A vegan-friendly nanotechnology approach to counteract vitamin B12 deficiency in plant-based diets

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Achieving the Sustainable Development Goals
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Plant-based foods

Rapidly growing industry

$43.77 billion (2023)

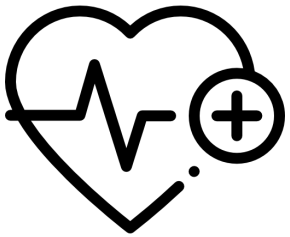
projected to reach **$162 billion** by 2030

↑ Awareness of sustainability, animal welfare, and health

↑ Innovation in food technology

Plant-based diets

Significant impact on global health and sustainability

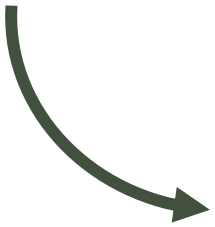


- ↓ Risk of chronic diseases, such as heart disease and diabetes
- ↑ Gut health
- ↓ Inflammation

- ↓ Greenhouse gas emissions
- ↓ Cropland, irrigation water and fertilizer

Plant-based diets

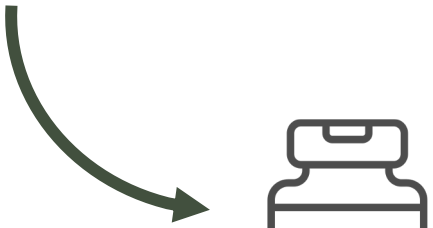
Nutritional deficiencies



Need for supplementation

Plant-based diets

Nutritional deficiencies



Need for supplementation

Vitamin B12

Vitamin B12

- Essential for neurologic function, red blood cell production, and DNA synthesis
- Absent in most of plant-derived foods

Deficiencies increase the risk of several neuro, vascular, immune, and inflammatory disorders

Need for supplementation or consume of fortified foods

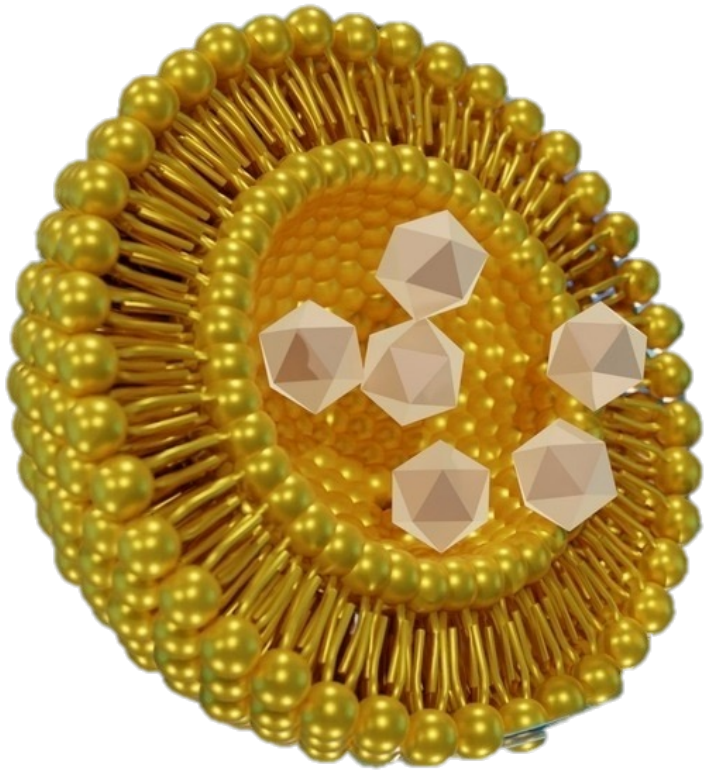
Vitamin B12-fortified foods

- Limited bioavailability
- Low stability under different pH and temperature conditions
- Insufficient dosage to guarantee daily needs
- Food processing may lead to vitamin B12 losses

