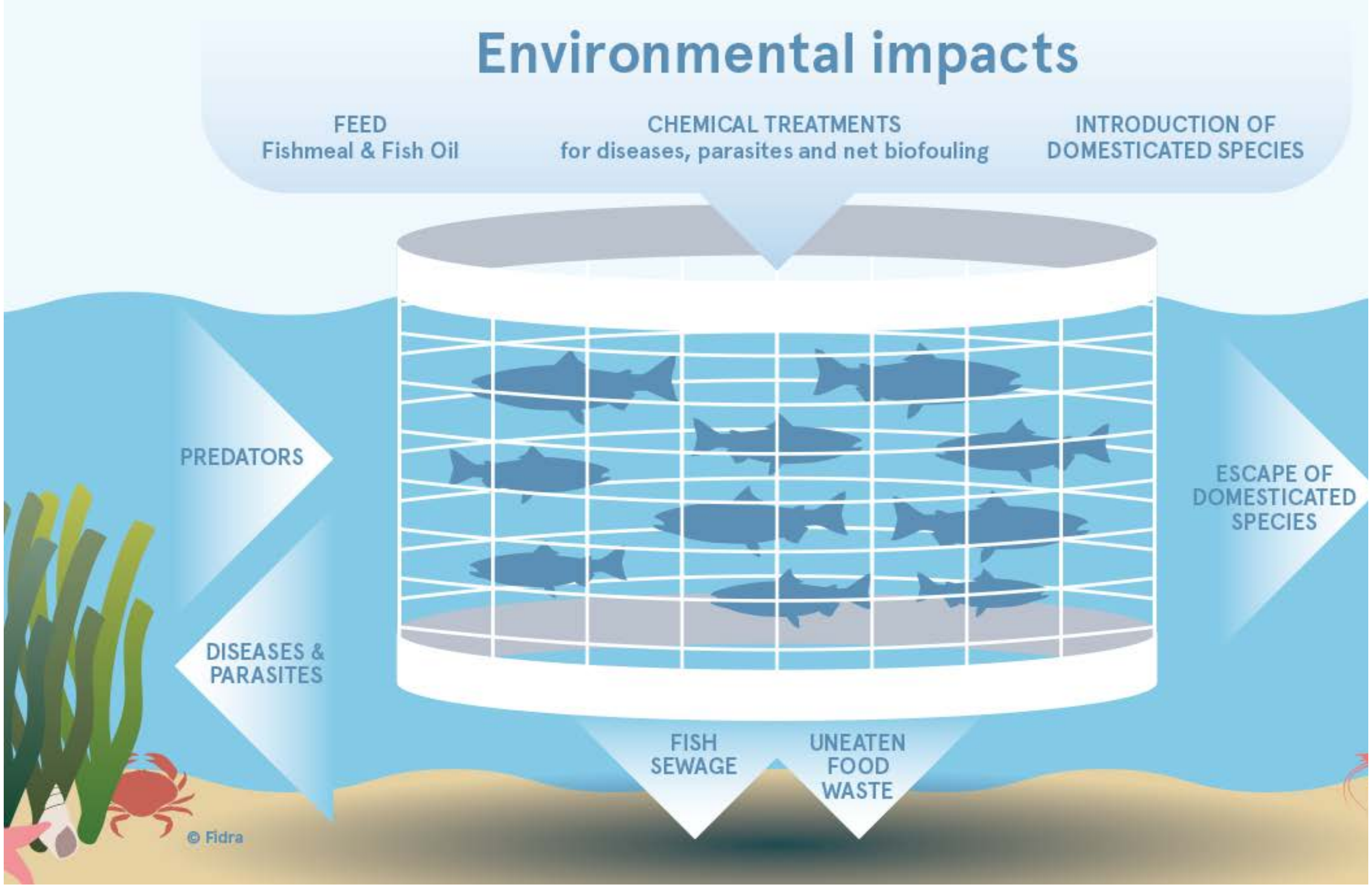
Fish are an important source of omega-3 fatty acids and essential amino acids that make up our proteins. However, eating fish has some downsides.

They can concentrate heavy metals and toxic organic chemicals in their tissues and pass them on to us. Furthermore, most ocean fisheries are overfished or at maximum production.

Aquaculture is producing a growing share of world seafood.

But fish farms can have serious environmental impacts, including water pollution, disease transmission to wild fish and habitat destruction.

