in-vitality

"Yogurt di spirulina: le proprietà nutrizionali di spirulina ed i benefici dei batteri lattici"

Alberto Niccolai[1], Emer Shannon[2], Nissreen Abu-Ghannam[2], Natascia Biondi[1], Liliana Rodolfi[1,3], Mario R. Tredici[1]

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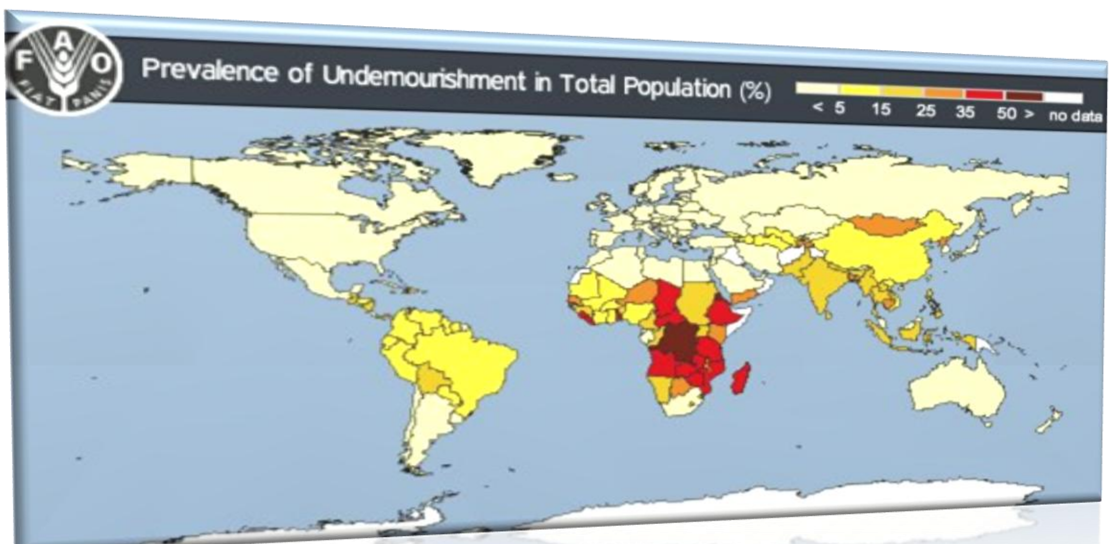
[2] School of Food Science and Environmental Health, Dublin Institute of Technology, Ireland;
[3] FoodMicroTeam S.r.l, Florence, Italy

20th November 2019

SITUAZIONE ATTUALE

795 milioni di persone sono cronicamente sottoalimentate



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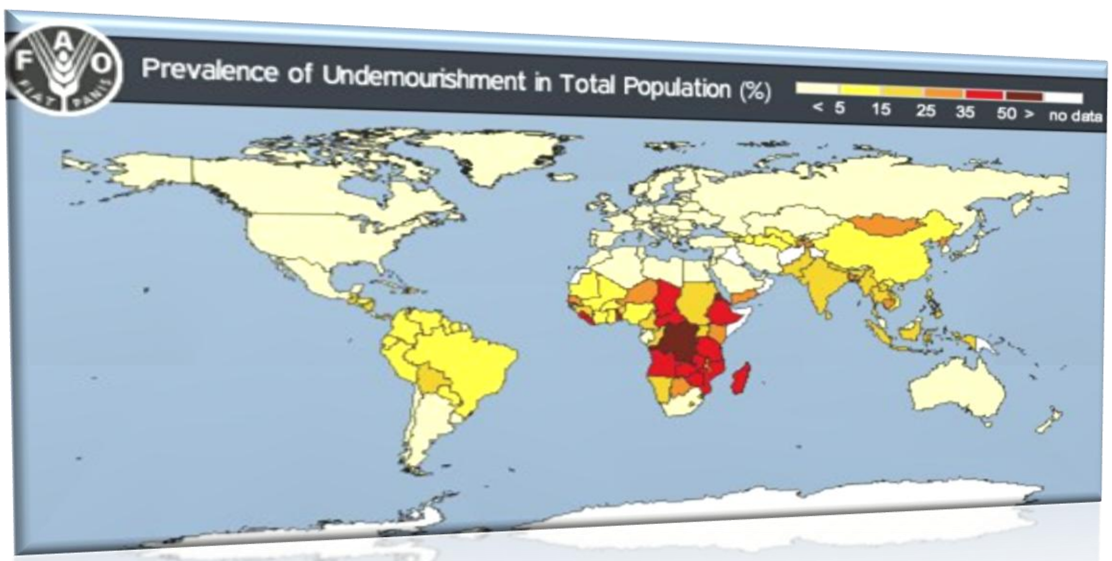
795 milioni di persone sono cronicamente sottoalimentate

9 miliardi di persone che abiteranno la terra nel 2044 consumeranno materie prime come farebbero oggi 13 miliardi di persone



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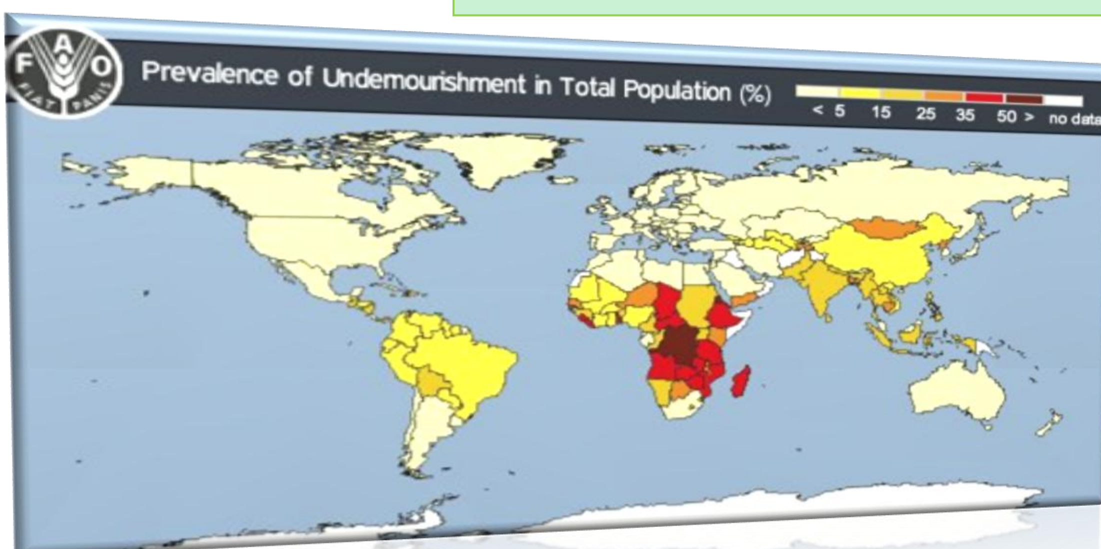
795 milioni di persone sono cronicamente sottoalimentate

9 miliardi di persone che abiteranno la terra nel 2044 consumeranno materie prime come farebbero oggi 13 miliardi di persone

la produzione mondiale di cibo e materie prime dovrebbe aumentare del **110%** nei prossimi 40 anni



I PRINCIPALI OSTACOLI da superare:

Richieste di acqua dolce in crescita da aree urbanizzate e agricoltura

Cambiamento climatico imputabile alla pressione antropica sull'ambiente

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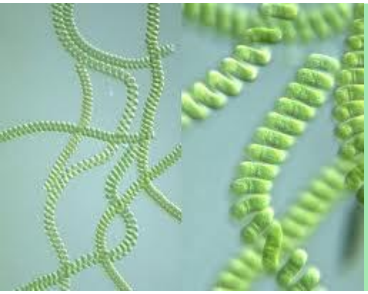
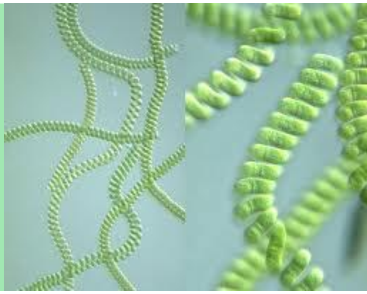
S F I D A

M I C R O A L G H E



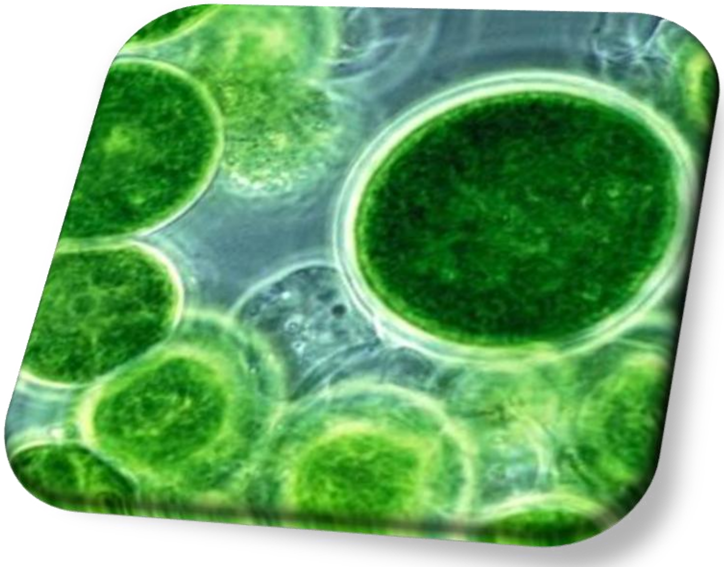
Organismi fototrofi

50% dell'attività fotosintetica sulla terra



COLTURE ALGALI

- **buona produttività**
- **non richiedono terreno fertile**
- **possono crescere su acqua salata**
- **non richiedono erbicidi o pesticidi**
- **sintetizzano co-prodotti di alto valore**



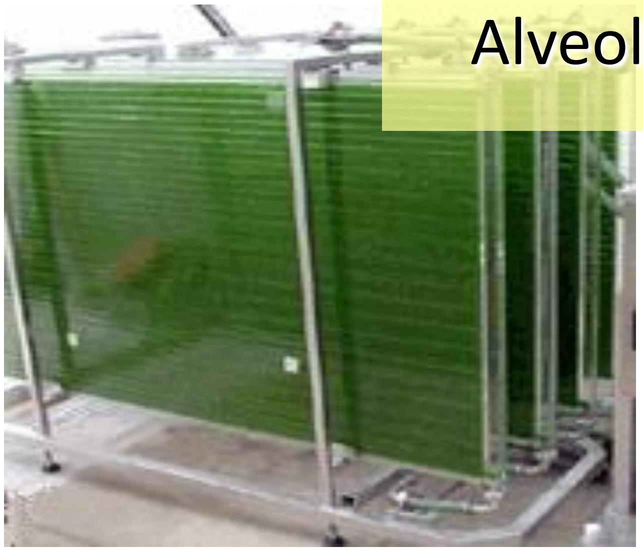
SISTEMI COLTURALI

APERTI

CHIUSI

FOTOBIOREATTORI PIATTI

Alveolari



GWPI

Camera di coltura
usa e getta

In vetro

GWPII

APPLICAZIONI MICROALGALI

Integratori alimentari (capsule e compresse)

APPLICAZIONI MICROALGALI

➡ **Integratori alimentari (capsule e compresse)**

➡ **Alimentazione in acquacoltura per molluschi, gamberi, zooplancton**

Microalga	Anno di approvazione come cibo nell'EU	Applicazioni e prodotti
Arthrospira platensis (spirulina)	Utilizzato prima del maggio 1997	Nutrizione umana e animale, cosmesi
Chlorella luteoviridis	Utilizzato prima del maggio 1997	Nutrizione umana, acquacoltura, cosmesi
Chlorella pyrenoidosa	Utilizzato prima del maggio 1997	Nutrizione umana, acquacoltura, cosmesi
Chlorella vulgaris	Utilizzato prima del maggio 1997	Nutrizione umana, acquacoltura, cosmesi
Aphanizomenon flos-aquae	Utilizzato prima del maggio 1997	Nutrizione umana
Odontella aurita	Approvato nel 2005	Nutrizione umana, cosmesi
Tetraselmis chuii	Approvato nel 2014	Nutrizione umana
Haematococcus pluvialis	Approvato nel 2014	Acquacoltura, astaxantina

APPLICAZIONI MICROALGALI

Il mercato alimentare è dominato da pochi generi microalgali

- ***Arthrospira***
- ***Chlorella***
- ***Dunaliella***
- ***Haematococcus***

Biomasse o estratti incorporati in pasta, biscotti, pane, snack, caramelle, yogurt, gelati, bevande

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Biomasse o estratti incorporati in pasta, biscotti, pane, snack, caramelle, yogurt, gelati, bevande

~ 15.000 t/anno

Prodotto	Specie	Stato
Cibi funzionali e integratori alimentari	***Arthrospira*** **(6000-7000 t)** ***Chlorella*** **(4000-7000 t)** ***Dunaliella*** **(1000-1600 t)** ***Haematococcus*** **(280-350 t)**	**Commerciale** (Raceway ponds, circular ponds, lagoons, PBR)

Microalga	Costo biomassa (€/kg)	Mercato (€ Milioni)
Arthrospira	5-50	120-160
Chlorella	12-40	100-130
Haematococcus	60-100	70-110
Dunaliella	150-340	80-100

APPLICAZIONI MICROALGALI

Quali sono i **componenti cellulari più interessanti e promettenti** per un **futuro sviluppo commerciale di prodotti nutraceutici**, ricchi in **probiotici** a **base di microalghe** e **cianobatteri**?