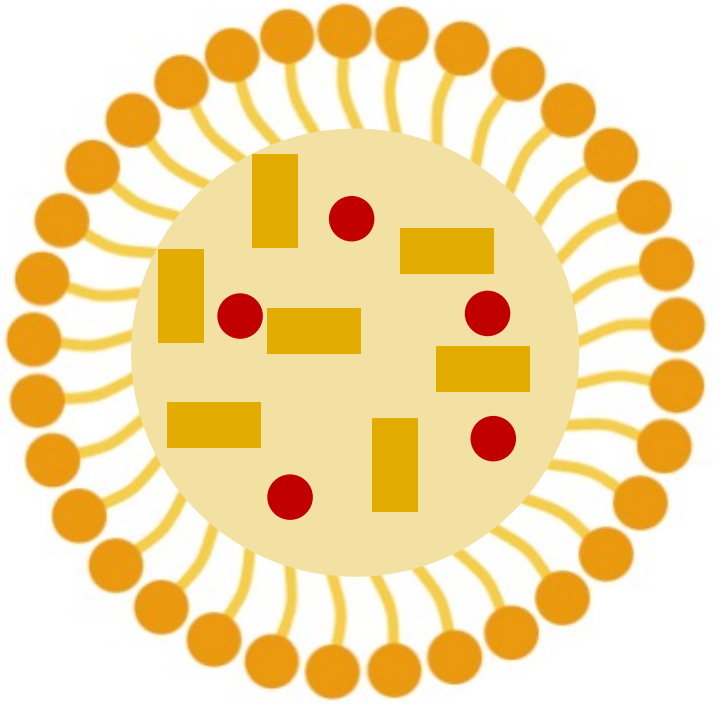
Need to produce vitamin B12-fortified foods with improved stability and nutritional value

Nanoencapsulation

- Improved stability and shelf-life
- Enhanced oral bioavailability
- Controlled and targeted delivery
- Reduced side effects
- Improved sensory properties

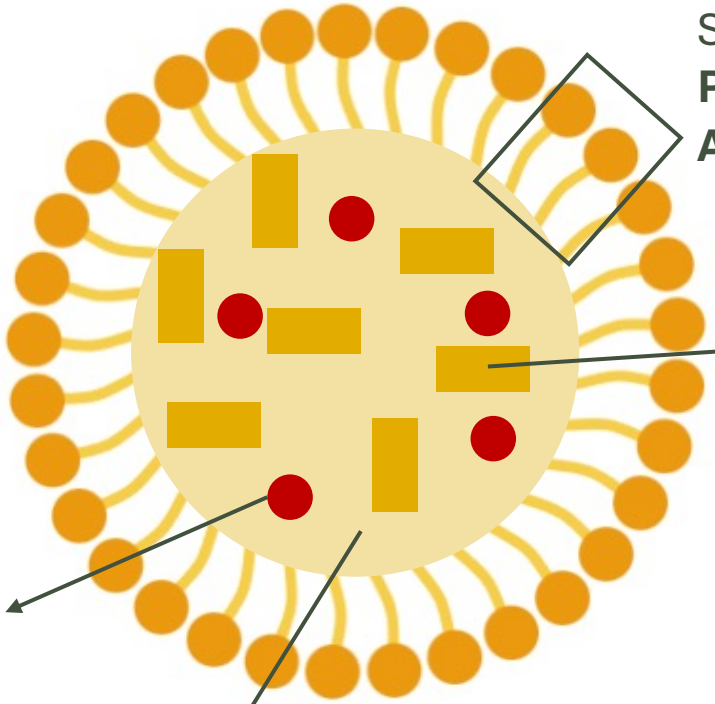


Strategy



Design of a vegan-friendly nanoformulation based on nanostructured lipid carriers (NLC) for vitamin B12 encapsulation

Strategy



Surfactant: Soy lecithin
Plant-based
Adequate emulsifying properties

Solid lipid: Compritol
High melting point and stability
Adequate for oral administration

