4th International Scientific Conference
"Dilemmas of Human Nutrition Sciences - Today and Tomorrow"
„PLANT DIET – BENEFITS AND RISKS"
June 12-13, 2025 - Bialystok

Optimization of emulsion stability in almond and coconut milk alternatives through formulation and process modifications

Tomasz Szelepa [1,*], Marek Rzeszotarski [1], Rita Brzezińska [2], Joanna Bryś [2]

[1]Witpol Sp. z o.o., Stodzew 54B; 08-441 Parysów, Poland

[2]Department of Chemistry, Institute of Food Sciences, Warsaw University of Life Sciences, 159c, Nowoursynowska St.,02-776 Warsaw, Poland

*e-mail of corresponding author: tszelepa@wit-pol.com.pl

Investigation conducted by WITPOL Sp. z o.o. on improving emulsion stability in plant-based nut beverages, focused on reducing fat separation as part of the FEMA.01.01-IP.01-023Q/24-00 project.

Fundusze Europejskie dla Mazowsza | Rzeczpospolita Polska | Dofinansowane przez Unię Europejską | Mazowsze. serce Polski

PURPOSE

The popularity of plant-based drinks like almond and coconut milk is on the rise due to their nutritional benefits, lower environmental impact, and suitability for lactose-intolerant or vegan diets, which is a result of the growing consumer demand for dairy alternatives. The oil-in-water emulsions made of coconut and almond milk have the potential to become unstable due to factors such as creaming, phase separation, and sedimentation, which can negatively impact shelf life and consumer acceptance. Droplet size distribution, interfacial tension, viscosity, and the presence of emulsifiers and stabilizers are all factors that can affect the stability of plant milk alternatives. Processing conditions, especially homogenization pressure and duration, are crucial for keeping fat globules dispersed uniformly. Food emulsifiers are commonly utilized to increase the stability and viscosity of the emulsion in the continuous phase. These strategies are necessary to guarantee the proper nutritional quality and stability of nut-based milk alternatives in commercial applications.

The main goal of the project was to enhance the physical stability of almond and coconut milk by optimizing homogenization parameters, evaluating food-grade emulsifiers, and reformulating recipes to improve their stability and sensory attributes.

witpol

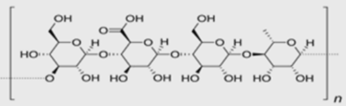
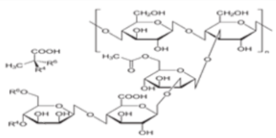
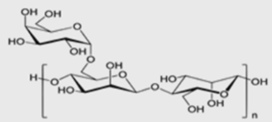
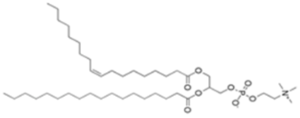
Investigation conducted by WITPOL Sp. z o.o. on improving emulsion stability in plant-based nut beverages, focused on reducing fat separation as part of the FEMA.01.01-IP.01-023Q/24-00 project.

4th International Scientific Conference
"Dilemmas of Human Nutrition Sciences - Today and Tomorrow"
„PLANT DIET – BENEFITS AND RISKS"
June 12-13, 2025 - Bialystok

MATERIALS AND METHODS

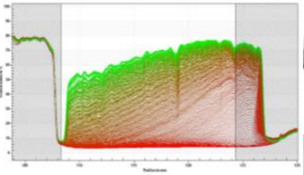
Different variants of the technological process:

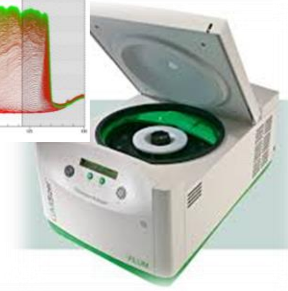
- optimization of pressure and duration of homogenization
- reformulating recipes

Tested emulsifiers	Chemical formula
Gellan Gum (**GEG**)	
Xanthan Gum (**XG**)	
Guar Gum (**GG**)	
Lecithin (**L**)	

Used analytical methods:

- Instability index
- Creaming rate
- Spin test
- Determination of dry matter
- Particle size testing
- Brix measurements
- Color measurements in CIE LAB color scale
- pH measurements
- Microbial tests
- Sensory evaluation





Investigation conducted by WITPOL Sp. z o.o. on improving emulsion stability in plant-based nut beverages, focused on reducing fat separation as part of the FEMA.01.01-IP.01-023Q/24-00 project.

RESULTS

Table 1. Physicochemical properties of tested formulas of almond milk alternatives.

Analytical method	Variants of almond milk alternatives			
	Gellan Gum (GEG)	Xanthan Gum (XG)	Guar Gum (GG)	Lecithin (L)
pH	7,22 ± 0,20	6,90 ± 0,05	7,57 ± 0,63	7,30 ± 0,12
Brix [%]	2,17 ± 3,53	3,06 ± 4,27	2,31 ± 3,50	2,71 ± 4,09
Dry matter [%]	6,34 ± 1,70	8,69 ± 0,15	7,01 ± 1,26	8,50 ± 1,07
Particle size [µm]	3,41 ± 1,34	1,25 ± 1,49	2,88 ± 1,44	2,24 ± 1,20
Spin test [%]	2,25 ± 0,35	2,29 ± 0,39	2,25 ± 0,42	1,93 ± 0,61

