Algae Technical Standards for Compositional and Quality Assessment

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AAFCO Proficiency Testing Program Committee Meeting

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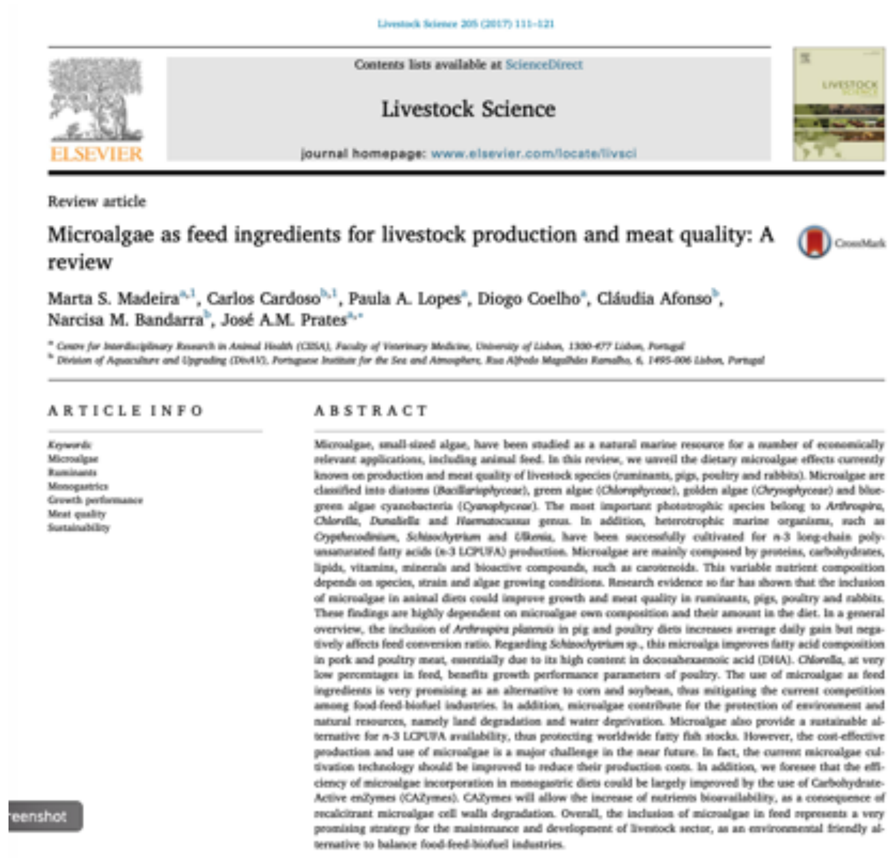
Algae Production for Ingredient Use

- Algae Biomass production for incorporation as food/feed ingredient
- Ingredient characterization for composition, limits on contaminants, and stability
- Route to align on technical metrics around product:
  - Food/feed characterizaiton
  - Nutraceutical
  - Non-edible consumer goods

https://www.algae4feed.org

Algae as Feed Ingredients

- The use, potential and constraints of microalgae in livestock diets is promising
- Inclusion of microalgae in feed could improve animal growth and meat quality.
- Microalgae are very attractive alternatives to staple food crops in feeds.
- Microalgae could help the sustainability of livestock production systems.
- The cost-effective use of microalgae is a major challenge for animal feeding



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Review article

Microalgae as feed ingredients for livestock production and meat quality: A review

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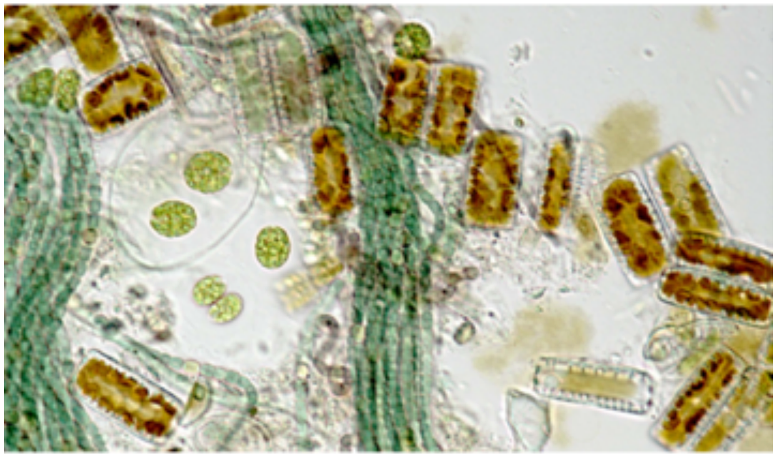
Monogastrics
Growth performance
Meat quality
Sustainability