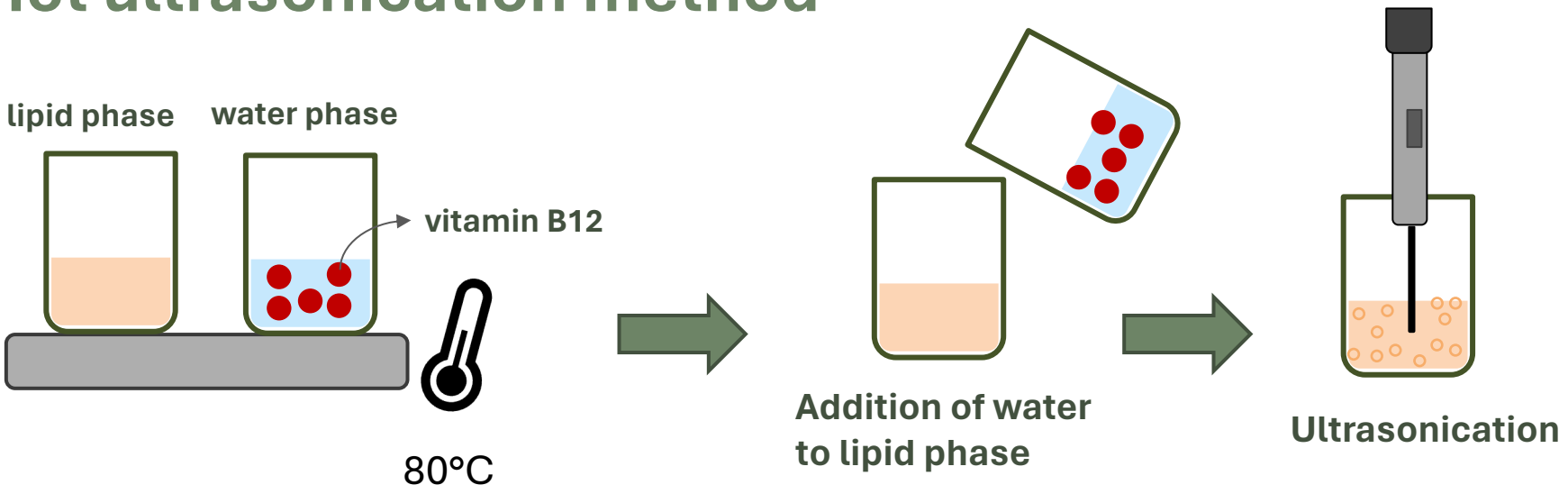
Vitamin B12

Liquid lipid: extracted from *Opuntia ficus-indica* seed oil
High antioxidant activity
Nutritional value: rich in linoleic and palmitic acids
Valorization of a natural resource waste

universidade de aveiro

Nanoparticles production

Hot ultrasonication method



- ✓ Simple method
- ✓ Low cost manufacture
- ✓ Potential for scale-up

Physicochemical characterization

Formulation	Particle Size (nm)	PDI	Zeta Potential (mV)	Encapsulation efficiency (%)
SLN (w/o oil)	1330 ± 84	0.379 ± 0.03	-53 ± 2	-
NLC	212 ± 3	0.137 ± 0.00	-44 ± 1	-
NLC Vit B12	332 ± 7	0.206 ± 0.00	-41 ± 1	53 ± 2

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✓ Opuntia ficus-indica seed oil incorporation significantly improves nanoparticle size and PDI

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✓ Suitable size for oral admnistration and intestinal absorption

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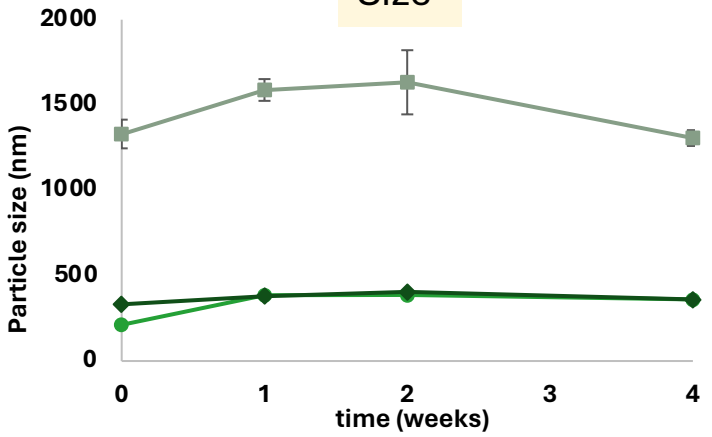
- ✓ Highly negative zeta potential, suggesting high particle stability
- ✓ More than 50% of encapsulation efficiency