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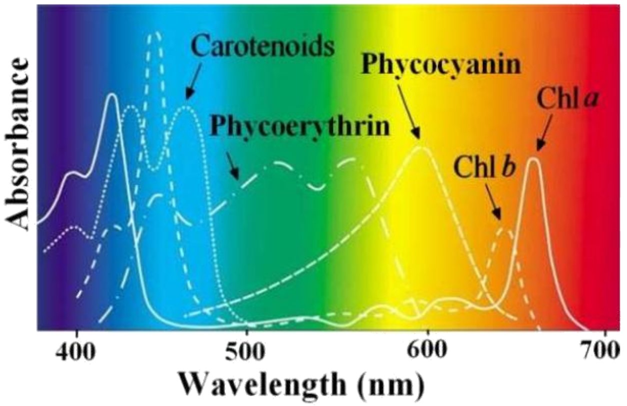
Pigmenti

Acidi grassi

Proteine

APPLICAZIONI MICROALGALI



- ✓ Pigmenti
- Acidi grassi
- Proteine

Colore	Specie microalgali	Tipo di pigmento	Contento pigmento (%)
Rosso	*Haematococcus pluvialis* *Chlorella zofingiensis*	Astaxantina	Fino al 4
Arancio	*Dunaliella salina*	β-carotene	Fino al 12
Giallo	*Chlorella zofingensis* *Scenedesmus almeriensis* *Muriellopsis* sp.	Luteina	0.34 0.45 0.43
Marrone	Diatomee e Haptophyta	Fucoxantina	0.6-1.2
Verde	Maggior parte delle Chlorophyta	Clorofilla	1-3
Blu	*Arthrospira platensis* (spirulina)	C-Ficocianina	10-12

APPLICAZIONI MICROALGALI

Coloranti nell'industria alimentare

Integratori alimentari con funzione antiossidante

Rendere vivo il colore della carne di salmone

Bevande/cibi funzionali a base di ficocianina

APPLICAZIONI MICROALGALI

Pigmenti

✓ Acidi grassi

Proteine

Acidi grassi essenziali → PUFAs

- Omega-3
- Omega-6

EPA e DHA esercitano un'importante effetto sulla salute

APPLICAZIONI MICROALGALI

Pigmenti

✓ Acidi grassi

Proteine

Acidi grassi essenziali → **PUFAs**

Omega-3 | Omega-6

EPA e DHA esercitano un importante effetto sulla salute

Molti studi suggeriscono che EPA e DHA

Ω **Supportano salute cardiovascolare (EPA e DHA)**

Ω **Esercitano effetti antagonisti contro diverse forme di cancro ed anche contro disturbi infiammatori e autoimmuni (EPA)**

Ω **Giocano un ruolo essenziale nello sviluppo di retina e cervello (DHA)**

APPLICAZIONI MICROALGALI

DOSI RACCOMANDATE Nuove linee guida EFSA (EU, 2010)		
PUFA	Popolazione	Quantitativo
DHA+EPA	Adulto generico	250* mg/giorno
DHA	Neonati 6 mesi - Bambini 2 anni età	100 mg/giorno
DHA	Donne durante gravidanza e allattamento	100 mg/giorno

*Più del doppio in pazienti con malattie coronariche

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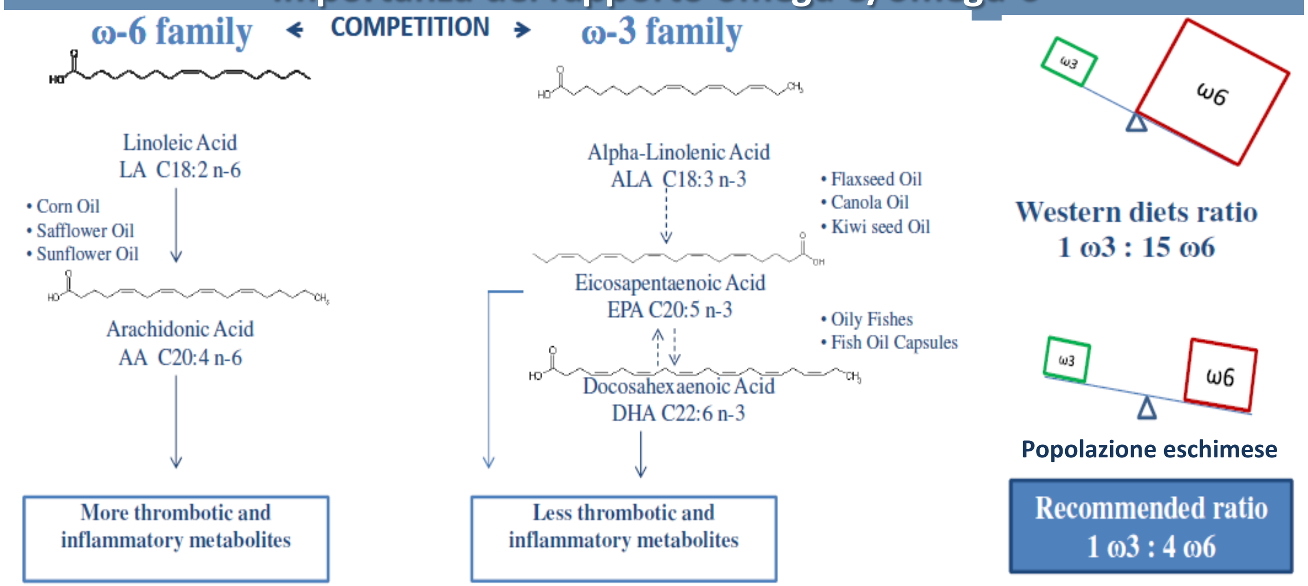
Importanza del rapporto omega-3/omega-6



APPLICAZIONI MICROALGALI

Pigmenti

Acidi grassi

✓Proteine

Arthrospira platensis e *Chlorella vulgaris*

Elevato contenuto proteico → sino al 70% (peso secco)

APPLICAZIONI MICROALGALI

Pigmenti

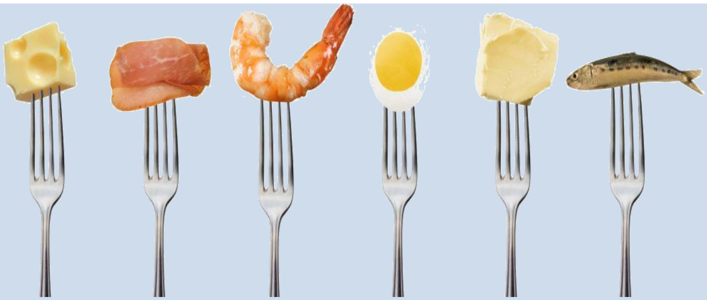
Acidi grassi

✓Proteine

Arthrospira platensis e *Chlorella vulgaris*

Elevato contenuto proteico → sino al 70% (peso secco)

→ Possono rappresentare la **parte proteica della dieta**



→ Buoni **sostituti** per le **proteine** di **origine animale**

APPLICAZIONI MICROALGALI

Dalla quantificazione delle proteine
(analizzatore elementare CHNO)

Assumendo al giorno **5 grammi** di ***Arthrospira platensis* F&M-C256** o ***Chlorella vulgaris* Allma**

la quantità di solito consigliata dalle informazioni nutrizionali per diversi prodotti a base di *Arthrospira* e *Chlorella*
(Website Aurospirul; Website MyProtein; Website Bulk Powders; Website Health Ranger Store)

una persona può arricchire la dieta quotidiana fino a **3,5** o **2,8%** rispettivamente di **proteine non animali**, con ridotto quantitativo di lipidi (rispettivamente solo 0,5 e 0,8%)

Pigmenti

Acidi grassi

✓Proteine

APPLICAZIONI MICROALGALI

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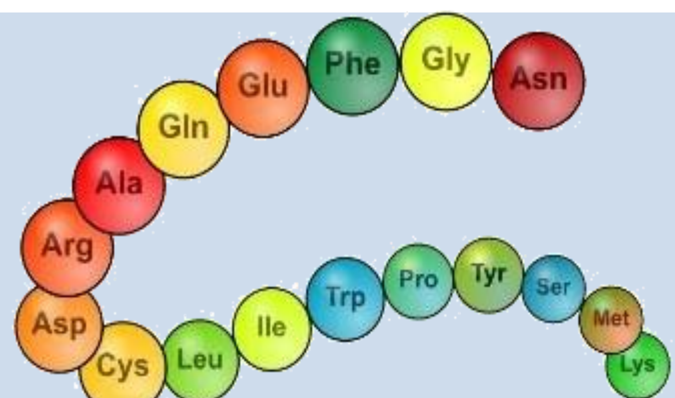
Pigmenti

Acidi grassi

✓Proteine

Le biomasse di *Arthrospira* e *Chlorella* contengono la maggior parte degli **aminoacidi essenziali**



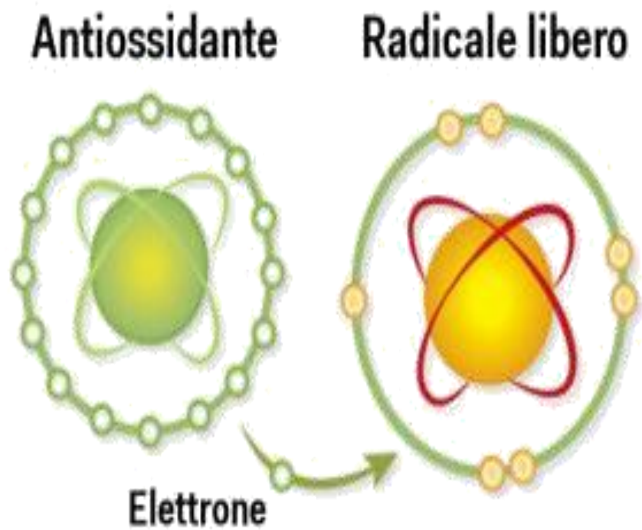
APPLICAZIONI MICROALGALI

Pigmenti

Acidi grassi

✓Proteine

Studi recenti hanno dimostrato le **proprietà antinfiammatorie**, **antiossidanti** e **antitumorali di alcuni peptidi bioattivi** derivanti da **microalghe** con possibili future applicazioni nel campo farmaceutico
(Ovando et al., 2016; Saha et al., 2016)



APPLICAZIONI MICROALGALI

Potenziali clienti sul mercato

3^ età

Sportivi

Bambini

Vegetariani e vegani

Donne in menopausa

Donne in gravidanza ed allattamento

Fare sempre riferimento ad un medico e/o un nutrizionista

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Journal of Applied Phycology (2019) 31:1077–1083
https://doi.org/10.1007/s10811-018-1602-3

CrossMark

Lactic acid fermentation of *Arthrospira platensis* (spirulina) biomass for probiotic-based products

Alberto Niccolai[1] · Emer Shannon[2] · Nissreen Abu-Ghannam[2] · Natascia Biondi[1] · Liliana Rodolfi[1,3] · Mario R. Tredici[1]

Received: 19 July 2018 / Revised and accepted: 8 August 2018 / Published online: 8 September 2018

Abstract

The first objective of this study was to evaluate the use of lyophilised biomass of the cyanobacterium *Arthrospira platensis* F&M-C256 as the sole substrate for lactic acid fermentation by the probiotic bacterium *Lactobacillus plantarum* ATCC 8014. After 48 h of fermentation, the bacterial concentration was 10.6 log CFU mL^{-1} and lactic acid concentration reached 3.7 g L^{-1}. Lyophilised *A. platensis* F&M-C256 biomass was shown to be a suitable substrate for *L. plantarum* ATCC 8014 growth. The second objective of the

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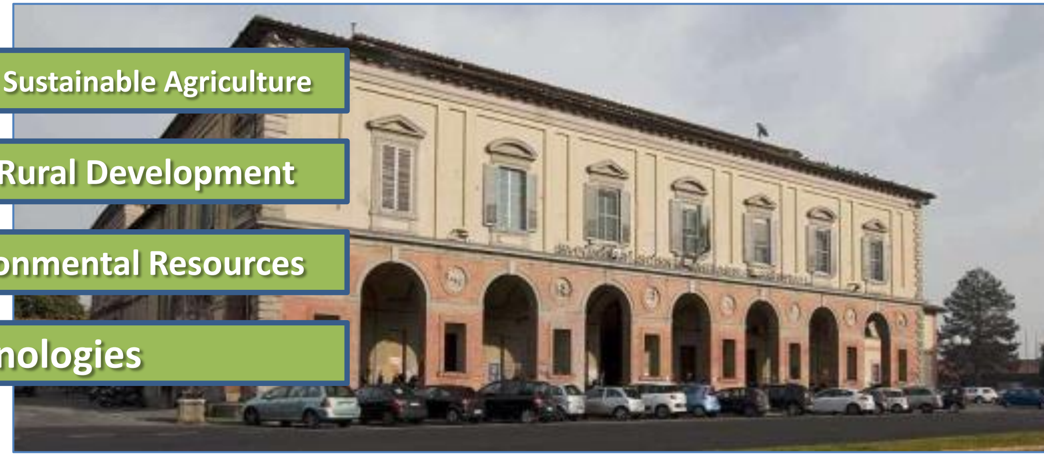

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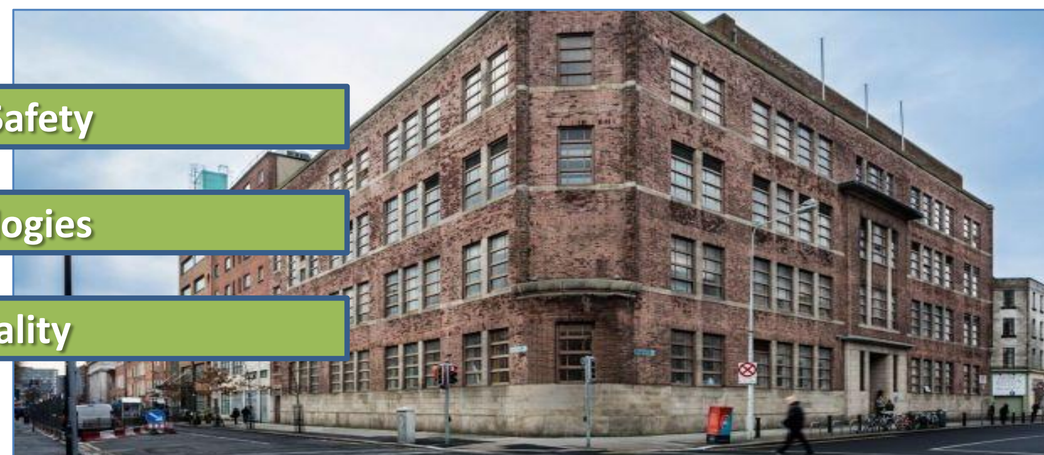
- Water Sciences and Air quality



http://www.dit.ie/

F&M Company

http://www.femonline.it/

Design and realisation of pilot and industrial photobioreactors

Selection of PUFA- and carotenoid-rich microalgae

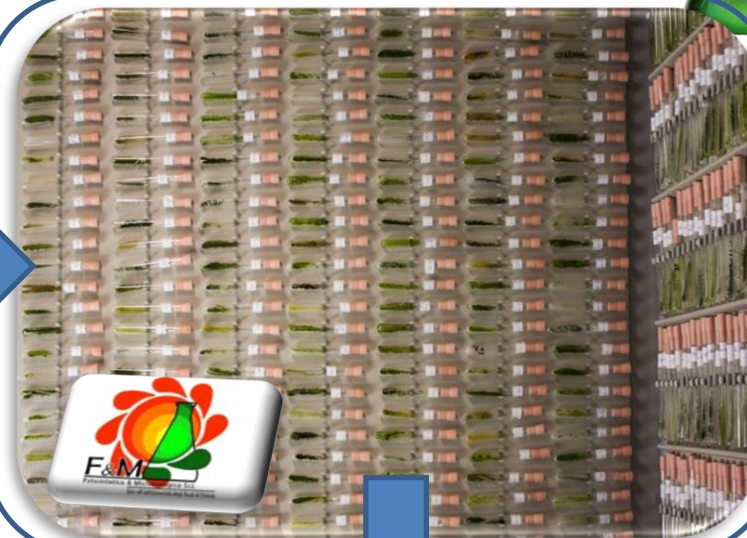
Microalgae and cyanobacteria culture for food/feed/bioactives production

Selection of microalgae as promising feed for fish and mollusks

A. platensis F&M-C256 biomass production

A. platensis F&M-C256 (spirulina)

Does not require EU Novel Food approval (Reg EC 258/97)