ABSTRACT

Microalgae, small-sized algae, have been studied as a natural marine resource for a number of economically relevant applications, including animal feed. In this review, we unveil the dietary microalgae effects currently known on production and meat quality of livestock species (ruminants, pigs, poultry and rabbits). Microalgae are classified into diatoms (*Bacillariophyceae*), green algae (*Chlorophyceae*), golden algae (*Chrysophyceae*) and blue-green algae cyanobacteria (*Cyanophyceae*). The most important phototrophic species belong to *Arthrospira*, *Chlorella*, *Dunaliella* and *Haematococcus* genus. In addition, heterotrophic marine organisms, such as *Crypthecodinium*, *Schizochytrium* and *Ulkenia*, have been successfully cultivated for *n*-3 long-chain polyunsaturated fatty acids (*n*-3 LCPUFA) production. Microalgae are mainly composed by proteins, carbohydrates, lipids, vitamins, minerals and bioactive compounds, such as carotenoids. This variable nutrient composition depends on species, strain and algae growing conditions. Research evidence so far has shown that the inclusion of microalgae in animal diets could improve growth and meat quality in ruminants, pigs, poultry and rabbits. These findings are highly dependent on microalgae own composition and their amount in the diet. In a general overview, the inclusion of *Arthrospira platensis* in pig and poultry diets increases average daily gain but negatively affects feed conversion ratio. Regarding *Schizochytrium* sp., this microalga improves fatty acid composition in pork and poultry meat, essentially due to its high content in docosahexaenoic acid (DHA). *Chlorella*, at very low percentages in feed, benefits growth performance parameters of poultry. The use of microalgae as feed ingredients is very promising as an alternative to corn and soybean, thus mitigating the current competition among food-feed-biofuel industries. In addition, microalgae contribute for the protection of environment and natural resources, namely land degradation and water deprivation. Microalgae also provide a sustainable alternative for *n*-3 LCPUFA availability, thus protecting worldwide fatty fish stocks. However, the cost-effective production and use of microalgae is a major challenge in the near future. In fact, the current microalgae cultivation technology should be improved to reduce their production costs. In addition, we foresee that the efficiency of microalgae incorporation in monogastric diets could be largely improved by the use of Carbohydrate-Active enZymes (CAZymes). CAZymes will allow the increase of nutrients bioavailability, as a consequence of recalcitrant microalgae cell walls degradation. Overall, the inclusion of microalgae in feed represents a very promising strategy for the maintenance and development of livestock sector, as an environmental friendly alternative to balance food-feed-biofuel industries.

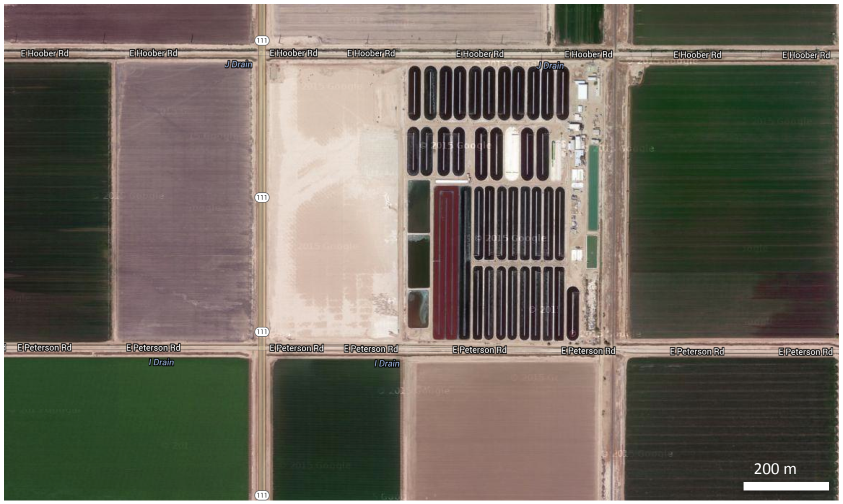
https://www.sciencedirect.com/science/article/pii/S1871141317302858

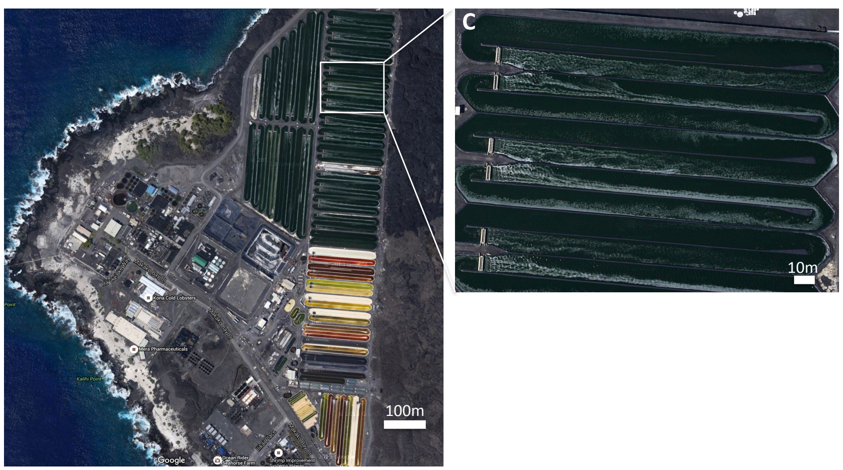
Why Algae?