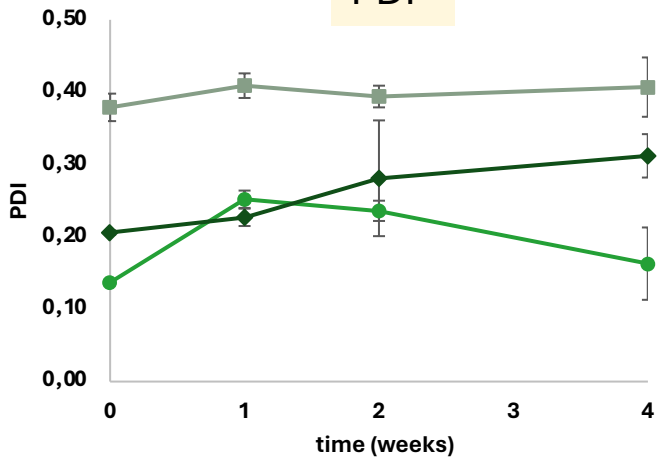
Storage stability

SLN
NLC
NLC Vit B12

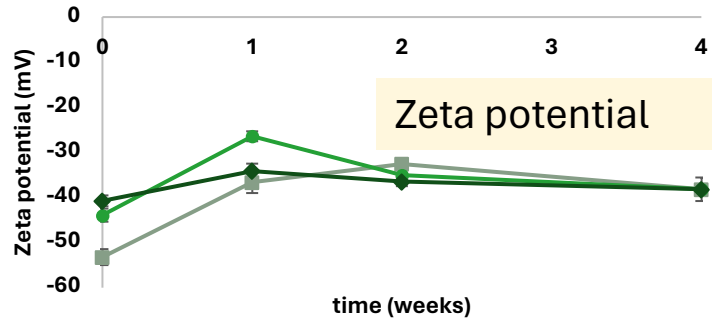
Size



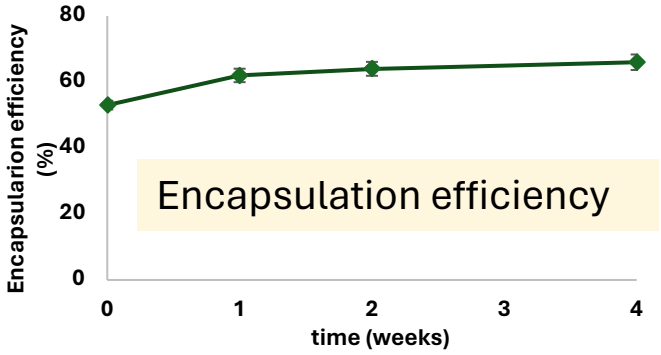
PDI



Zeta potential

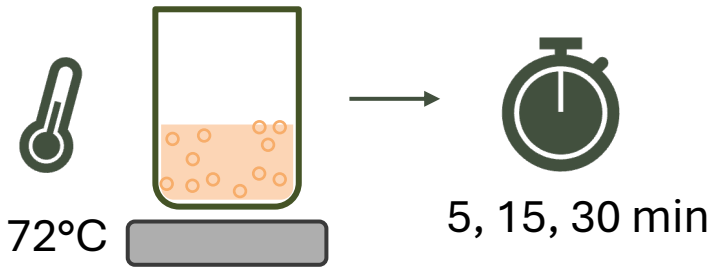


Encapsulation efficiency



Nanoparticles remained stable over 4 weeks

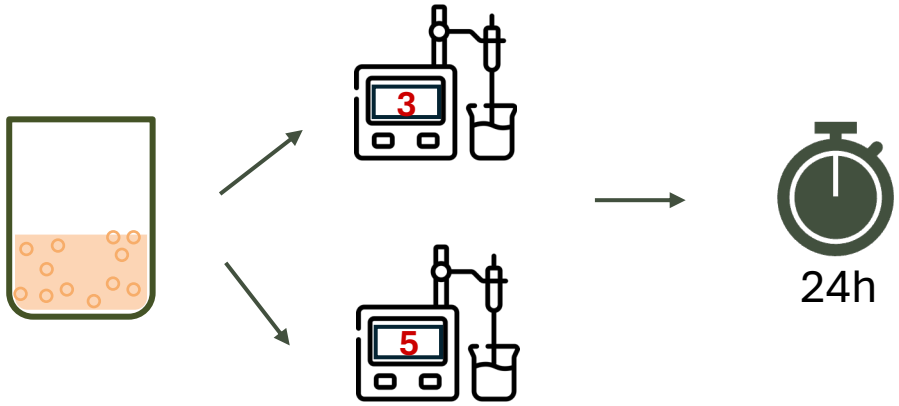
Resistance to termal treatments



Treatment time (min)	Particle Size (nm)	PDI	Zeta Potential (mV)	Encapsulation efficiency (%)
5	357 ± 19	0.180 ± 0.04	-38 ± 1	61 ± 2
15	369 ± 4	0.188 ± 0.05	-40 ± 4	60 ± 1
30	374 ± 13	0.191 ± 0.05	-40 ± 3	60 ± 1

Nanoparticles exhibited high thermal stability upon exposure to thermal treatments typically used in the food industry

Resistance to acidic pH



pH	Particle Size (nm)	Polydispersity	Zeta Potential (mV)	Encapsulation efficiency (%)