Stored -20 °C

Bacterial inoculum preparation

Cruinn

Cruinn Diagnostics Limited

L. plantarum ATCC 8014

Bacterial inoculum preparation

Cruinn Diagnostics Limite

L. plantarum ATCC 8014

1 mL of LAB 8014

25 mL

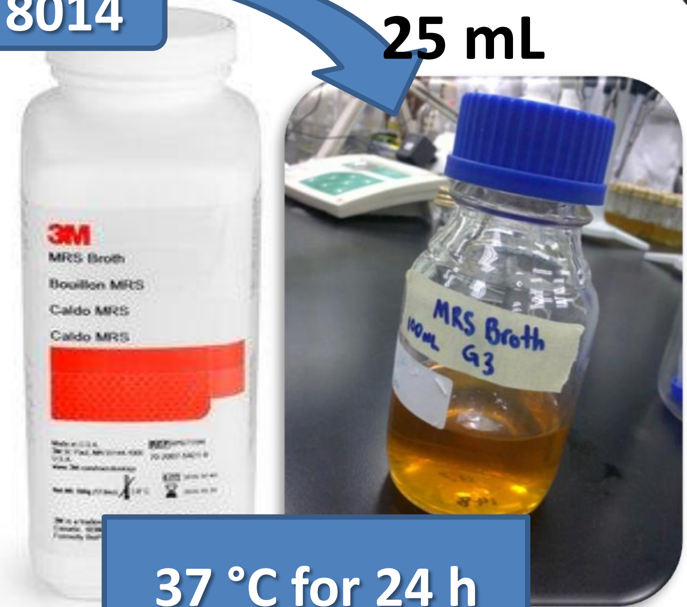
Bacterial inoculum preparation

Cruinn Diagnostics Limited

L. plantarum ATCC 8014

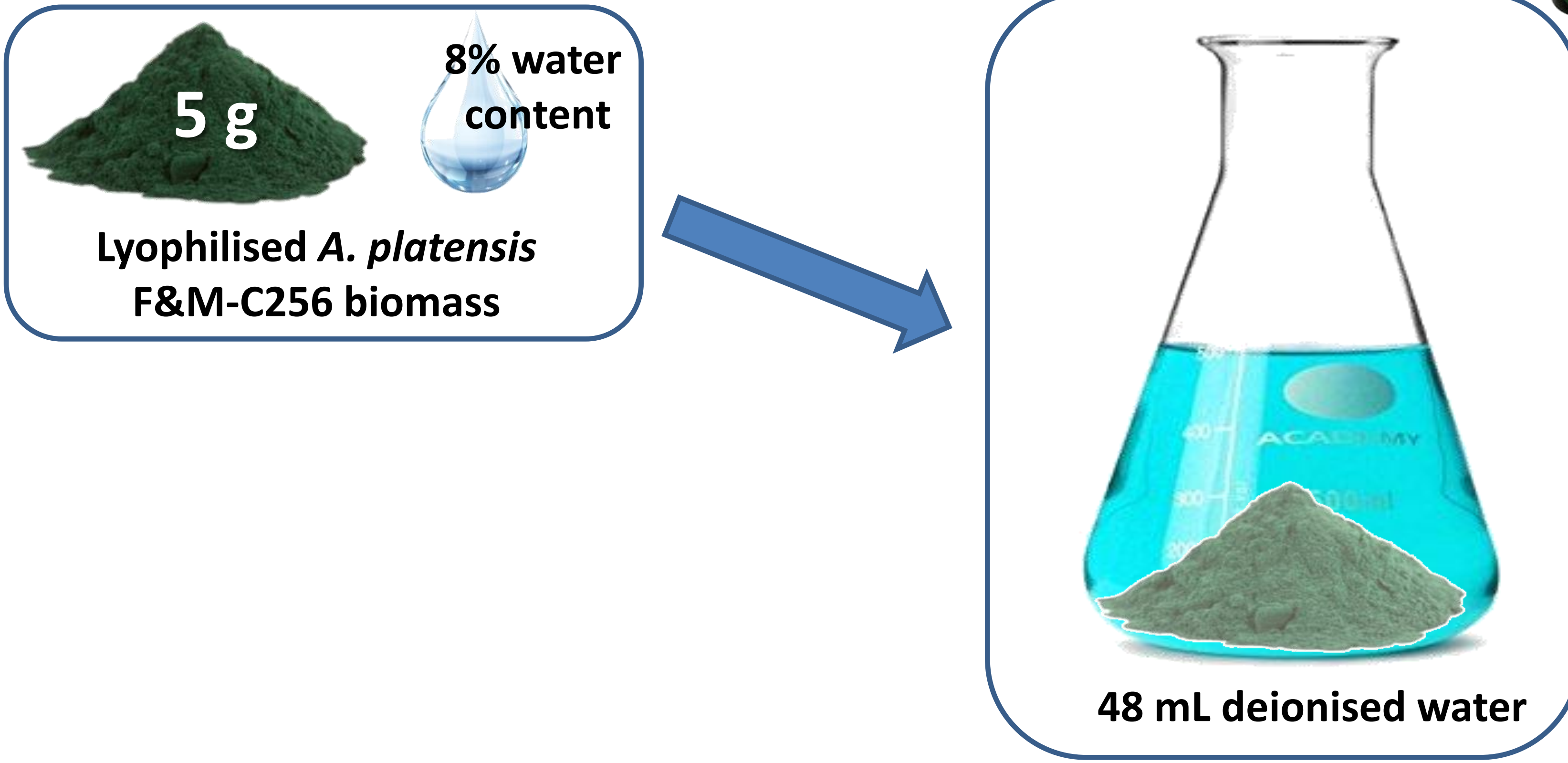
1 mL of LAB 8014

25 mL

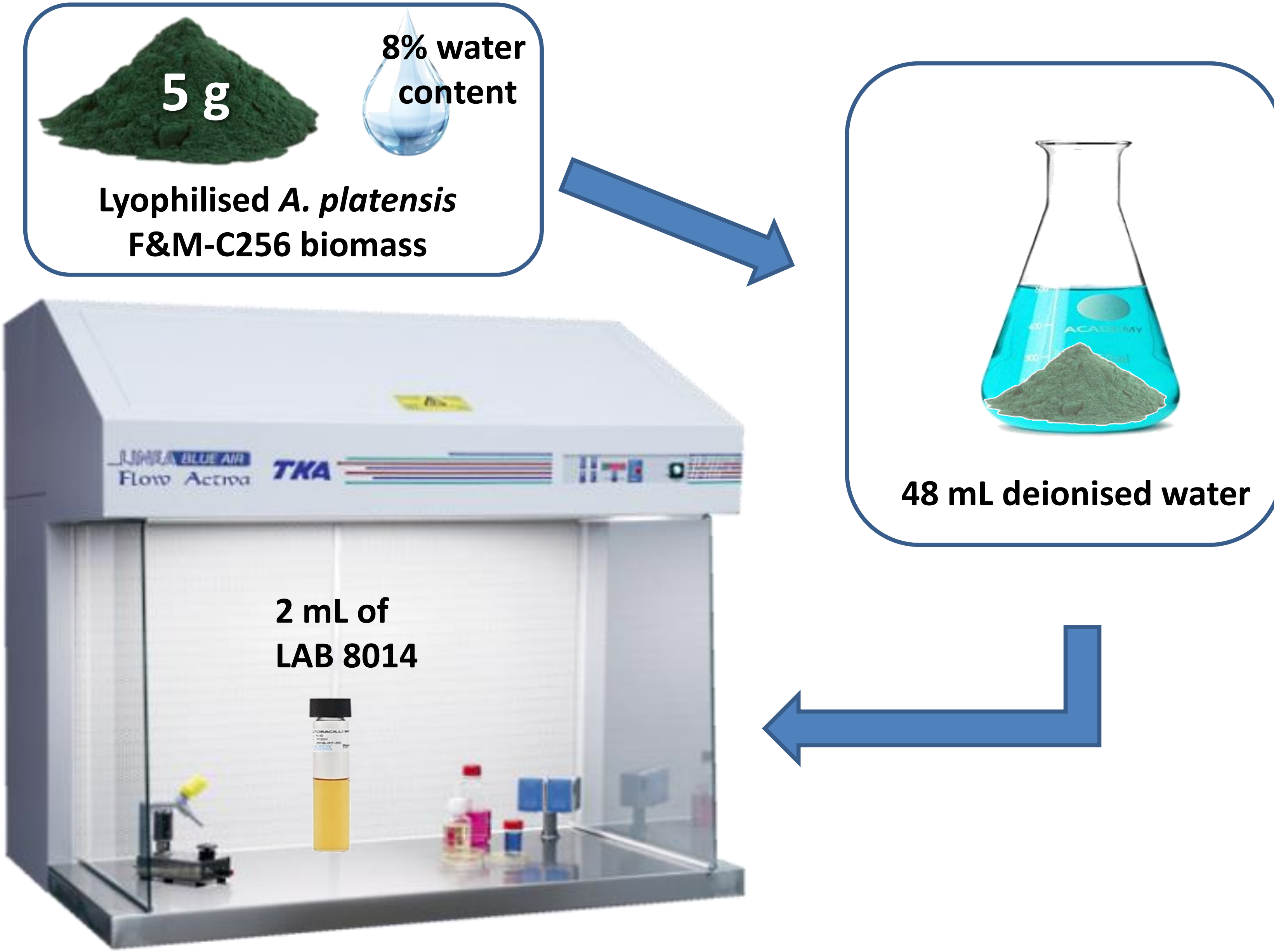


37 °C for 24 h

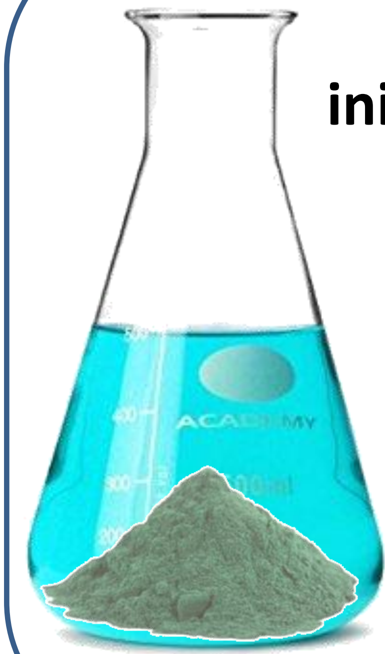
Fermentation



Fermentation



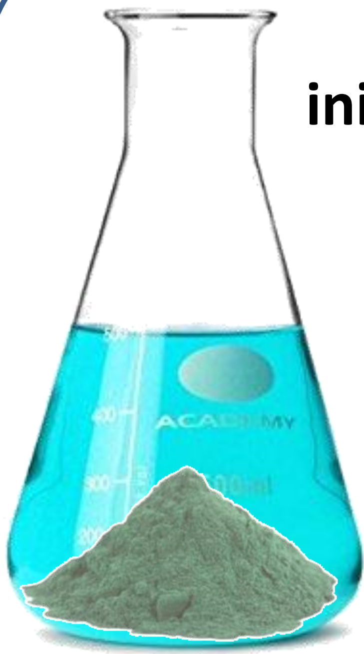
Fermentation



initial *A. platensis* biomass concentration of the inoculated suspension

92 g dry weight L^{-1}

Fermentation



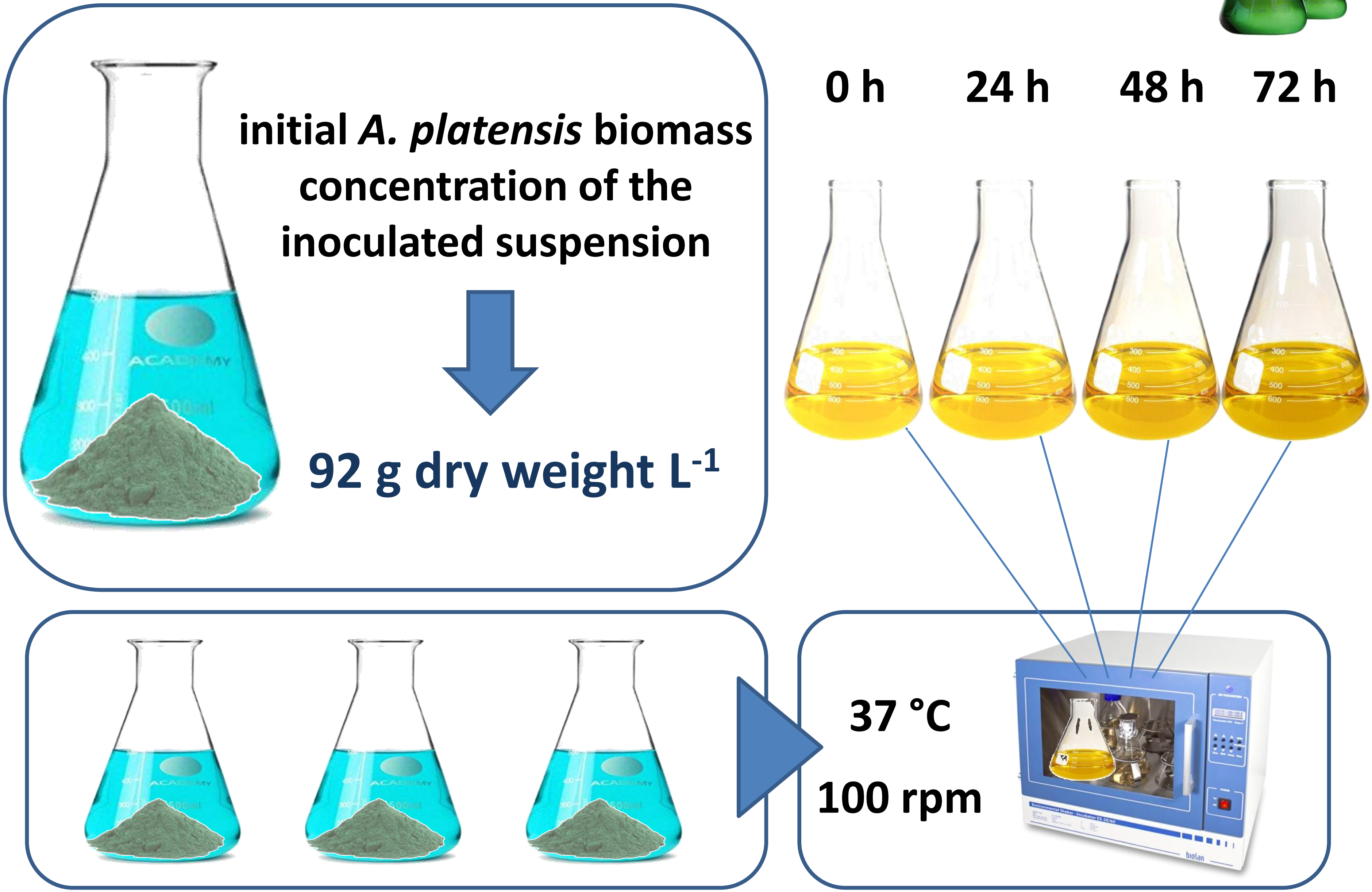
initial *A. platensis* biomass concentration of the inoculated suspension