- Photosynthetic microorganisms capable of accumulating more biomass and lipid compared to terrestrial plants
- Estimated biomass (@25g m^{-2} day^{-1}):
  - 90 T ha^{-1} yr^{-1} | **40 T $acre^{-1}$ yr^{-1}**
- Produced Oil:
  - 18 T ha^{-1} yr^{-1} | **8 T $acre^{-1}$ yr^{-1}** (assuming 20% oil in biomass)
- CO_2 accumulation potential of 180 T ha^{-1} yr (> 80 T $acre^{-1}$ yr^{-1})

Algae Farming –
New Frontier of Agriculture





US algae Farms currently in operation 20-100 acres (HI, TX, NM, CA, …)

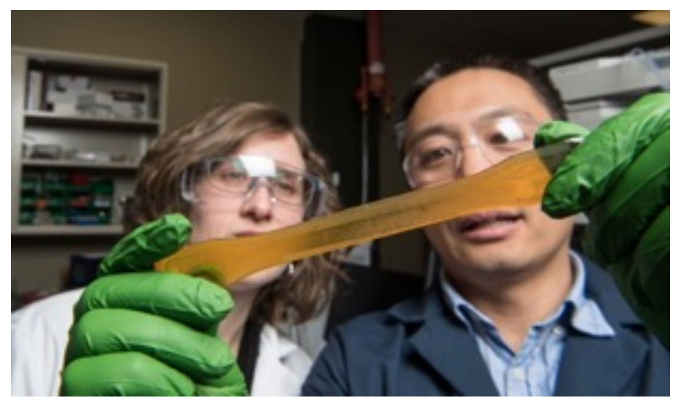
Imperial, Texas, 360 acre farm, 45 acres in production

QUALITAS HEALTH

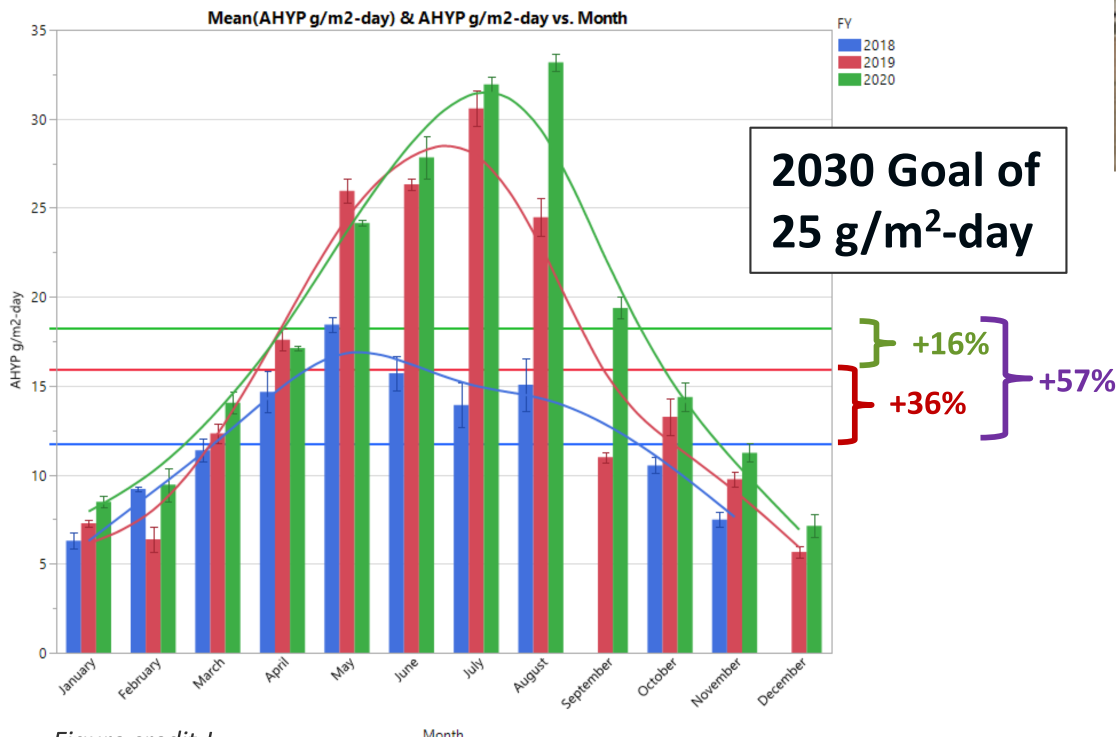
Columbus, New Mexico, 900 acre farm, 98 acres in production