3	346 ± 21	0.203 ± 0.004	-30.04 ± 9	51± 2
5	358 ± 9	0.191 ± 0.003	-38.04 ± 3	57± 1

NLC display robust stability profile under acidic pH conditions, indicating their suitability for food product applications

Resistance to simulated gastrointestinal digestion

Resistance to simulated gastrointestinal digestion

	Particle Size (nm)	PDI	Zeta Potential (mV)	Free Vitamin B12 (%)
Initial solution	389 ± 7	0.174 ± 0.032	-38 ± 1	48 ± 3
During gastric digestion	397 ± 4	0.193 ± 0.061	-37 ± 3	62 ± 1
During intestinal digestion	461 ± 2	0.211 ± 0.052	-30 ± 4	73 ± 2
After digestion	502 ± 17	0.371 ± 0.039	-21 ± 2	82 ± 2

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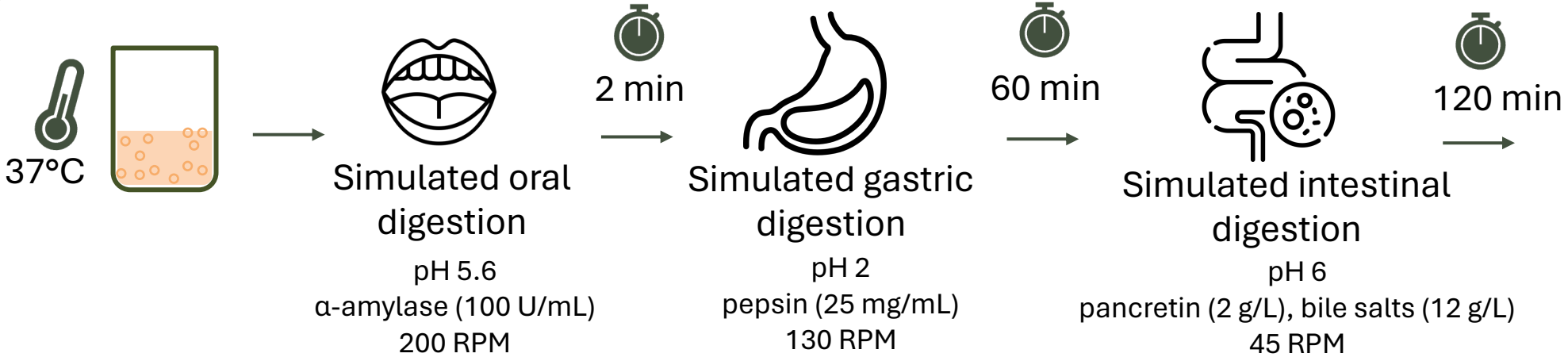
Nanoparticles were able to resist the harsh conditions of the oral and gastric digestion with only a limited amount of vitamin B12 release