Demand for small ocean fish to feed those raised on farms is depleting wild stocks.



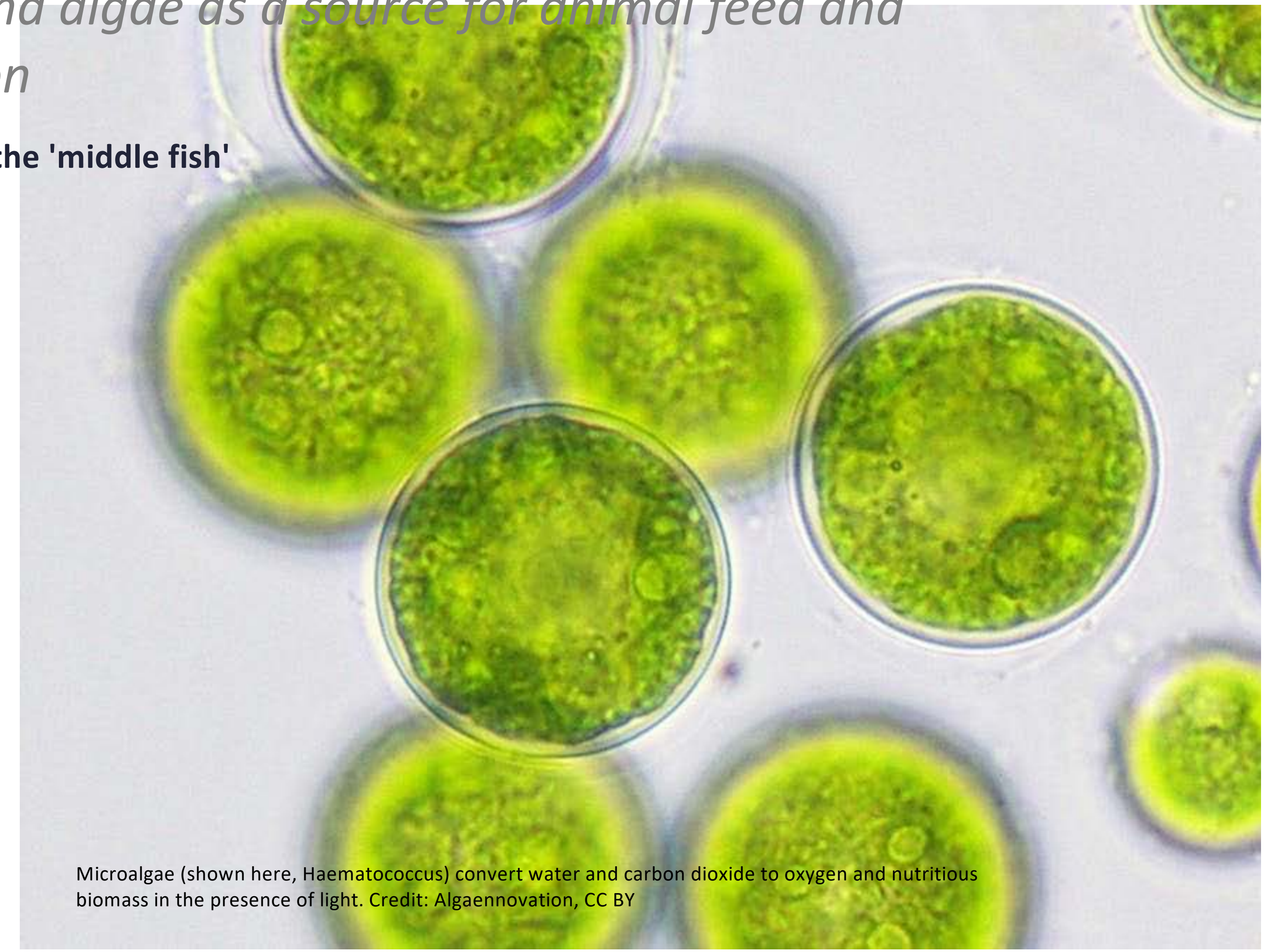
- *Solutions: Seaweed and algae as a source for animal feed and environmental solution*

An alternative approach: Cutting out the 'middle fish'

Alternative solution:
commercial production of marine microalgae as a staple human food and feed for animals and farmed fish.