Algae Opportunities For Market Impact

- **Water treatment** and nutrient recovery (Clearas, Gross-Wen Technology)
- Biomass incorporation as **feed/food ingredient**
- **Biopolymer** introduction and licensing to Patagonia, Algix, Honda, …
- **Strain engineering** for biomass productivity, carbon capture and compositional improvements (ExxonMobil)
- Real-time **spectroscopic monitoring** of crop quality (Global Algae Innovations)
- **Carbon capture** technology demonstration (New Belgium Brewery, Qualitas)

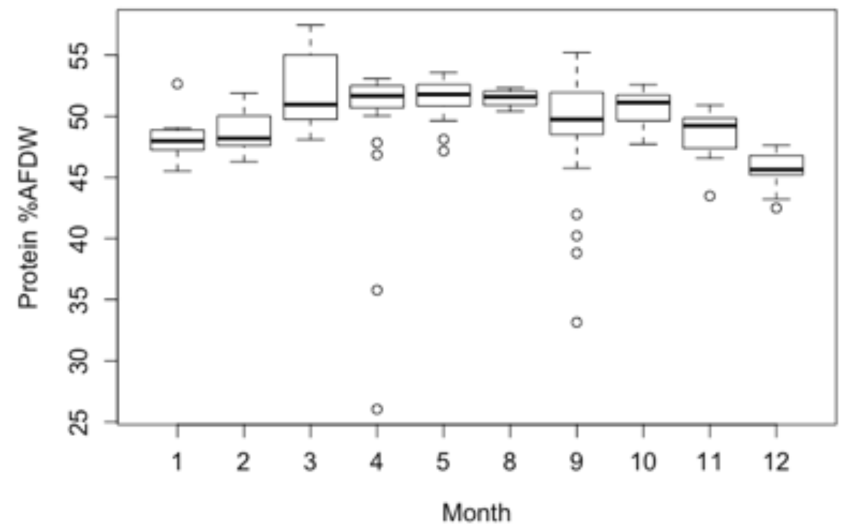


Direct outdoor production demonstration at testbed scale



2030 Goal of 25 g/m^2-day

Figure credit J. McGowen



DISCOVR

Algae Technical Standards Background

- Mission: “*Provide a common language for information to flow to industrial stakeholders to aid with commercialization of algal biofuels and bioproducts*”
  - Liaising with standards organizations, government, academic and industrial partners through monthly teleconference meetings (2013-2019)
  - **Document and disseminate industrial consensus around metrics needed to support the commercial adoption of algae-based products**, regulatory process considerations and standards to ensure relevance to state of the art algae technologies

Technical Standards Committee (2013-2019)

- Expanded committee to include expertise from industry, covering food, feed, fuels, cultivation and wastewater expertise
- Disseminated ***Industrial Algae Measurements v. 8.0***, covering state of the art production of algal biomass, products, food, feed and fuels, with ***>170 up-to-date citations***
- Initiate the development of **Voluntary Quality Seal** on algal biomass quality parameters with industry workshop/roundtable discussion to support commercial adoption of algae-products

Industry Survey (2018)

Done surveymonkey.com

Algae Quality Initiative

ABO Tec

The algae indust
strive to produce
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standards. Becau
experiences will
individuals partic
starting a discus
can do to help m
trust and suppor
members of the i
importance place
standards and id
metrics and how
the Technical Sta
develop a produc
ultimately protec

2. Which industry segm
represent? Please selec
apply.

- [ ] Algae production
- [ ] Food ingredients/product
- [ ] Biofeed
- [ ] Nutraceuticals/suppleme
- [ ] Pharmaceuticals
- [ ] Personal care/cosmetics/ products
- [ ] Fertilizers/soil amendme
- [ ] Waste water remediation
- [ ] Education
- [ ] Research
- [ ] Marketing
- [ ] Packaging/ink
- [ ] Purification/extraction
- [ ] Analytical chemistry

4. Check the exis
standards that yc

- [ ] Non-GMO produ
- [ ] GMO certified
- [ ] USDA certified organic
- [ ] ISO 9001:2008
- [ ] FSSC 22000, HACCP
- [ ] FDA GRAS
- [ ] AAFCO or cGMP
- [ ] Kosher
- [ ] Halal
- [ ] GOED
- [ ] Natural Products Association
- [ ] Eurofins Non-GMO verified

Other (please specify)

7. How effectively is each production parameter currently covered by existing regulatory standards?

10. What other algae industry supply chain best practices and regulatory guidance are needed to assure quality and safety for consumers?

8. How effectively is each production parameter currently covered by existing analytical methodology available at commercial contract laboratories?

11. What is the primary benefit you derive or would like to obtain from the ABO's Technical Standards Committee?

9. In your opinion, how important are each of the following production parameters in determining biomass/product quality?