92 g dry weight L^{-1}

37 °C

100 rpm

Fermentation



Microbiological analyses

0 h

24 h

48 h

72 h

Microbiological analyses

0 h **24 h** **48 h** **72 h**

Microbiological analyses

0 h **24 h** **48 h** **72 h**

Lactic acid determination

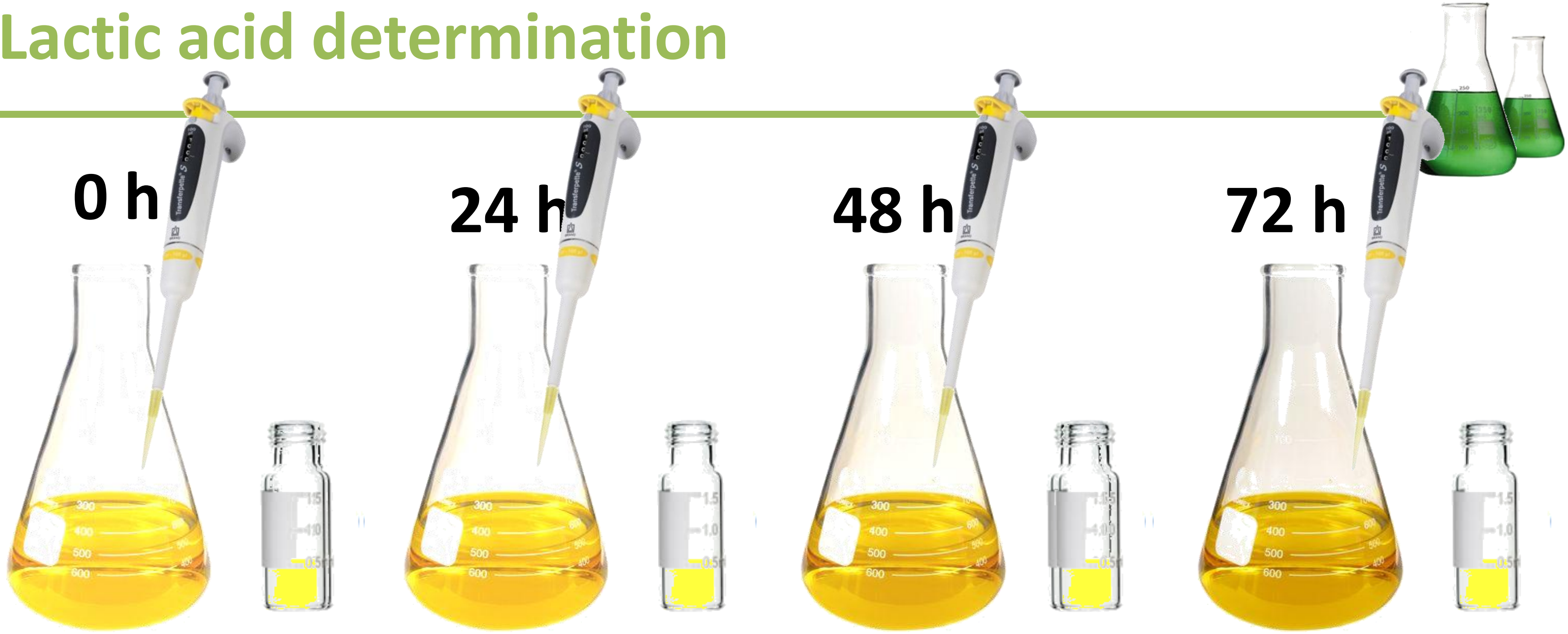
0 h

24 h

48 h

72 h

Lactic acid determination



Lactic acid determination

0 h

24 h

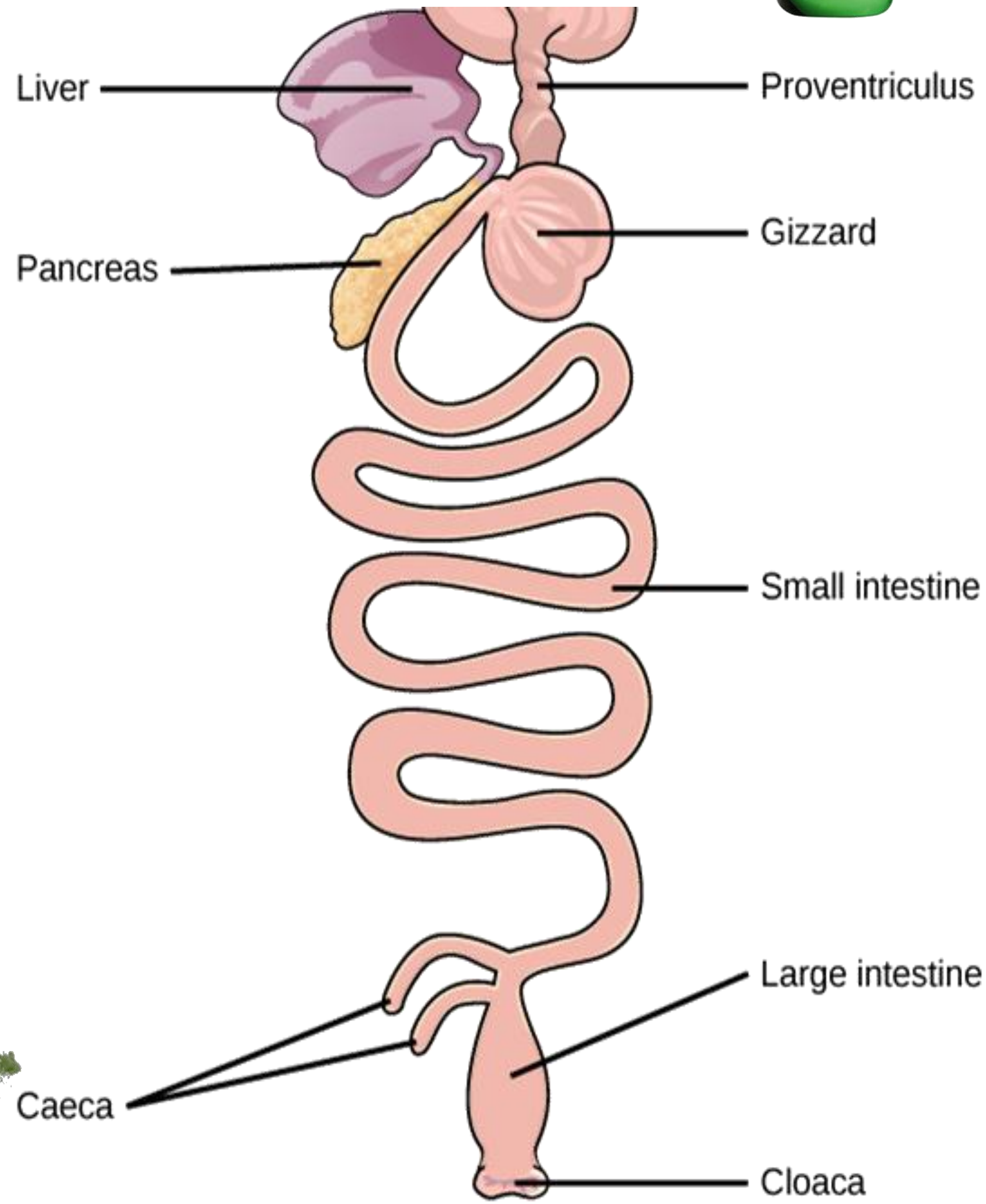
48 h

72 h

In vitro digestibility

0 h **72 h**

Boisen and Fernández (1997) method

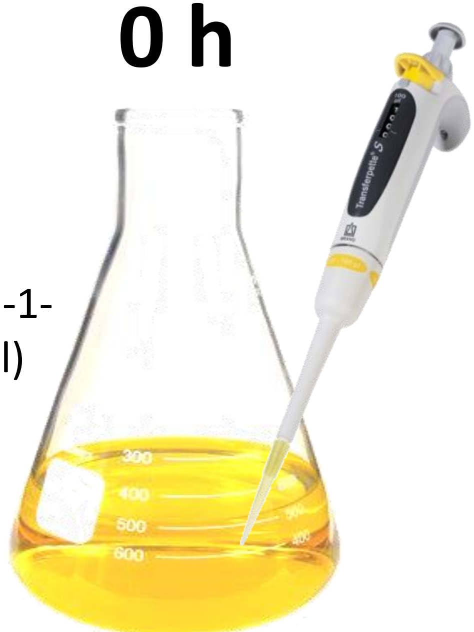


DPPH assay and total phenolic content determination

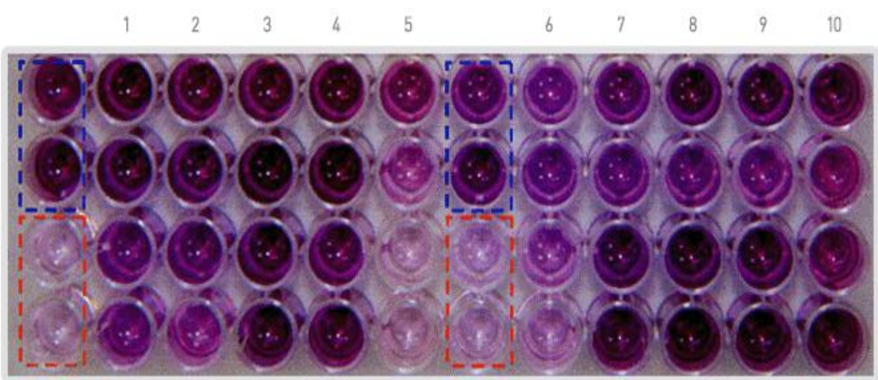
0 h

72 h

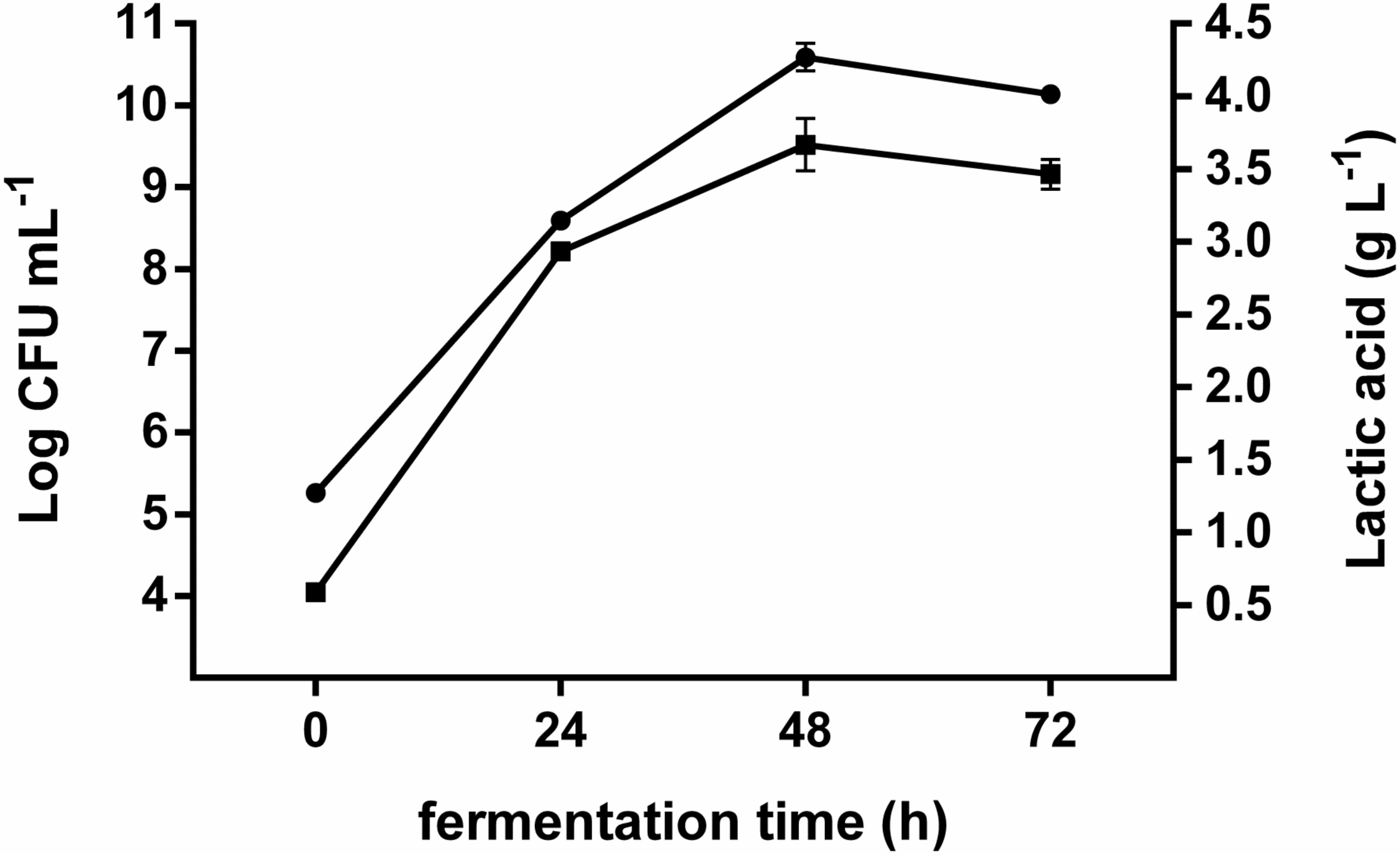
DPPH Assay
(2,2-diphenyl-1-picrylhydrazyl)



Folin-Ciocalteu Assay



Suitability of *A. platensis* biomass for LAB growth and lactic acid fermentation



Growth curve (●) of and lactic acid production (■) by LAB 8014 in a broth containing *A. platensis* F&M-C256 biomass as the sole substrate. The amount of biomass at the start of the experiment (time zero) was 92 g (dry weight) L^{-1}. Values are expressed as means ± SD.