These tiny organisms are the ultimate source of omega-3 fatty acids and amino acids that humans need in our diets, and which many of us get by eating fish.

But fish are merely aquatic intermediaries in the nutrition business. We can feed the world more efficiently by "cutting out the middle fish."



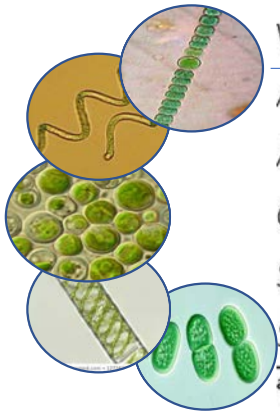
Microalgae (shown here, Haematococcus) convert water and carbon dioxide to oxygen and nutritious biomass in the presence of light. Credit: Algaennovation, CC BY

Microalgae are a nearly untapped resource, and are found in both freshwater and marine aquatic systems.

Although they are only few micrometers in size, they produce amino acids, fatty acids, vitamins, minerals, antioxidants, polymers and carbohydrates.

Fatty acid	Sp	Cv	Sc	Dt	Nanno	Neo
14:0	0.34	3.07	1.48	0.47	7.16	0.43
16:0	40.16	25.07	21.78	17.70	23.35	19.35
16:1	9.19	5.25	5.95	0.88	26.87	1.85
16:2	N.D.	N.D.	3.96	3.03	0.39	1.74
16:3	0.42	1.27	0.68	1.24	0.48	0.96
16:4	0.16	4.06	0.43	10.56	N.D.	7.24
18:0	1.18	0.63	0.45	N.D.	0.45	0.98
18:1	5.43	12.64	17.93	4.87	13.20	20.29
18:2	17.89	7.19	21.74	12.37	1.21	12.99
18:3	18.32	19.05	3.76	30.19	N.D.	17.43
18:4	0.08	N.D.	0.21	N.D.	N.D.	2.10
20:0	0.06	0.09	N.D.	N.D.	N.D.	N.D.
20:1	N.D.	0.93	N.D.	N.D.	N.D.	N.D.
20:2	0.48	N.D.	N.D.	N.D.	N.D.	N.D.
20:3	N.D.	0.83	N.D.	N.D.	N.D.	N.D.
20:4	N.D.	0.23	N.D.	N.D.	2.74	N.D.
20:5	N.D.	0.46	N.D.	N.D.	14.31	N.D.
SFA	41.74	28.86	23.71	18.17	30.96	20.76
MUFA	14.62	18.82	23.88	5.75	40.07	22.14
PUFA	37.35	33.09	30.78	57.39	19.13	42.46

Dual potential of microalgae as a sustainable biofuel feedstock and animal feed
•December 2013
•Journal of Animal Science and Biotechnology 4(1):53



Source	Crude protein	Carbohydrates	Lipids
Soybean	37	30	20
Corn	10	85	4
Wheat	14	84	2
Anabaena cylindrical	43-56	25-30	4-7
Arthrospira maxima	60-71	13-16	6-7
Chlorella vulgaris	51-58	12-17	14-22
Spirogyra sp.	6-20	33-64	11-21
Synechococcus sp.	73	15	11

[a]Adapted from [11,44-46].

Nannochloropsis oculata

For example, the omega-3 rich microalgae *Nannochloropsis oculata*, or simply Nanno, is a promising potential source of high-nutrient food and feed.

It is 40 percent protein by dry weight, of which one-third contains essential amino acids, and 6 percent EPA omega-3 essential fatty acid in a highly bioavailable form.