Contaminants during cultivation

- Low importance
-
- Medium importance
-
- High importance

Water source used, water treatment prior to cultivation

- Low importance
-

Goals | Outcome of Focus Group

- Gap analysis can indicate Focus Group mission space
- Expand outreach for feedback on algae quality standards, to ***identify route towards metrics for consumer algae commercial product adoption***
- Continue to identify, adapt, generate, and recommend measurements and guidelines that address targeted markets for algal biomass

Outcome:

- Prioritized list of when agreement on standards will most benefit budding industry
- Actionable approach to provide support

Technical Standards Focus Group - March 19, 2020

ThinkTank

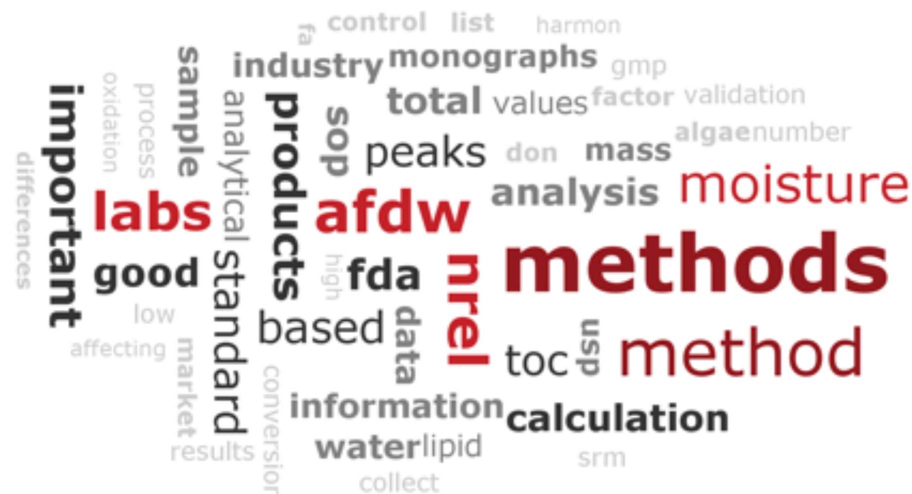
the platform for collective intelligence

Lauren Illing, BCS
Leslie Ovard, INL

Fully online workshop discussion to aid with gap analysis of analytical needs to support large-scale commercialization of algae

Industry + Contract Laboratories

- Qualitas (Jakob Nalley)
- Corbion (John Carney)
- MicrobioEngineering
- Algae4all (Amha Belay)
- Harmon Consulting (Valerie Harmon)
- Eurofins (Lars Reimann)
- Exact Scientific (Kent Oostra)
- ARPA-e (MARINER) (Marc von Keitz, David Lee)
- BETO (Devinn Lambert, Liz Burrows)



Outcome of Focus Group


ELSEVIER

Algal Research

Review article

A new algae technical standards focus group: Summarizing and guiding the algae state of the art

Lieve M.L. Laurens

- Support for concerted effort in **reference material** establishment, followed by nation-wide ring-test for characterization
- Successful Gap and Priority Analysis
- Continuation planned with extended participation and plan towards guidance document (monograph)

Gap and Priority Analysis
Biomass composition, elemental composition, energy content
Identification methodology, contamination tracking and genetic analysis
Safety, toxins (e.g. mycotoxins), heavy metals
Labeling/reporting requirements

https://www.sciencedirect.com/science/article/pii/S2211926420310092

Compositional Analysis State-of-the-Art

Identify

- Research what commercial testing is available, what methods are used, and what is specifically advertised as appropriate for algae?

Characterize

- Send NREL's *Nannochloropsis* and *Scenedesmus* NREL SRMs to multiple labs for testing

Compare

- Match up the NREL in house data on the SRM to the commercial lab data and identify gaps

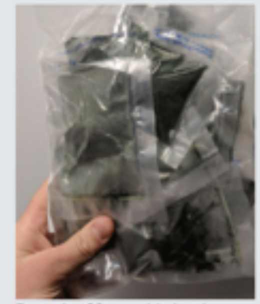
Sample Reference Biomass Materials Available

A sample of a reference biomass material is available upon request for collaborating groups aiming to align data between different procedures or fine-tuning the implementation of the microalgae compositional analysis methods.

Two species of algae—*Nannochloropsis* and *Scenedesmus*—were harvested at the Arizona Center for Algae Technology and Innovation at Arizona State University resulting in biomass that was freeze-dried, certified by our team of analytical chemists, and vacuum-packaged for distribution.

Request a sample (as long as supplies last).