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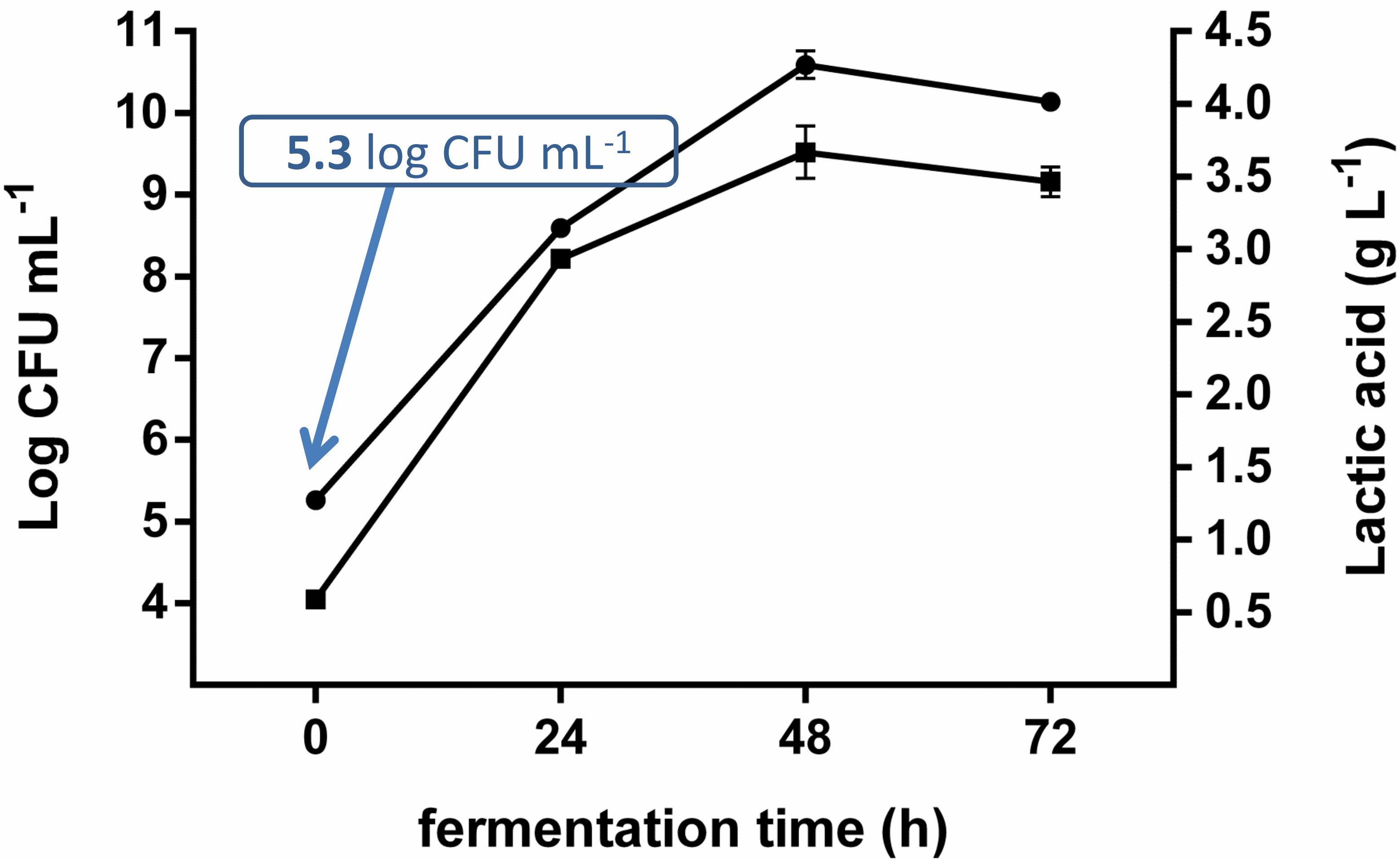

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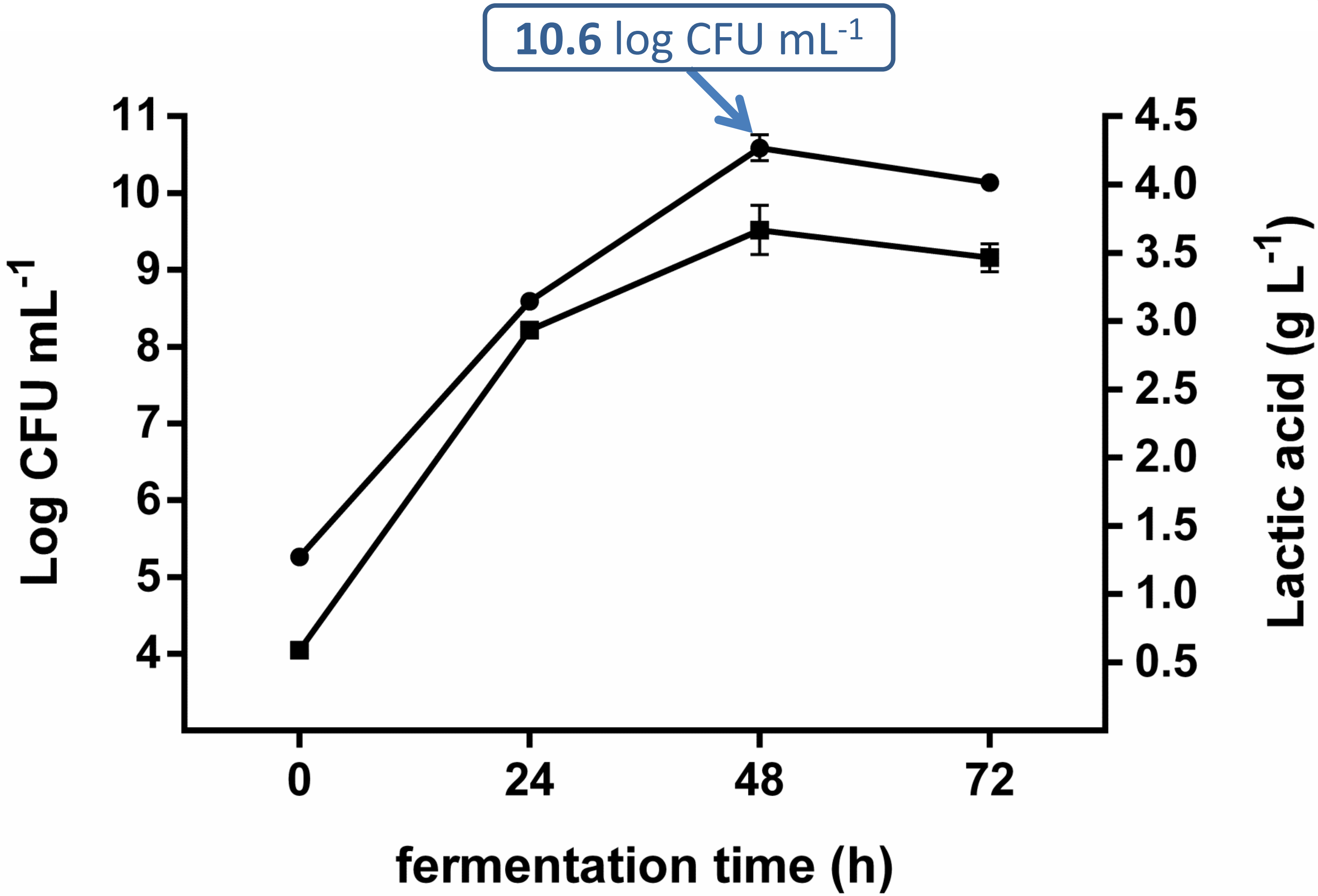

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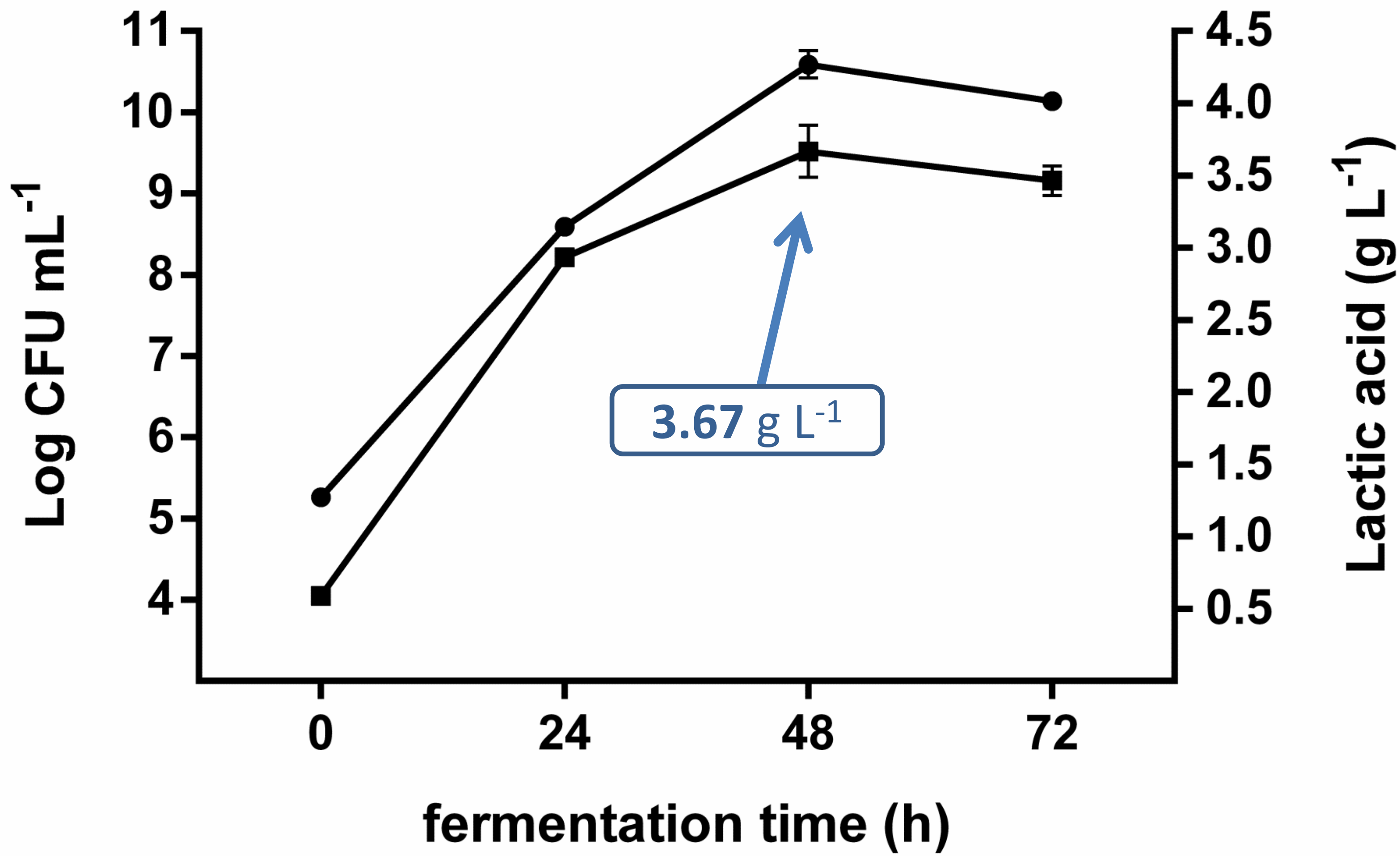

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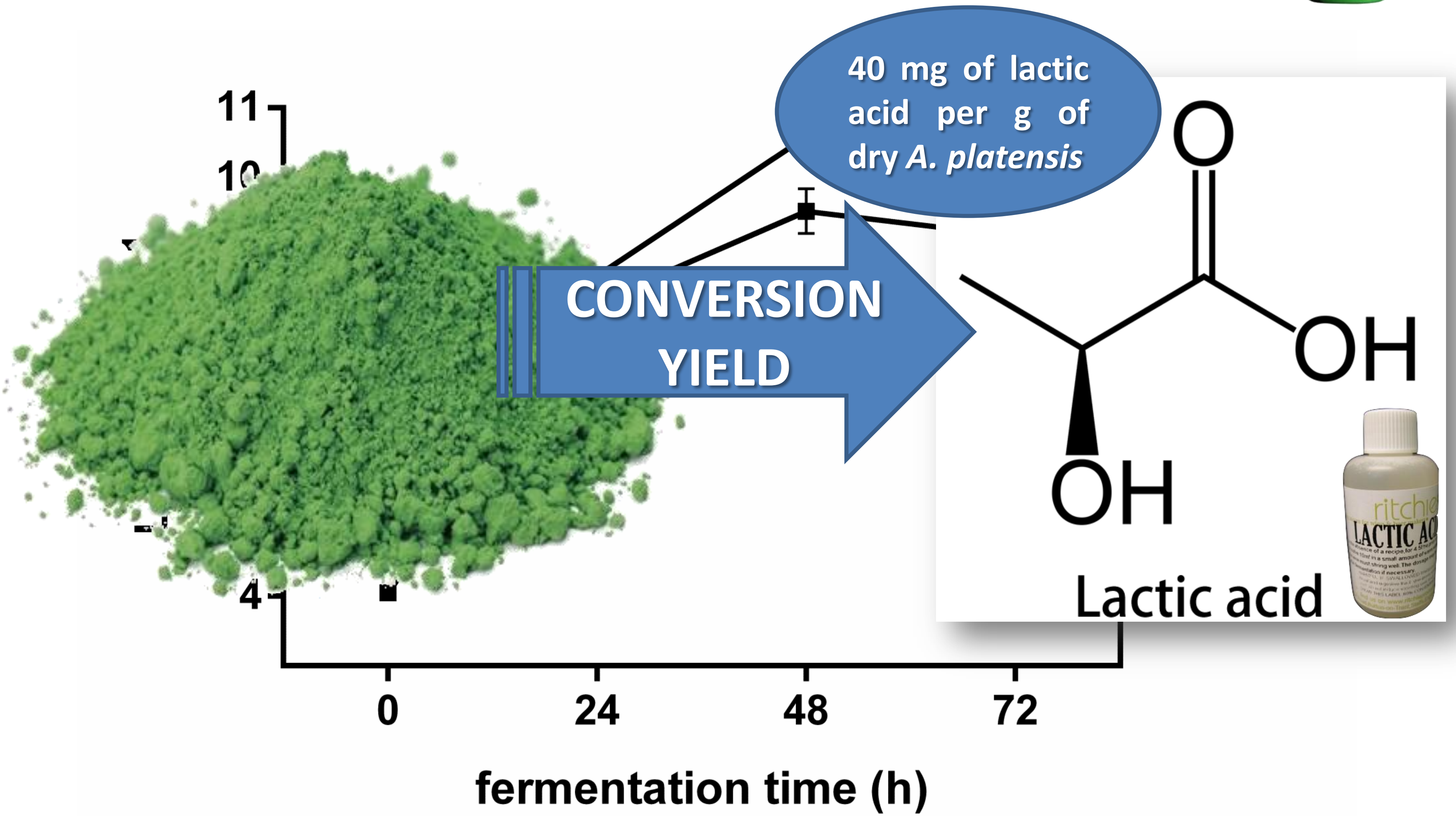

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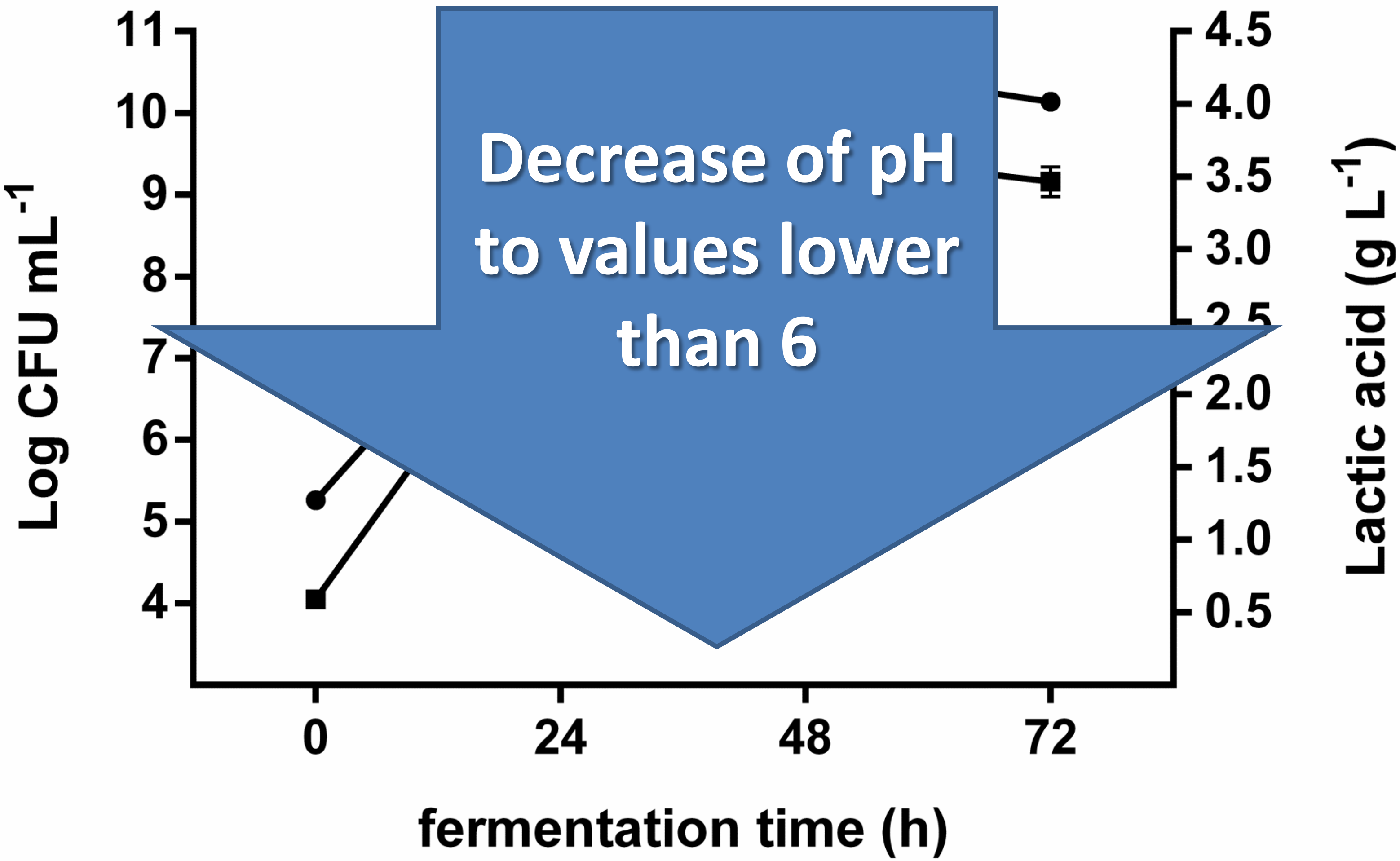

Growth curve (●) of and lactic acid production (■) by LAB 8014 in a broth containing *A. platensis* F&M-C256 biomass as the sole substrate. The amount of biomass at the start of the experiment (time zero) was 92 g (dry weight) L^{-1}. Values are expressed as means ± SD.