Resistance to simulated gastrointestinal digestion



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Nanoparticle aggregation occurred under intestinal digestion with partial release of vitamin B12

Free vitamin B12 can be absorbed in the intestine

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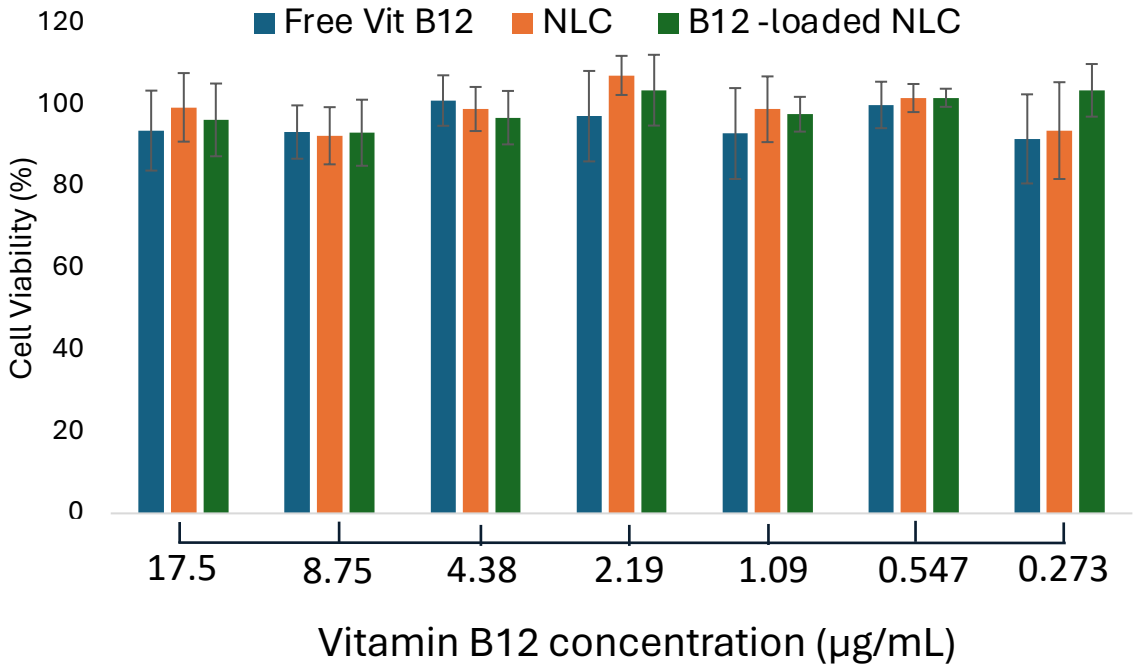
~20 % of the vitamin B12 remained in the NLC after digestion, which can be absorbed in the intestine

Cytocompatibility

L929 cell line

(ISO 10993-5)



Nanoparticles were cytocompatible up to **17.5 µg/mL** of Vitamin B12

Above the recommended daily dose of **2.4 µg** per day

Conclusions

Vegan-friendly vitamin B12- loaded NLC were rationally designed:

- ✓ Adequate characteristics for oral admnistration
- ✓ Resistance to termal treatments and acidic pH conditions
- ✓ Resistance to simulated oral and gastric digestion
- ✓ After gastrointestinal digestion, 20% of vit B12 remained entrapped
- ✓ Cytocompatibility up to 17.5 µg/mL of Vitamin B12

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Potential for the production of improved vitamin B12-fortified foods

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Thank you for listening!