Only a handful of algal species are used commercially now, but hundreds of strains have the potential to become food and feed sources.
Microalgae are currently used as a food ingredient, a food supplement and as aquafeed for fish.
Algae in animal feed and its environmental impact.
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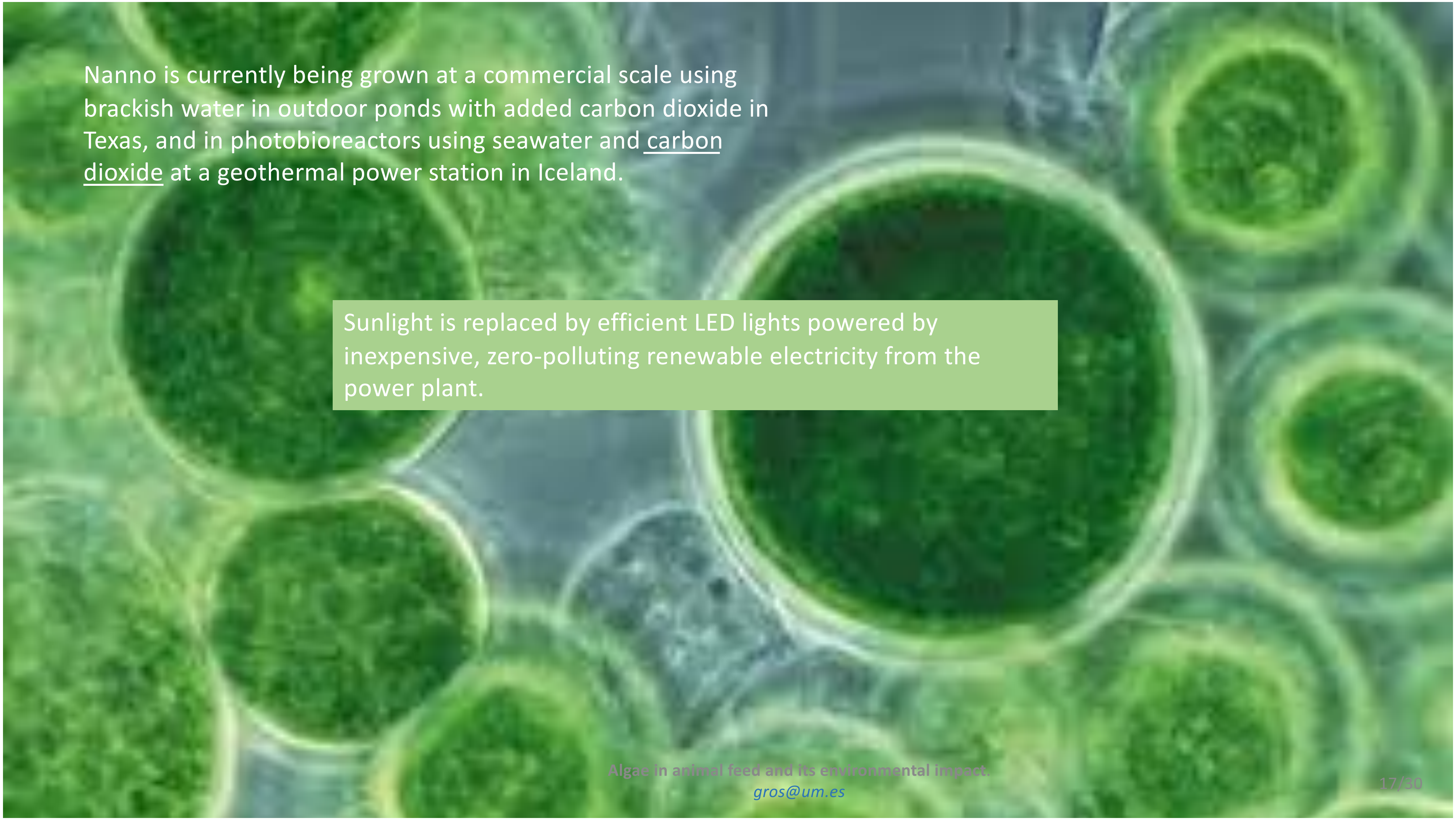
Producing Nanno

Microalgae are commercially cultivated using several methods that have a range of sustainability footprints.

- The first is an aerobically fermented system, where cultivation is performed in dark, mixing vessels using sugar as the main energy source for the algae.
- Algae may also be cultivated in open ponds, using either fresh- or saltwater, carbon dioxide and sunlight.
- Alternatively, they may be grown in brackish water or seawater in closed, transparent tubes called photobioreactors.