CONTACT US



Example of freeze-dried and vacuum sealed packages of algae biomass. *Photo by NREL*

https://www.nrel.gov/bioenergy/microalgae-analysis.html

Available Commercial Testing

- Most readily available commercial testing was nutritional proximate testing by the AOAC
- This testing is already being used by some algae industry members (as the ABO survey suggested) and is well established in commercial labs
- This led us to concentrate on AOAC methods

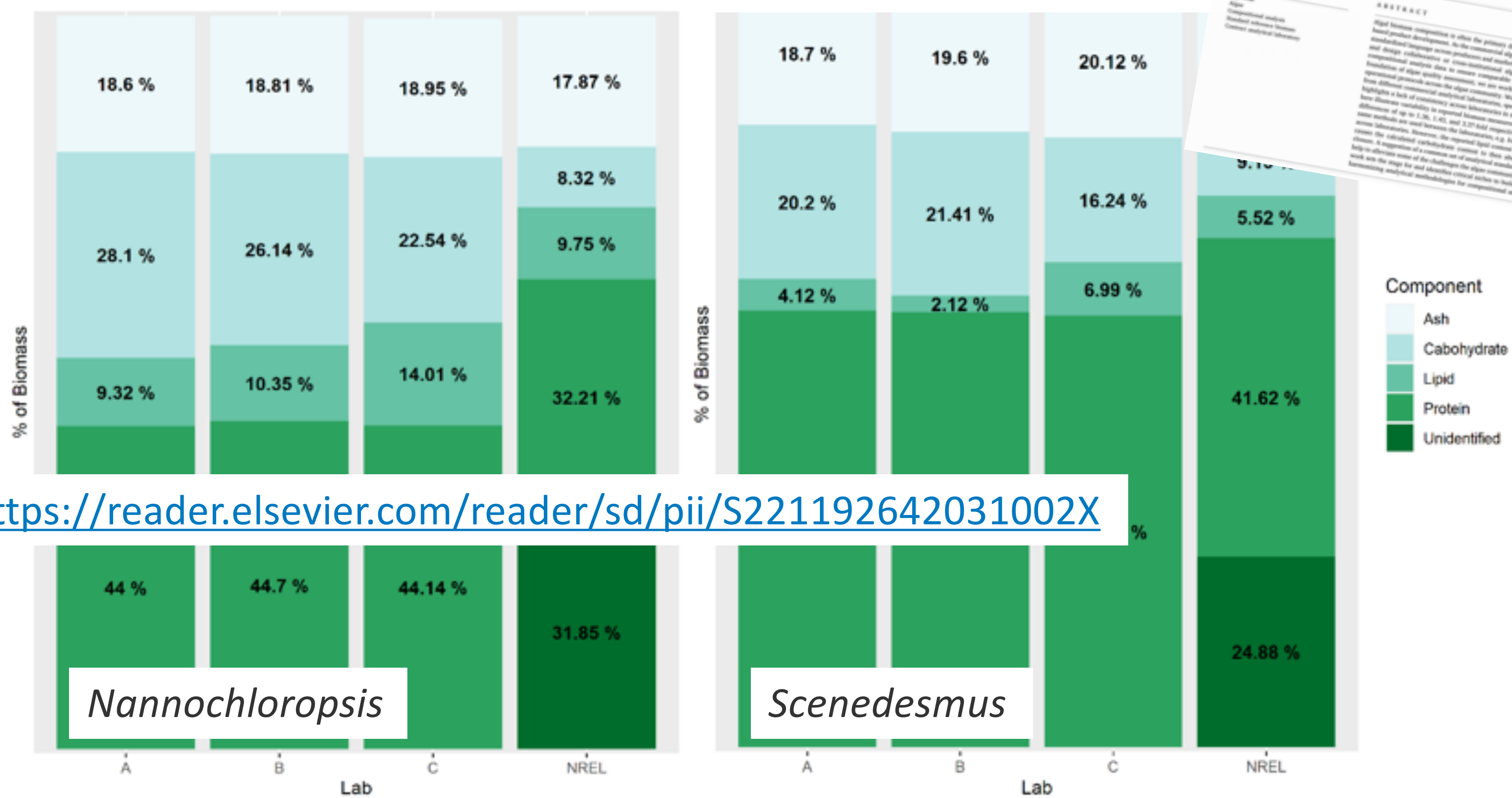
Compositional Analysis Commercial Laboratory Comparison

Analysis (Biomass Characteristics)	Contract Laboratory option
Moisture*	AOAC **934.06** or **AOAC 990.20**
Fiber	AOAC **991.43**
Ash*	AOAC **923.03**, AOAC 942.05, AOAC **945.46**
Protein	AOAC **992.15** (includes nitrogen)
Carbohydrates (CFR 21 carb= weight – (protein +Fat + moisture + Ash)	**Difference analysis** AOAC **986.25**
Fat (total lipids)*	AOAC **996.06**, AOAC 960.39, AOAC 920.39, AOAC **922.06**, AOAC **932.06**
Fatty acids*	ISO 15304M, AOAC 996.06
Chlorophyll*	AOAC **942.04**
Total phosphorus	on AOAC **985.01**
Total nitrogen	For protein analysis AOAC **992.15**, ASTM D4629