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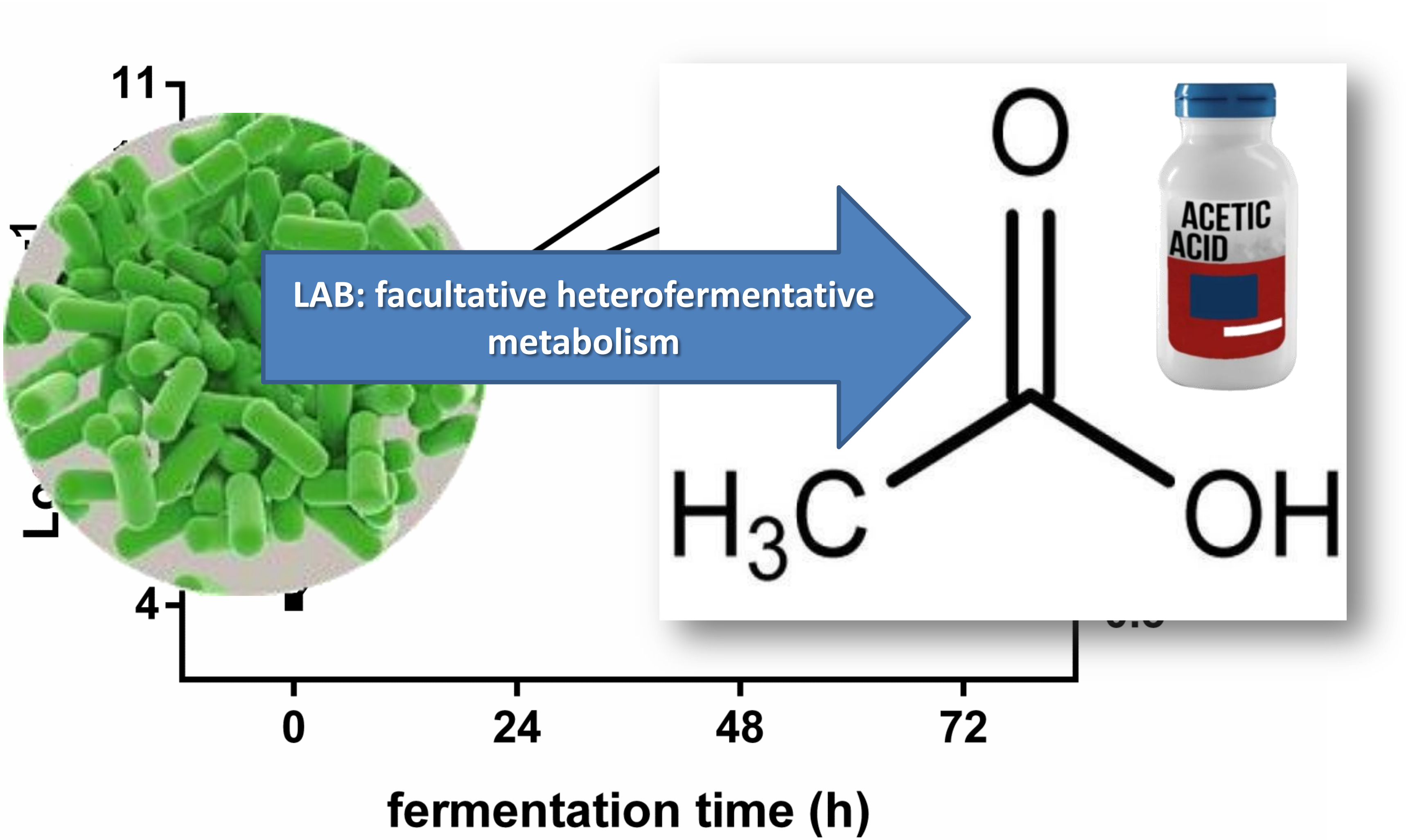

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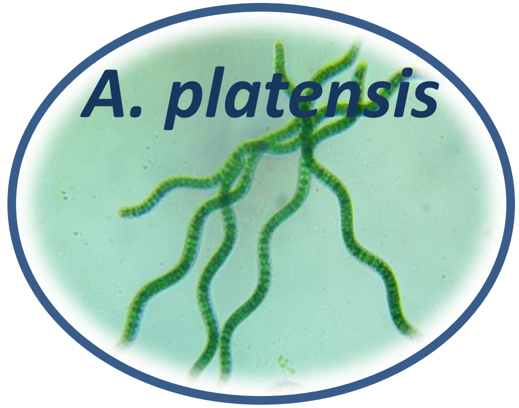
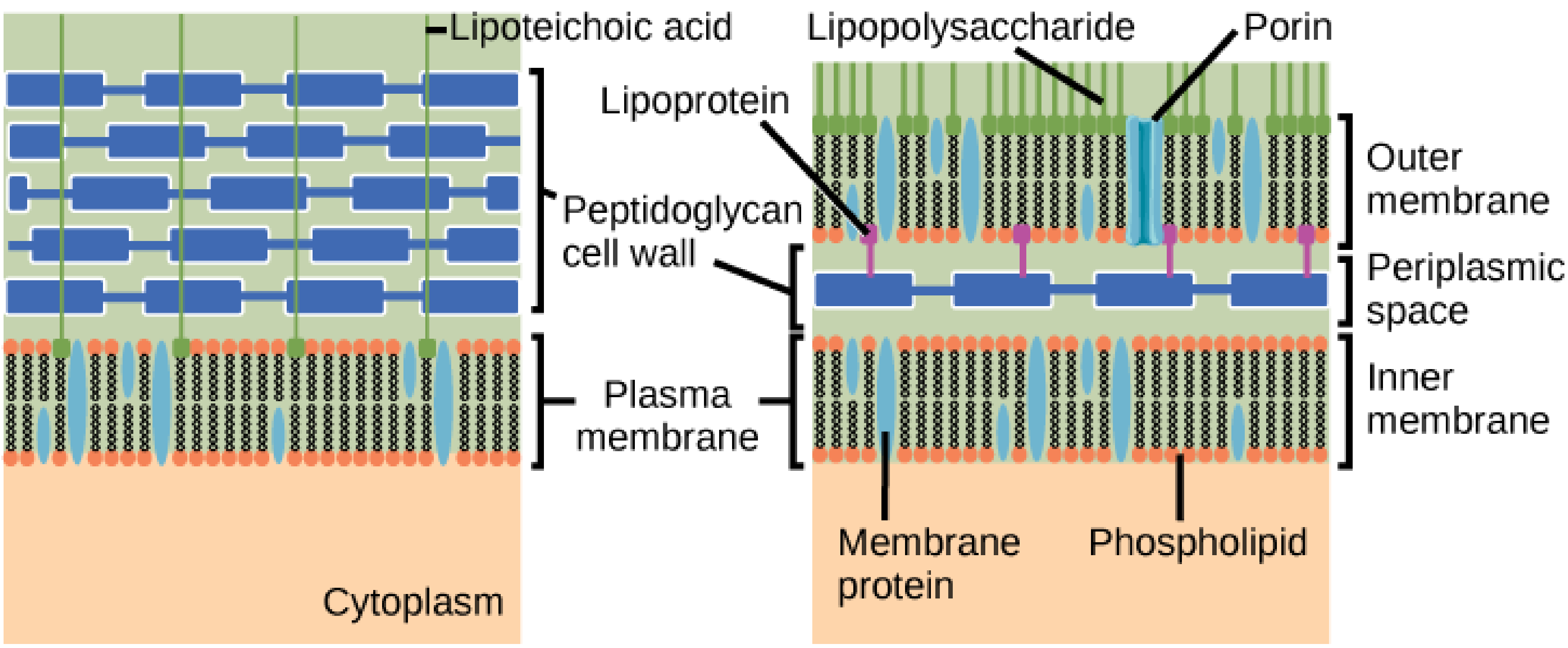
In vitro digestibility of fermented *A. platensis* biomass

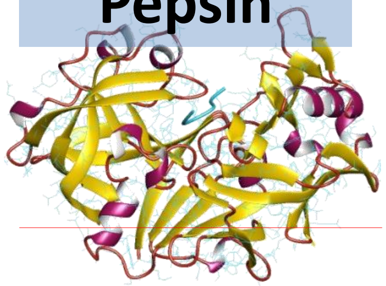




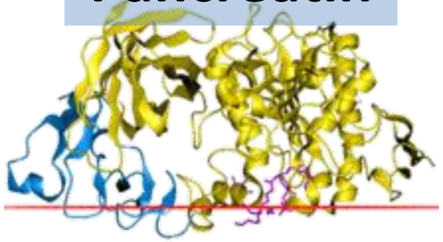
Gram-positive bacteria **Gram-negative bacteria**

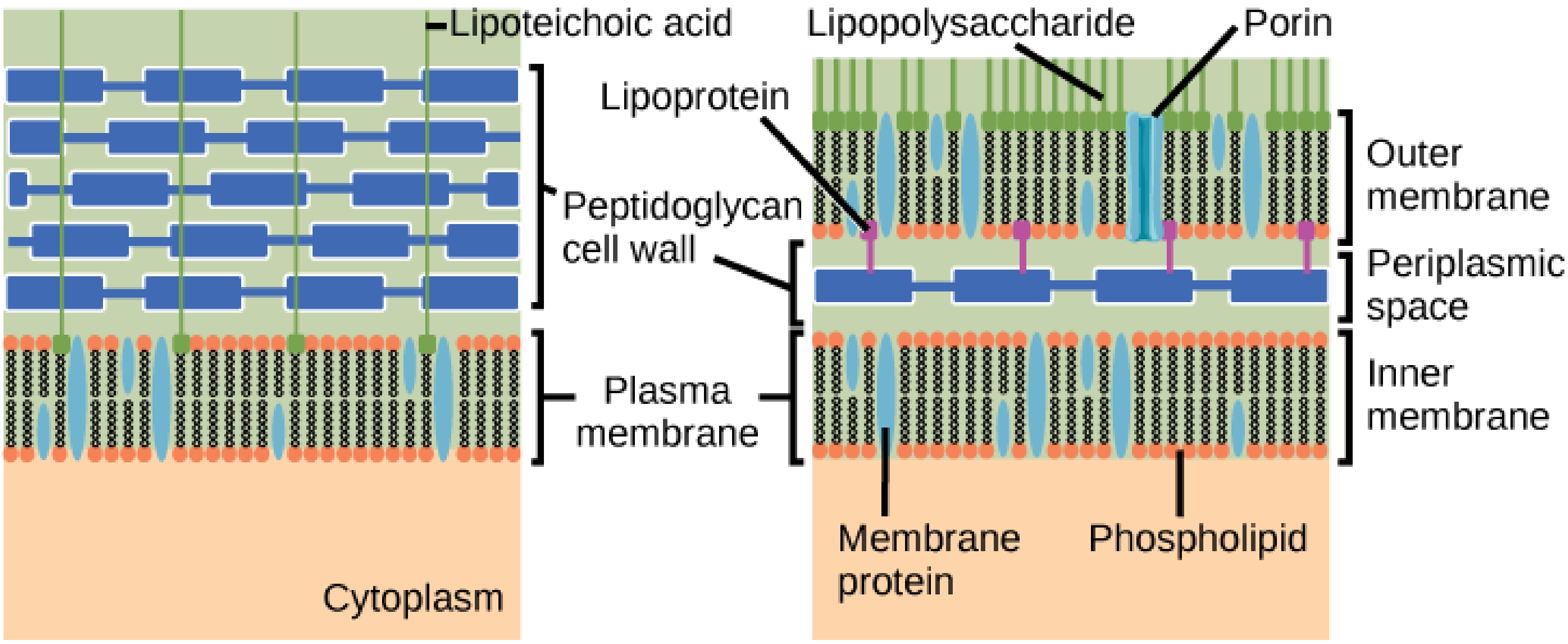
In vitro digestibility of fermented *A. platensis* biomass