Nanno is currently being grown at a commercial scale using brackish water in outdoor ponds with added carbon dioxide in Texas, and in photobioreactors using seawater and carbon dioxide at a geothermal power station in Iceland.
Sunlight is replaced by efficient LED lights powered by inexpensive, zero-polluting renewable electricity from the power plant.
Algae in animal feed and its environmental impact.
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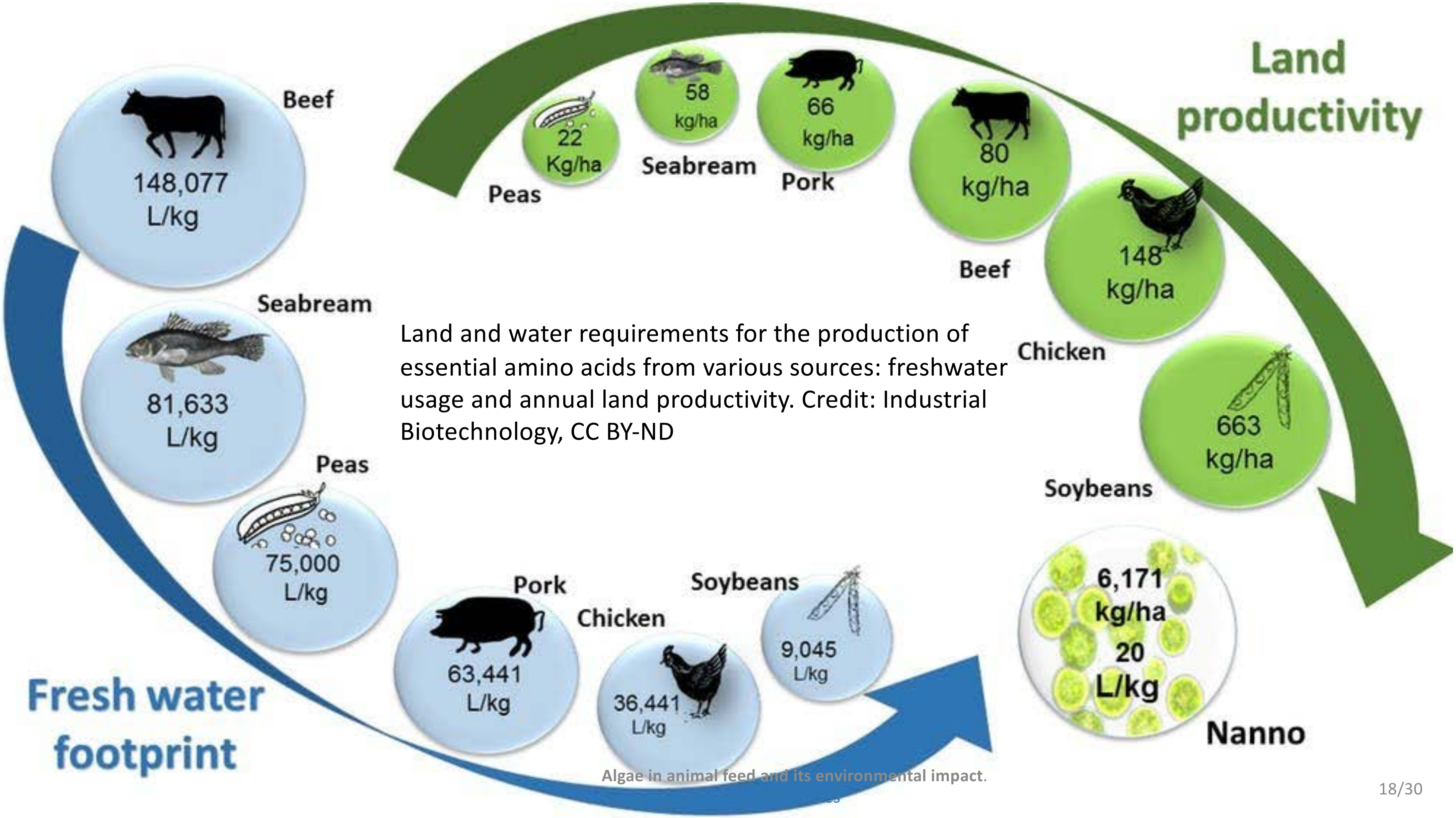
17/30



Land and water requirements for the production of essential amino acids from various sources: freshwater usage and annual land productivity. Credit: Industrial Biotechnology, CC BY-ND

- *Some experiences with algae in animal feed and its environmental impact*

Ascophyllum nodosum

2007

2003-4

"Differentiation in sensory quality of pig meat fed with prebiotic algae and effect on the intestinal flora of the pig"