Interlaboratory Comparisons

Component	Lab A	Lab B	Lab C
Ash	AOAC 923.03 (550 ºC combustion in furnace)	AOAC 923.03	AOAC 945.46
Carbohydrates	CFR 21 calculated	Not provided	AOAC 986.25 calculated
Lipid	AOAC 996.06/954.02 (FAME by GC/ether extraction after HCl)	AOAC 996.06/954.02	AOAC 932.06 (ether extraction after NH4OH pretreatment)
Protein	AOAC 992.15 (N x 6.25)	AOAC 992.15	AOAC 992.15
Moisture	AOAC 934.06 (6 hr at 70ºC)	AOAC 934.06	AOAC 990.20 (100ºC for 4 hr)

Methodology directly impacts compositional data



https://reader.elsevier.com/reader/sd/pii/S221192642031002X

Conclusions

- Aligning language around technical metrics and standards is critical to support the nascent algae application, e.g. as ingredient in **feed/food applications**
- An industry-led focus group discussion identified three major areas where technical standards are needed:
  - Characterizing algal biomass composition
  - Algae and product identification, detection methods
  - Biomass and product safety
- The group solicits input from the broader algae communities to help guide the future of technical standards

Next Focus Group Discussion Planned for April 2021, *virtual platform TBD*

Madeline Lane
Stefanie Van Wychen
Bonnie Panczak
Hannah Alt
Andy Politis
Steven Rowland
Tao Dong
Kaitlin Lesco

www.nrel.gov
www.nrel.gov/bioenergy/algal-biofuels.html

Lieve.Laurens@nrel.gov
@LieveLaurens
#NRELAlgae

Survey

Done 🔒 surveymonkey.com

Algae Quality Initiative
ABO Technical Standards Survey

The algae industry and all of ABO's member
strive to produce high quality products prod
in compliance with all relevant regulations a
standards. Because negative consumer
experiences will damage the industry and
individuals participating in the field, the ABC
starting a discussion around what the indust
can do to help members maintain consumer
trust and support. This survey is designed tc
members of the industry on the value and
importance placed on product quality, existi
standards and identify gaps in product quali
metrics and how the ABO as an organization
the Technical Standards Committee can hel
develop a producer-member seal of quality t
ultimately protect the consumer.

2. Which industry segment do you represent? Please select those that apply.

- ☐ Algae production
- ☐ Food ingredients/products
- ☐ Biofeed
- ☐ Nutraceuticals/supplements
- ☐ Pharmaceuticals
- ☐ Personal care/cosmetics/specialty products
- ☐ Fertilizers/soil amendment
- ☐ Waste water remediation
- ☐ Education
- ☐ Research
- ☐ Marketing
- ☐ Packaging/ink
- ☐ Purification/extraction
- ☐ Analytical chemistry

4. Check the existing certification standards that your company follows.

- ☐ Non-GMO product verified
- ☐ GMO certified
- ☐ USDA certified organic
- ☐ ISO 9001:2008
- ☐ FSSC 22000, HACCP
- ☐ FDA GRAS
- ☐ AAFCO or cGMP
- ☐ Kosher
- ☐ Halal
- ☐ GOED
- ☐ Natural Products Associatic
- ☐ Eurofins Non-GMO verified

Other (please specify)

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Contaminants during cultivation

- ○ Low importance
- ○
- ○ Medium importance
- ○
- ○ High importance

Water source used, water treatment prior to cultivation

- ○ Low importance

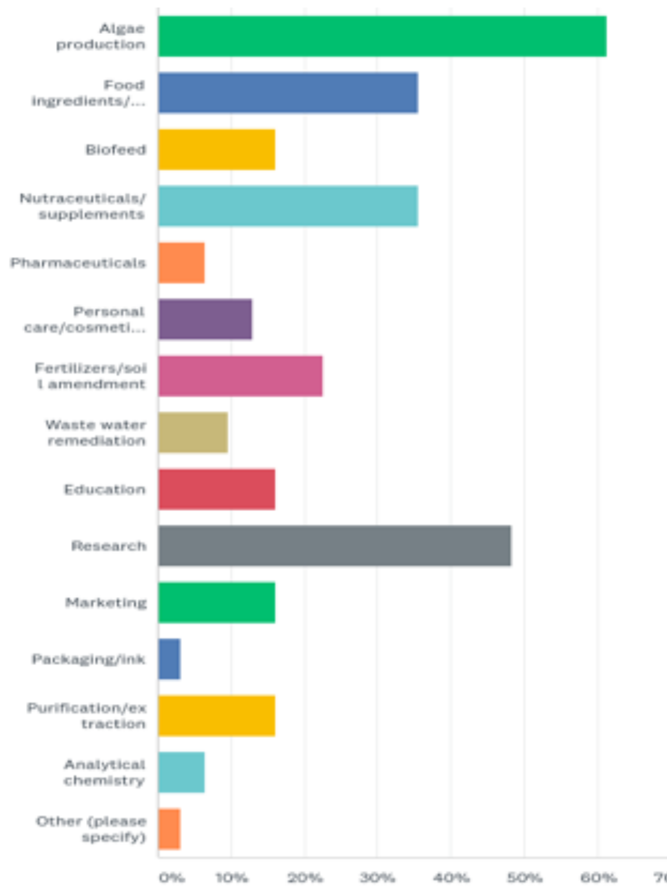
10. What other algae industry supply chain best practices and regulatory guidance are needed to assure quality and safety for consumers?