Pepsin



Pancreatin





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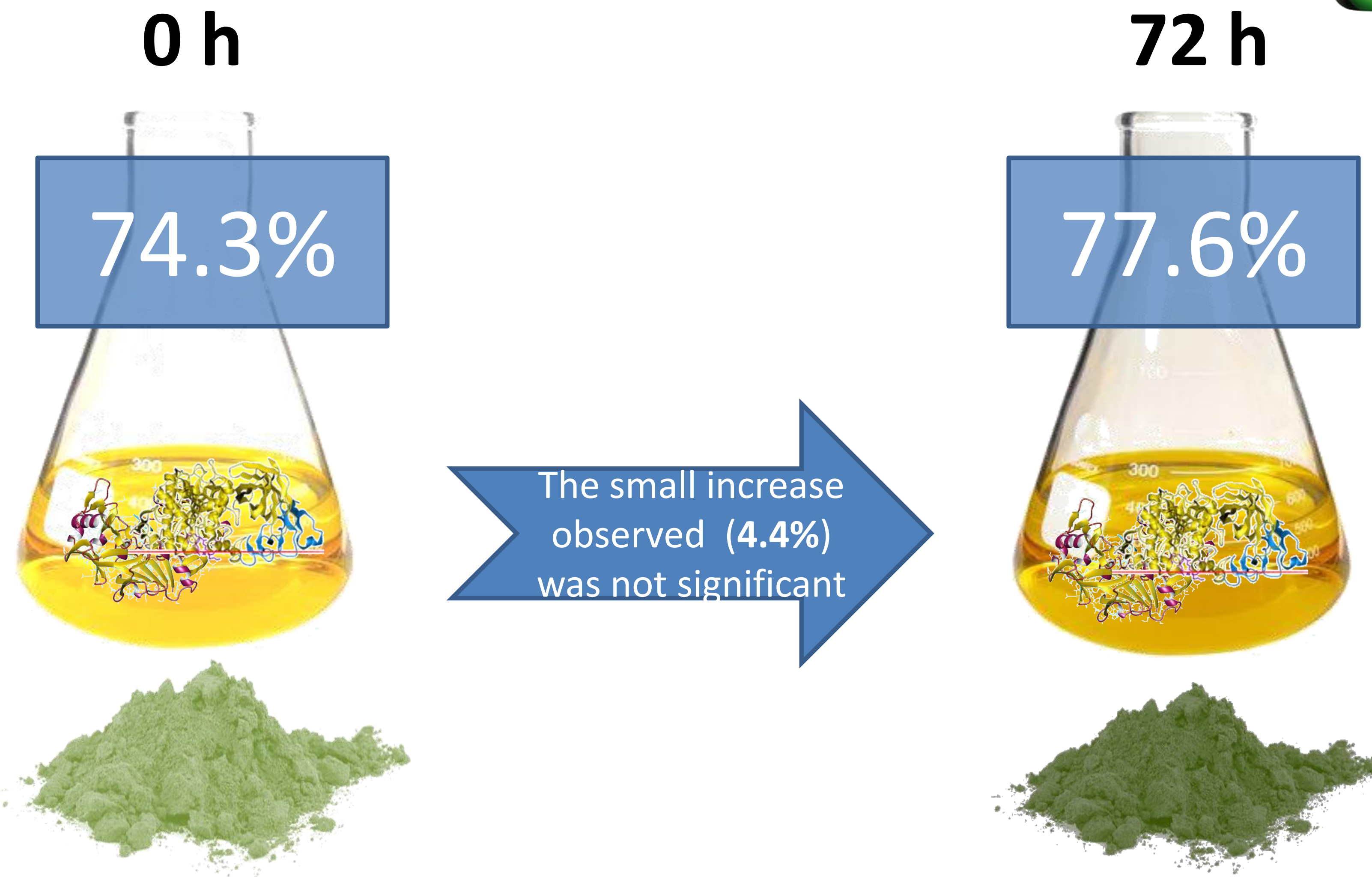
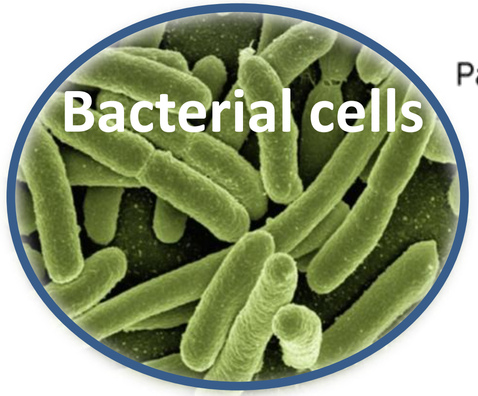
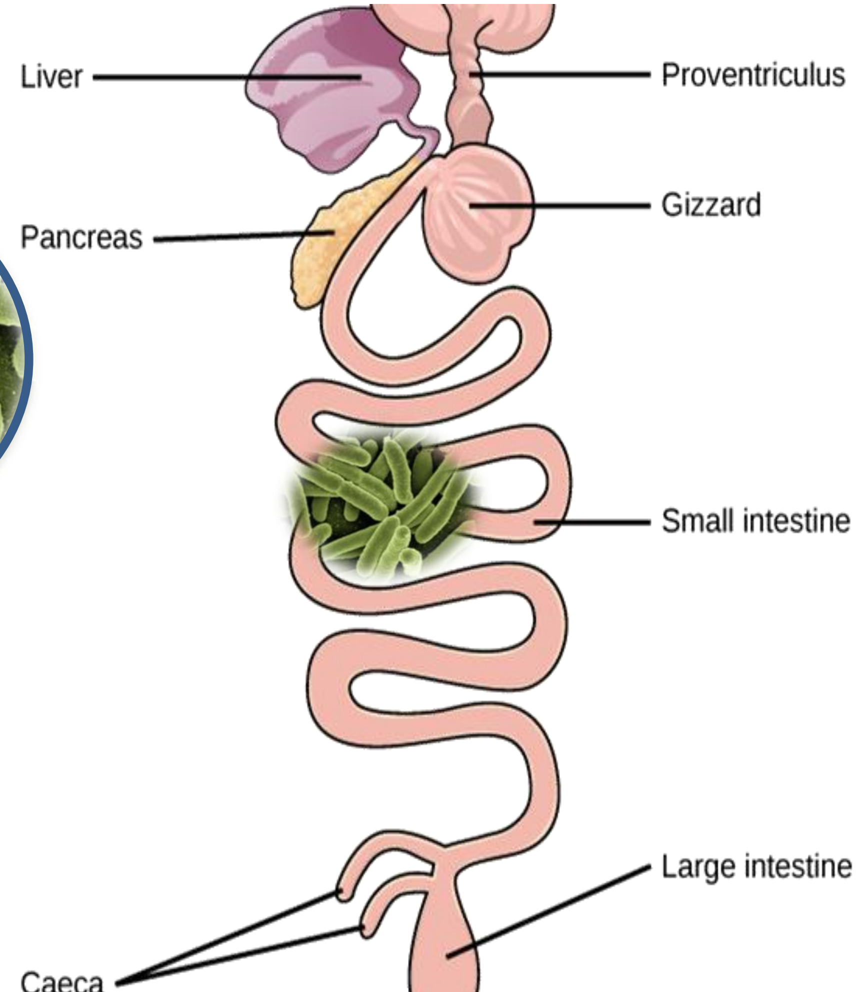


In vitro digestibility (% dry matter) of lyophilised fermentation broth at the start and at the end of fermentation

In vitro digestibility of fermented *A. platensis* biomass

72 h



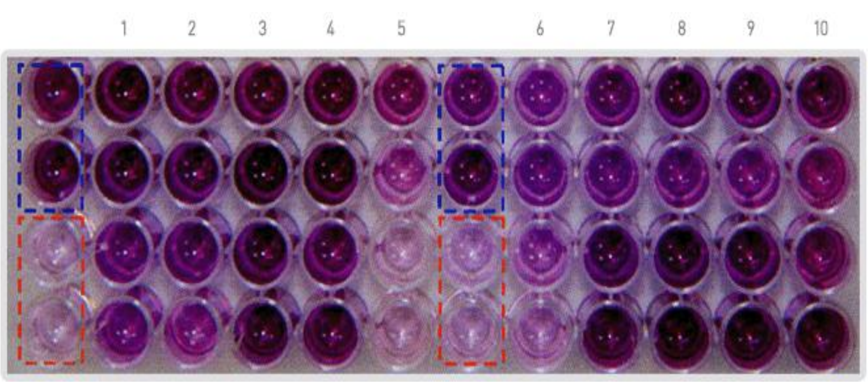


Low digestibility

Antioxidant capacity and phenolic content of fermented *A. platensis* biomass

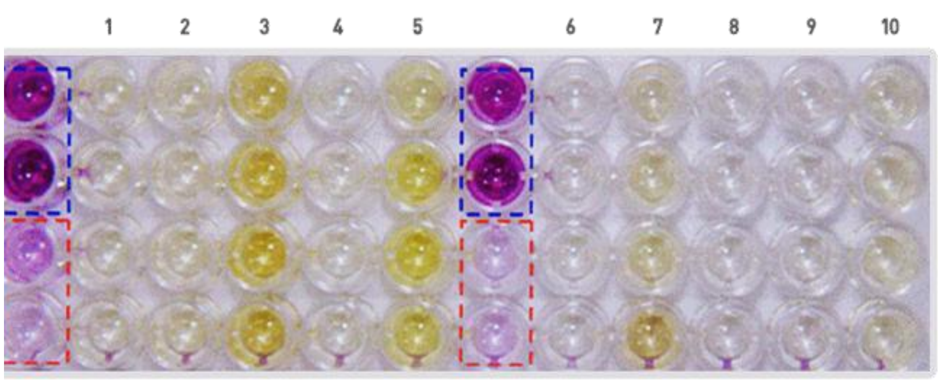
0 h

A **20.5%** DPPH inhibition **before fermentation**

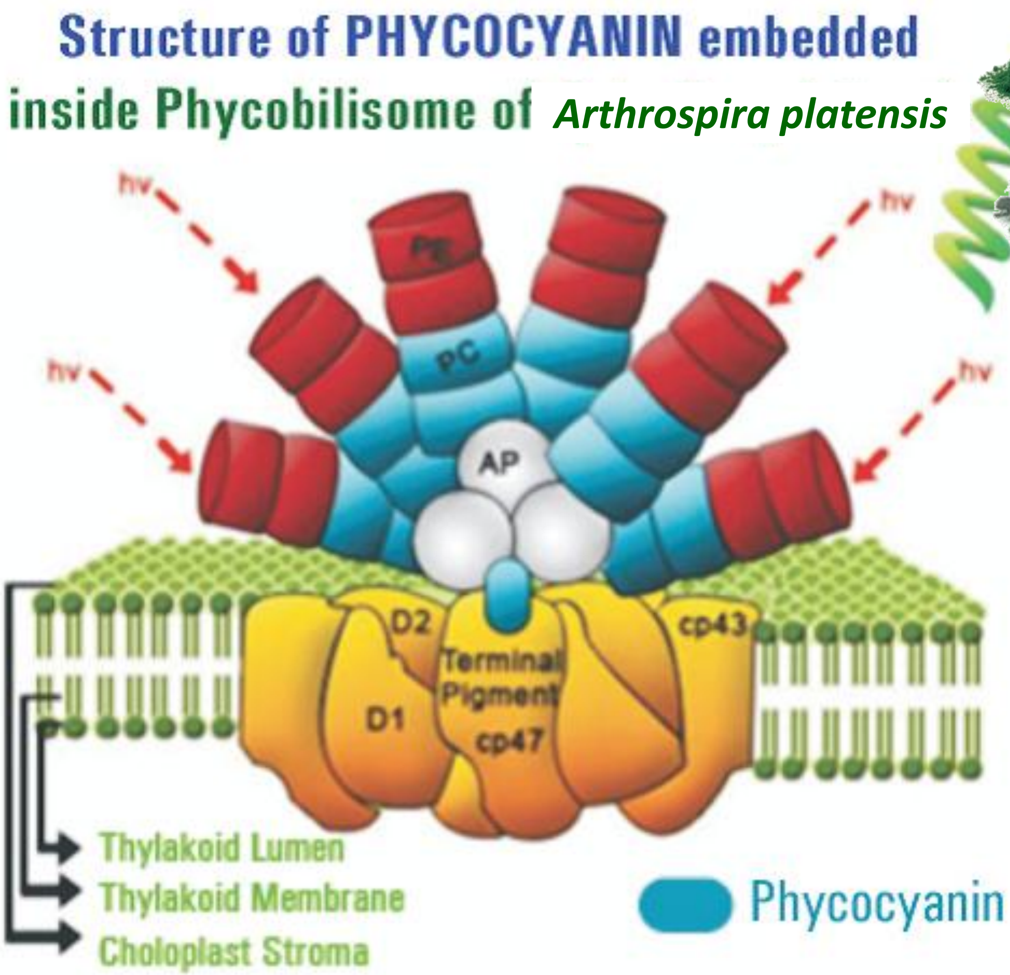


72 h

A **36.6%** DPPH inhibition **after fermentation**



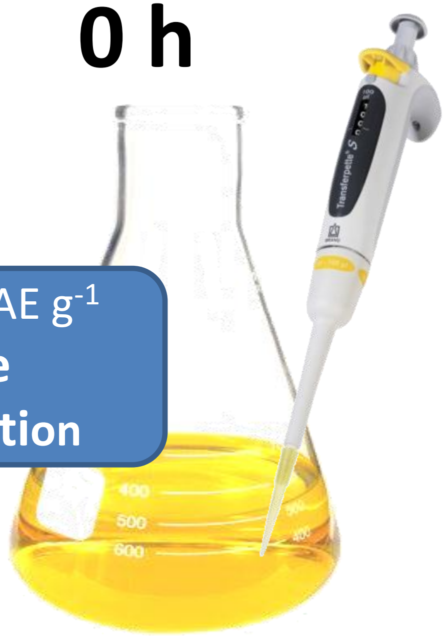
Antioxidant capacity and phenolic content of fermented *A. platensis* biomass



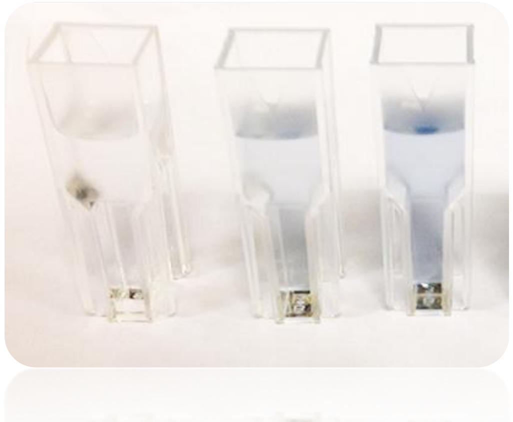
Phycocyanin contains an open chain tetrapyrrole chromophore, phycocyanobilin, which is covalently attached to an apoprotein

Antioxidant capacity and phenolic content of fermented *A. platensis* biomass

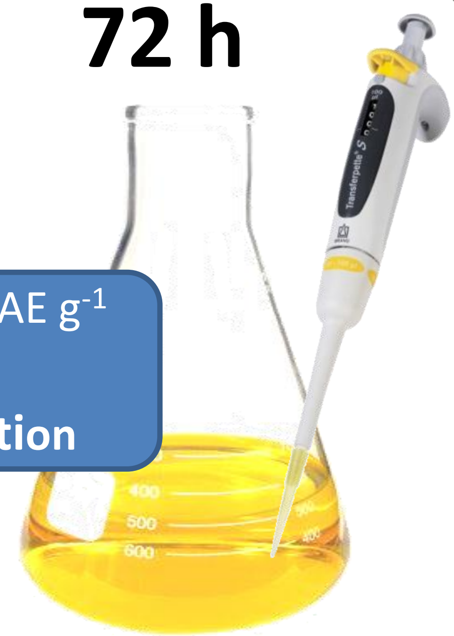
0 h



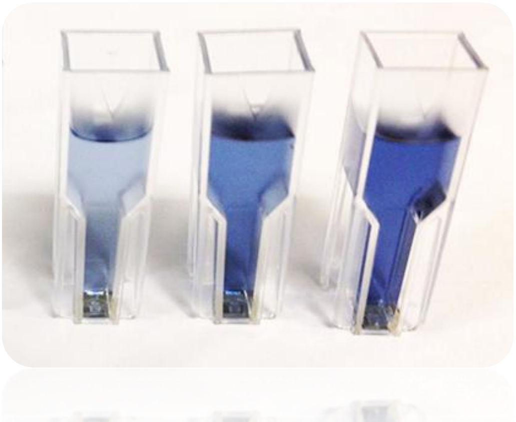
A **4.5** mg GAE g^{-1}
before
fermentation