ENTRADA ANIMALES CONTROL
n=377
x̄: 30 Kg

17/09/03 — ***24/09/03*** — ***23/10/03*** — ***24/11/03*** — ***22/12/03***

- 24/09/03: Recogida de muestras: SANGRE
- 23/10/03: Recogida de muestras: HECES 50gr
- 24/11/03: Recogida de muestras: SANGRE HECES 50gr
- 22/12/03: Recogida de muestras: SANGRE HECES 50gr

75 días

200gr prebiótico suplement/Ton

Sacrifício 17/12/03
Para Análisis Sensorial y Fisicoquímico
n: 115

ENTRADA ANIMALES TRATADOS
n=392
x̄: 33.18 Kg

- 15/10/03: Recogida de muestras: SANGRE
- 23/10/03: Recogida de muestras: HECES 50gr
- 24/11/03: Recogida de muestras: SANGRE HECES 50gr
- 22/12/03: Recogida de muestras: SANGRE HECES 50gr

02/10/03 — ***15/10/03 Dieta Algas Prebióticas*** — ***23/10/03*** — ***24/11/03*** — ***22/12/03***

PESO MEDIO DE LOS ANIMALES	Entrada al estudio	Primera toma de muestras	Segunda toma de muestras	Tercera toma de muestras	Cuarta toma de muestras
Control (macho)	30Kg	34,15Kg	55,61Kg	81Kg	107,23Kg
Control (hembra)	30Kg	30,38Kg	50,3Kg	76,53Kg	90,41Kg
Tratado (macho)	33,18Kg	32,25Kg	45,58Kg	71Kg	96,3Kg
Tratado (hembra)	33,18Kg	35,67Kg	47,69Kg	69Kg	91,92Kg

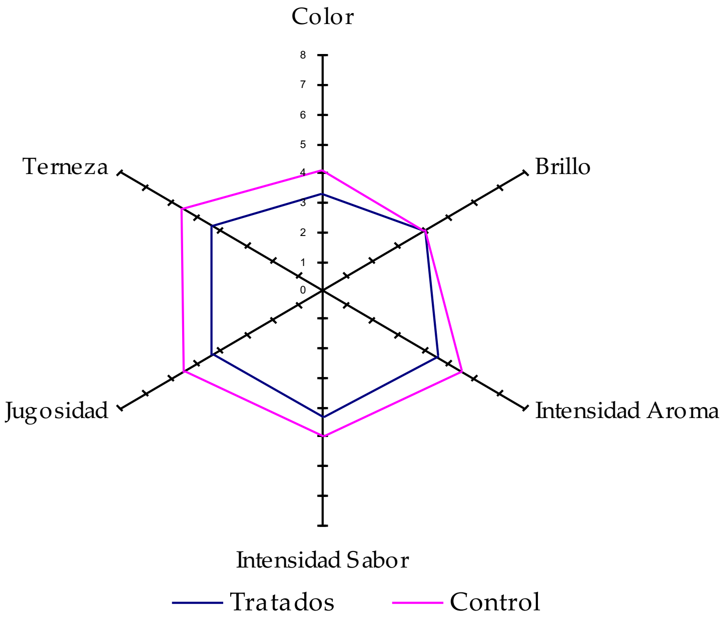
Periodo	Cerdos	Aerobios T.	Anaerobios T.	Enterobacterias
1^{er} Periodo	Control	8,59±0,22	8,67±0,32	5,59±0,62
	Prebióticos	8,51±0,24	9,10±0,06	5,60±0,43
	ANOVA	NS	***	NS
2^{do} Periodo	Control	8,36±0,19	8,56±0,21	3,05±1,59
	Prebióticos	8,74±0,40	8,74±0,40	5,64±0,57
	ANOVA	**	NS	***
3^{er} Periodo	Control	8,73±0,34	9,00±0,29	5,83±0,49
	Prebióticos	8,77±0,30	8,94±0,32	6,80±0,48
	ANOVA	NS	NS	***

Bifidobacterias	Lactobacilos
6,78±0,89	7,32±0,28
7,59±0,35	8,12±0,30
**	***
7,06±0,36	6,27±0,81
7,26±0,23	7,23±0,50
NS	**
6,49±0,58	6,40±0,81
7,23±0,43	7,45±0,66
**	**

Clostridios
0,99±1,47
0,44±1,03
NS
2,18±1,68
0,57±0,85
***
2,41±1,26
1,75±1,36
**

"Differentiation in sensory quality of pig meat fed with prebiotic algae and effect on the intestinal flora of the pig"

Sensory under UNE 87-010-93 y 87-017-92 and trained panel (11)



The control sample was defined by the judges as a sample of a reddish colour that is not too bright, with a moderately intense aroma and a mild flavour that presented a mild juiciness and moderate tenderness.