11. What is the primary benefit you derive or would like to obtain from the ABO's Technical Standards Committee?

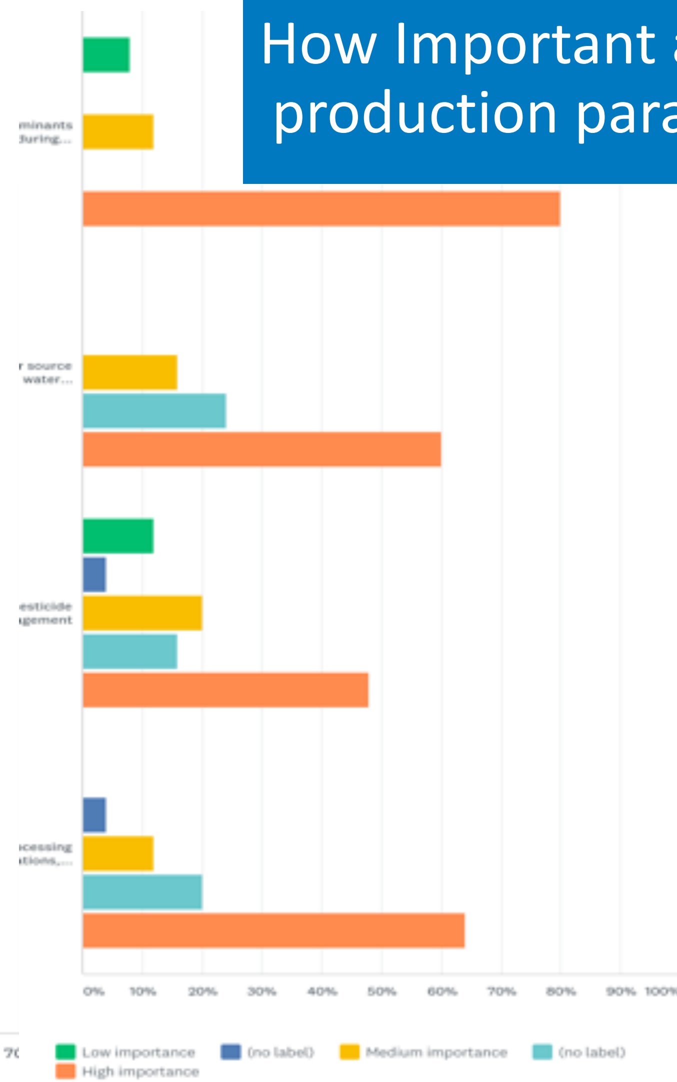
> 35 respondents (late 2018)

Mark Edwards and ABO Technical Standards Committee

Which Industry Segment?



How Important are these production parameters?



How effectively is each production parameter currently covered by existing regulatory standards?

- “Not well”
- “Partner and client specifications are often more strict that regulatory standards, although GOED in particular are becoming more and more aligned with the market”
- ““Poorly. Algae from nutrient reduction in clean wastewater is not specifically addressed in many of the regulations.”
- “Broadly covered. Some companies get away with minimal standards”
- “I'm unsure of any regulations that cover the production method”
- “Most regulators don't understand algae, and policies reflect a cut and paste approach from other products e.g. oysters, salmon, other foods. It significantly frustrates our enterprise. We need policymakers to understand this unique set of materials and products and design regulations that are appropriate- balancing industry growth with quality, environmental and social standards.”
- “Regulatory standards for post processing of algae seem to be straightforward (though it would be good to have ABO standards publish material on best practices), but it is unclear the level of regulatory oversight and safety is needed for production (especially outdoors). How often should ponds/water sources be tested for toxins/bacteria/heavy metals... What should the standards be if you are producing live algae for food/feeds(ie: for broodstocks) versus dried/processed material?”
- “Varies widely from through ISO9000 standards to basically no standards for quality of products such as ASTA levels.”
- “Covered, in terms of how you described it. However improvement required for universal standard”