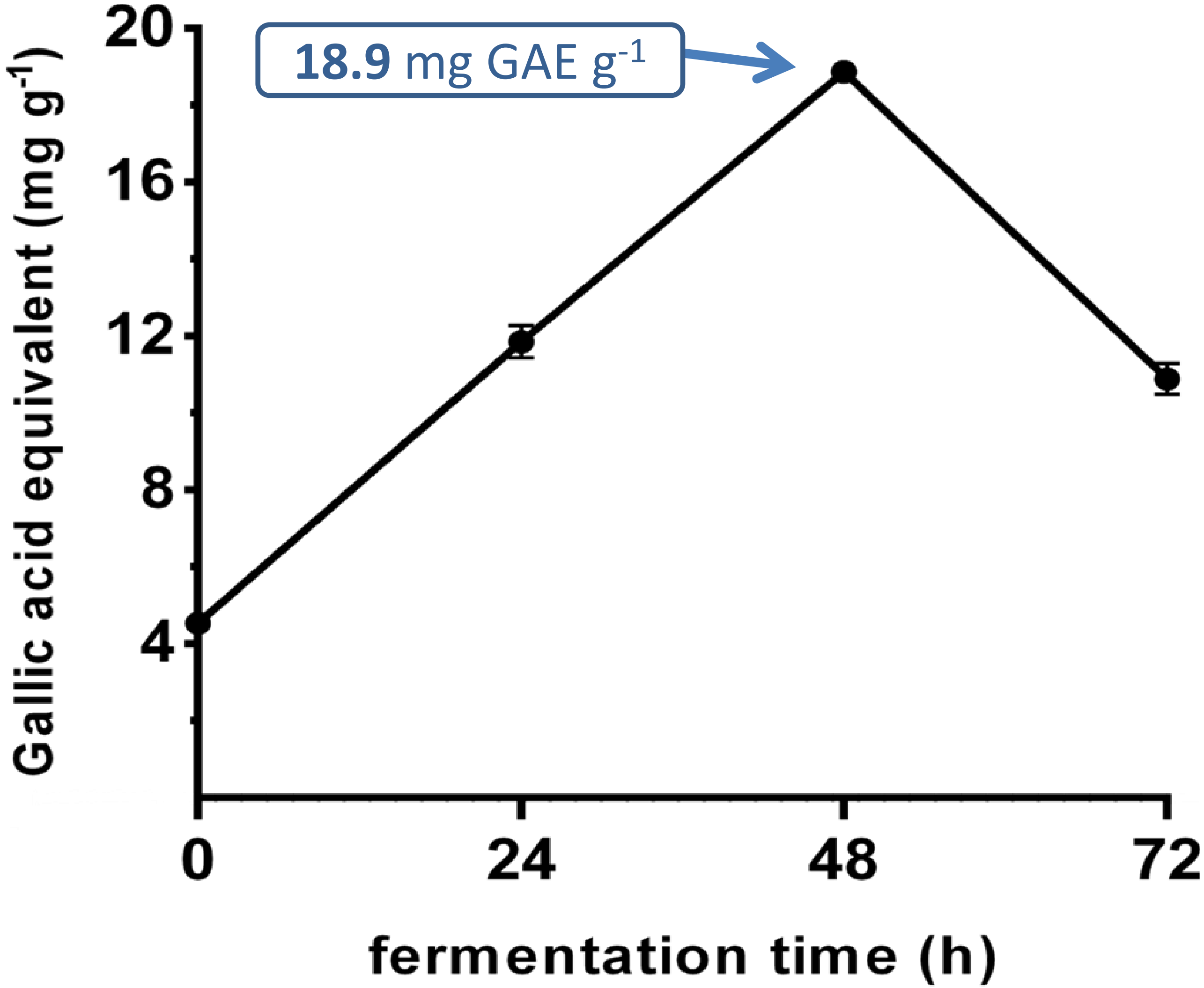
72 h



A **10.9** mg GAE g^{-1}
after
fermentation

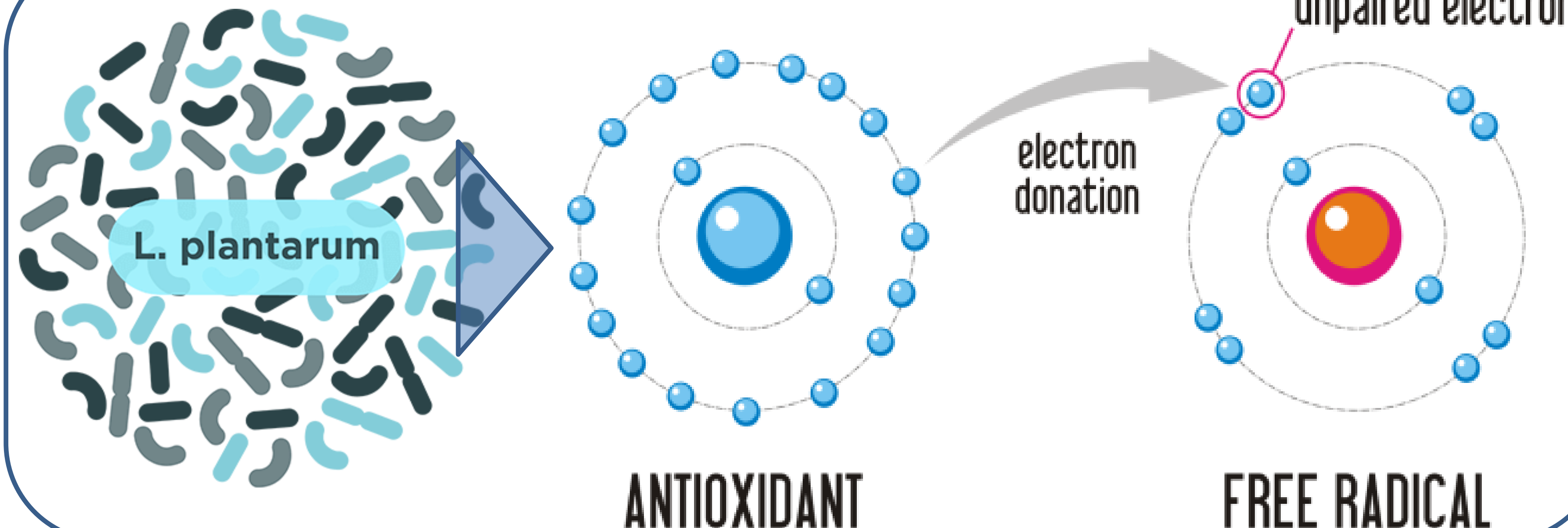


Antioxidant capacity and phenolic content of fermented *A. platensis* biomass



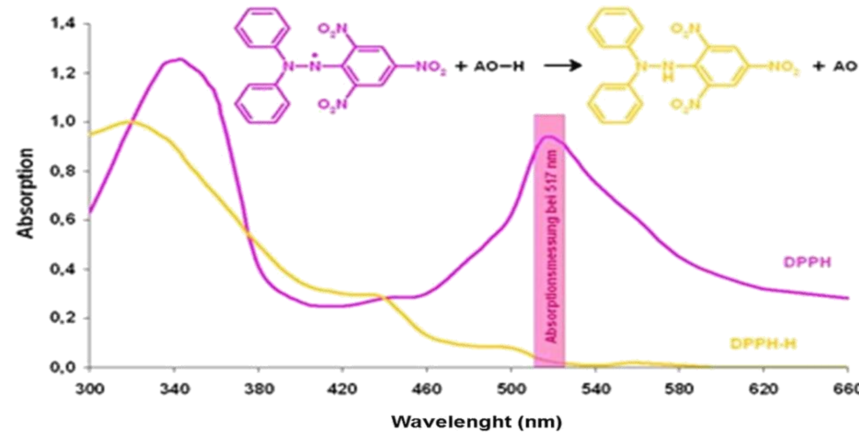
Total phenolic content, expressed as mg of gallic acid equivalent (GAE) per g of dry fermentation broth initially containing 92 g (dry weight) L^{-1} of *A. platensis* biomass. Values are expressed as means ± SD.

Antioxidant capacity and phenolic content of fermented *A. platensis* biomass



L-3-(4-hydroxyphenyl)-lactic acid

L-indole-3-lactic acid



Suzuki et al. (2013)

Concluding remarks

- This study shows that ***A. platensis*** **F&M-C256** is a **suitable growth substrate** for *Lactobacillus plantarum* ATCC 8014

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 At the end of fermentation ***L. plantarum*** ATCC 8014 cells **constitute** more than **20% of the broth** dry weight

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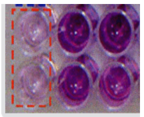 **Antioxidant activity was strongly increased** (of about 80%), **mainly due to the rise in total phenolic content**

Perspectives for the realization of functional products: YOGURT

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Effect of *Spirulina platensis* fortification on physicochemical, textural, antioxidant and sensory properties of yogurt during fermentation and storage

Mohamed Barkallah [a,*], Mouna Dammak [a], Ibtihel Louati [b], Faiez Hentati [a], Bilel Hadrich [a], Tahar Mechichi [b], Mohamed Ali Ayadi [c], Imen Fendri [d], Hamadi Attia [c], Slim Abdelkafi [a]

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[c] *Laboratoire Analyses, Valorisation et Sécurité des Aliments, Ecole Nationale d'Ingénieurs de Sfax, Université de Sfax, Route Soukra, Sfax 3038, Tunisia*
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A R T I C L E I N F O

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Antioxidant properties

A B S T R A C T

Due to the high consumption rate of fermented milk products such as yogurt, the fortification of these products will effectively reduce diseases associated with nutritional deficiencies. In the present study, after incorporating *Spirulina* into yogurt at four different concentrations (0.25, 0.5, 0.75 and 1%), we studied its effect on the fermentation process, texture, nutraceutical and sensory characteristics of yogurt. The addition of 0.25% of *Spirulina* was significantly sufficient to accelerate the end of fermentation ($p < 0.05$) and conserve the textural properties and sensory acceptability of the final milk product. This treatment also exhibited significant better water holding capacity and lower whey syneresis during 28 days of storage. During this period, the colored yogurt showed negligible variations for the L*, a* and b* indices, reflecting the strong stability of *Spirulina* color. Thanks to its high content in pigments, *Spirulina* considerably improve the antioxidant activity of the new formulated yogurt. Overall, it can be concluded that *Spirulina* can be used as a natural ingredient to develop a novel yogurt with high nutritional properties.

Perspectives for the realization of functional products: YOGURT

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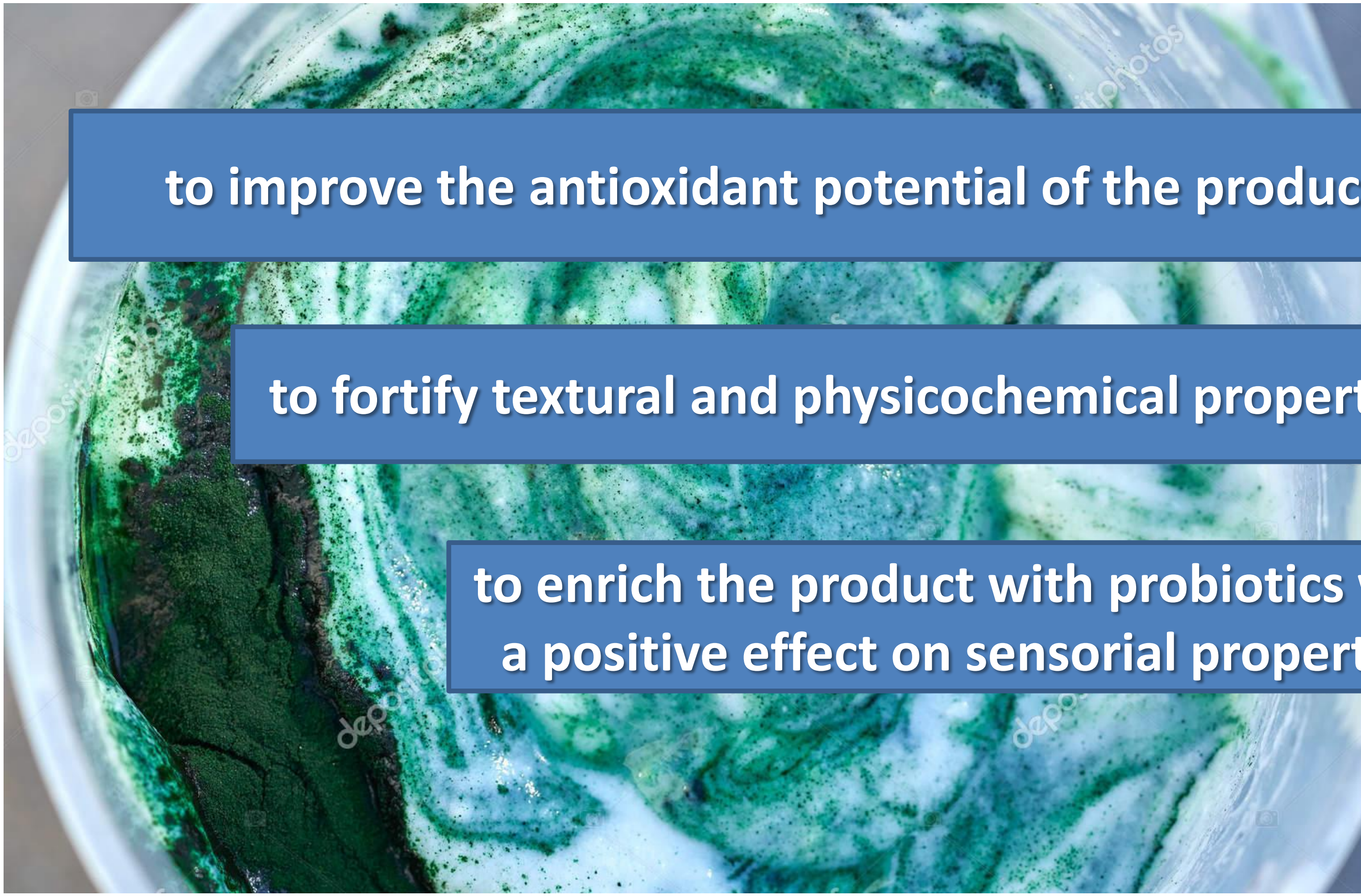
Yogurt greco con Spirulina

Lo **yogurt greco** è più compatto di quello tradizionale bianco e ha un sapore completamente diverso.

Lo yogurt è un derivato del latte che può essere di qualsiasi animale (capra, mucca e pecora) e anche di origine vegetale (come il latte di soia, di riso, di noci...)
perché deriva essenzialmente dalla fermentazione degli zuccheri, processo durante il quale il lattosio è trasformato in acido lattico che dona il tipico sapore acidulo allo yogurt.

Livegreen

Perspectives for the realization of functional products: YOGURT



to improve the antioxidant potential of the product

to fortify textural and physicochemical properties

to enrich the product with probiotics with a positive effect on sensorial properties

Conclusions

Fermentation by lactic acid bacteria is a **suitable technology to obtain innovative functional products** (such as **yogurt**) from ***A. platensis*** **F&M-C256**, **which can provide** to the consumer, besides the **highly nutritional components of spirulina** a **significant amount** of **probiotic *Lactobacillus* cells** conferring additional beneficial properties to the final product.

Aknowledgements

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Many thanks for your attention

Per domande e possibili collaborazioni

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