The treated sample was defined by the judges as a less bright reddish colour sample with a slightly intense aroma and slight flavour that presented a slightly dry juiciness and slightly hard tenderness.

- In view of the preliminary results, the use of prebiotic algae in the feeding of the pig farmer seems interesting.
- The effect on the sensory aspect perceived by consumers and on the beneficial microbial flora seems to have been demonstrated.
- New and more extensive research is needed to confirm this data.
- The nutritional study of meat is under development to know the effect on bromatological composition.

University of Minnesota West Central Research and Outreach Center

Lee Johnston, Pedro Urriola, Jerry Shurson, and Milena Saqui-Salces,

West Central Research and Outreach Center

Pork producers are being challenged by downstream market chains and consumers to decrease the carbon, land, and water footprints of their production systems.

One approach to address this rising challenge is to find new or non-traditional feed ingredients for use in swine diets that have a lower environmental footprint.

Because feed is one of the largest contributors to the carbon footprint of pork production, it makes sense to look for alternative feed ingredients that have a lower carbon footprint than traditional ingredients like corn and soybean meal.

Some of these possibilities include novel ingredients like single cell proteins, insect meal, recycled human food wastes, and microalgae to name a few.

Microalgae are single-celled organisms that have been studied for a wide variety of applications in wastewater remediation and production of biofuels, pigments, bio-fertilizers, and livestock feed among others (Figure 1).

These organisms can grow very rapidly by capturing carbon dioxide and sunlight to produce biomass that is rich in nutrients such as carbohydrates, proteins, and fats.

Microalgae can be dried and fed to livestock or it can be processed in biorefineries to extract oil and protein for industrial purposes.

The remaining components (mainly carbohydrate) may be a source of low cost energy in swine diets.
Microalgae carbohydrates have been described as having prebiotic properties with potential health benefits to pigs.

To evaluate this possibility, our group recently determined the effects of feeding a microalgae extract on growth performance of nursery pigs.

This MAE represented the portion that remained after partial extraction of fat by mechanical methods

MAE in diets fed to pigs

Nursery phase

Beginning at weaning (21 days of age)

Diets in each nursery phase

6 weeks post-weaning.

MAE was included in diets as a partial replacement for corn.

- Phase 1 = 1 to 14 days

  lactose (20%),
  soy protein concentrate (15%),
  dried whey (5.5%) and
  fish meal (5%) in addition to
  corn and soybean meal.

- Phase 2 = 15 to 28 days

  these same high quality ingredients but at lower concentrations.

- Phase 3 = 29 to 42 days

Low dietary levels of MAE (1 and 5%)

- *included to evaluate possible **prebiotic effects** of microalgae in the gut of weaned pigs.*

High dietary levels of MAE (10 and 20%)

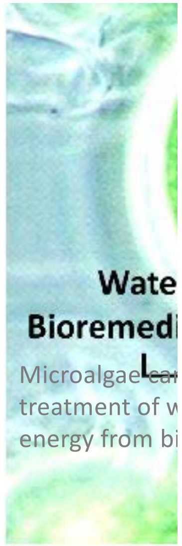
- *included to evaluate the utility of MAE as a significant **source of energy and nutrients** in nursery diets.*

Table 1. Effect of dietary microalgae extract (MAE) concentration on nursery pig performance and health*

	MAE concentration				
Trait	0%	1%	5%	10%	20%
Pig body weight, lbs					
Day 7	15.4	16.0	15.8	15.9	15.5
Day 42	57.9	60.8	60.5	61.2	58.5
ADG, lbs					
Day 1-7	0.20	0.27	0.25	0.26	0.21
Day 1-42	1.09	1.17	1.14	1.17	1.10
ADFI, lbs					
Day 1-7	0.26	0.32	0.30	0.31	0.27
Day 1-42	1.61	1.69	1.66	1.67	1.58
Healthy pigs, %**	81.7	93.3	90.0	96.7	93.3

*Adapted from: Urriola, P. E., J. A. Mielke, Q. Mao, Y. T. Hung, J. F. Kurtz, L. J. Johnston, G. C. Shurson, C. Chen, and M. Saqui-Salces. 2018. Evaluation of a partially de-oiled microalgae product in nursery pig diets. Translational Animal Sci. 2:169-183.

**Pigs surviving to day 42 and did not receive individual antibiotic treatments.



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**Pigs surviving to day 42 and did not receive individual antibiotic treatments.

Pigs experienced some coughing and diarrhea during the second week of the experiment, which resulted in the need to treat all pigs with neomycin (22 mg/kg BW) in drinking water for seven days.

18 additional pigs received individual antibiotic injections to combat persistent coughing and gaunt appearance.

Interestingly, the incidence of individual treatments and mortality in pigs fed MAE tended to be less than those fed the control diets that contained no MAE.

These data provide some suggestion that MAE may be useful to improve health and survival of health-challenged pigs.

Effect of dietary microalgae extract (MAE) concentration on nursery pig performance and health*

Trait	MAE concentration 0%	1%	5%	10%	20%
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**Pigs surviving to day 42 and did not receive individual antibiotic treatments.

- Another important observation in this study was that the **flowability of the meal diets** fed in this experiment progressively ***declined as MAE concentration increased.***
- The **poor handling characteristics of the 20% MAE** diet created challenges to ensure that feed flowed through feeders and was readily accessible to pigs.

Growth performance of pigs improved with the addition of MAE to diets.

*Body weights of pigs fed the **1%, 5%, and 10% MAE** diets were 2.6 to 3.3 pounds greater than pigs fed the control diet at the end of the nursery period.*

*Most of this increased body weight was realized during the **first 7 days** of the experiment.*

The increased body weight with low to moderate concentrations of dietary MAE (1 to 10%) was due to improved daily weight gain and increased daily feed intake, which also occurred early in the nursery period.

An interesting finding was that pigs fed the highest level of MAE (20%) performed similar to pigs fed no MAE.

This suggests that moderate dietary concentrations of MAE (1 to 10%) may enhance pig growth performance, but higher dietary levels (up to 20%) will support pig performance similar to corn-soybean meal based diets.

Conclusions

- The extracted microalgae product evaluated in this experiment had adequate energy and digestible nutrient content to support acceptable growth performance and health of nursery pigs.

- In fact, feeding MAE may be beneficial in reducing mortality in health-challenged pigs.

- Furthermore, microalgae have potential to serve as a feed ingredient that can be used to reduce the carbon footprint and improve the environmental sustainability of modern pork production systems.

- However, there are thousands of species of microalgae that respond to growing conditions in multiple ways which affects their nutrient composition and potential use as feed ingredients.

- As a result, additional studies are needed to further evaluate the potential use of microalgae species and microalgae co-products in swine diets.

Muestras:

- Ejemplares de dorada (*Sparus aurata*) de acuicultura cultivadas en el Instituto Oceanográfico de Mazarrón (Murcia).

- Dividimos en tres grupos con diferente tratamiento

Pienso base

Grupo control

+ 2% alginato   + 5% alginato

- NUTRITIONAL AND SENSORY QUALITY OF YOUR MEAT
  - *The addition of alginate to the gilthead sea bream (Sparus aurata) of aquaculture in doses of* ***2% or 5%*** *does NOT imply a significant modification.*
  - *Exception* ***a slight increase in fat concentration*** *in specimens with* ***5% alginate****, which does* ***not*** *translate into differences in the fatty acid profile.*
- PREBIOTIC EFFECT
  - *The alginate added in the study doses It is not enough to modify the gilthead gilt microbiota (Sparus aurata) on its own so that it can be considered to produce a prebiotic effect.*
  - *Despite its use with a prebiotic such as bacteria of the genus Lactobacillus, it can be an alternative of great interest in this species.*

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Sodium alginate as feed additive in cultured sea bream (*Sparus aurata*): Does it modify the quality of the flesh?

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A R T I C L E I N F O

Article history:

A B S T R A C T

The objective of this study was to evaluate the effect of sodium alginate obtained from brown seaweed as

Conclusions

1. Algae are a valuable ingredient for animal feed
2. Algae production not competing with agriculture
3. Possible to valorise side streams in local biorefineries with algae production (as stepping stone in circular economy and biobased)
4. Challenges to address, innovate and improve in cooperation with companies and research

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Thank You!
Any Questions?