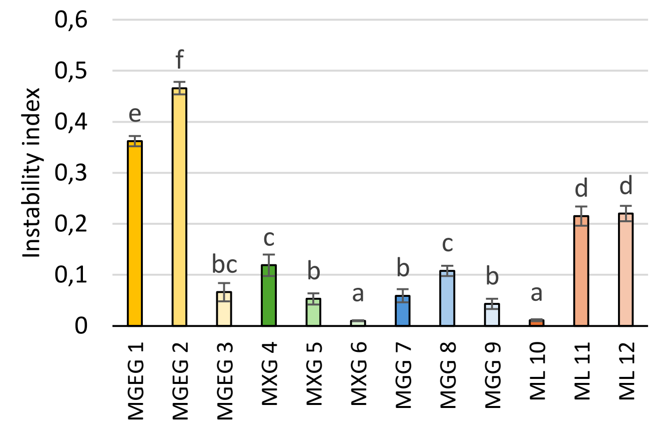


Figure 1. Instability index of tested formulas of almond milk alternatives.

- **In none of the cases was microbial growth demonstrated.**
- **The obtained ATP results were below 100 RLU, which indicates that the product is sterile.**

Table 2. Parameters influencing emulsion stability for the tested almond milk alternatives.

Parameter	Direction of influence	Observations
Particle size	improves stability (lower gravitational force, slower coalescence)	XG < L < GG < GEG
Phase viscosity (dry matter / Brix)	higher viscosity extends sedimentation time (Stokes)	XG ≈ L > GG > GEG
Type of used food emulsifiers	the structure of the polysaccharide network and the nature of the particle surface determine the strength of the interfacial film	L > XG > GEG ≈ GG
pH	too high value can lower the protein load and cause flocculation; too low value → coagulation	GG < L ≈ GEG < XG

witpol

Investigation conducted by WITPOL Sp. z o.o. on improving emulsion stability in plant-based nut beverages, focused on reducing fat separation as part of the FEMA.01.01-IP.01-023Q/24-00 project.

4th International Scientific Conference
"Dilemmas of Human Nutrition Sciences - Today and Tomorrow"
„PLANT DIET – BENEFITS AND RISKS"
June 12-13, 2025 - Bialystok

RESULTS

Table 1. Physicochemical properties of tested formulas of coconut milk alternatives.

Analytical method	Variants of coconut milk alternatives			
	Gellan Gum (GEG)	Xanthan Gum (XG)	Guar Gum (GG)	Lecithin (L)
pH	6,41 ± 0,07	6,37 ± 0,32	6,56 ± 0,55	6,67 ± 0,13
Brix [%]	2,96 ± 0,16	2,86 ± 0,04	-	-
Dry matter [%]	3,17 ± 0,09	3,46 ± 0,20	3,50 ± 0,43	3,20 ± 0,30
Particle size [µm]	1,14 ± 0,81	0,90 ± 1,27	6,18 ± 4,71	0,45 ± 0, 45
Spin test [%]	0,36 ± 0,14	0,40 ± 0,14	0,50 ± 0,10	0,35 ± 0,11

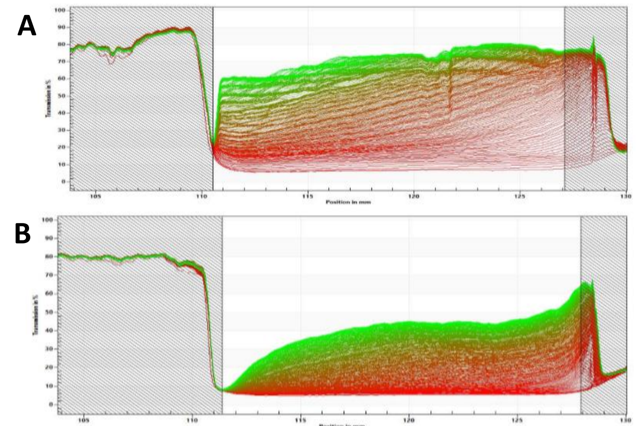


Figure 2. Dispersion analysis of coconut milk alternatives with addition of guar gum (**A**) and gellan gum (**B**)

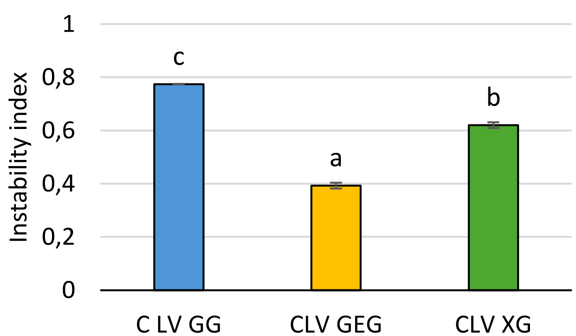


Figure 1. Instability index of tested formulas of coconut milk alternatives.

Table 2. Parameters influencing emulsion stability for the tested coconut milk alternatives.

Parameter	Direction of influence	Observations
Particle size	improves stability (lower gravitational force, slower coalescence)	**L < GEG ≈ XG < GG**
Phase viscosity (dry matter / Brix)	higher viscosity extends sedimentation time (Stokes)	**GG > XG > L > GEG**
Type of used food emulsifiers	the structure of the polysaccharide network and the nature of the particle surface determine the strength of the interfacial film	**L ≈ GEG > XG > GG**
pH	too high value can lower the protein load and cause flocculation; too low value → coagulation	**GG < L ≈ GEG < XG**

witpol

Investigation conducted by WITPOL Sp. z o.o. on improving emulsion stability in plant-based nut beverages, focused on reducing fat separation as part of the FEMA.01.01-IP.01-023Q/24-00 project.

CONCLUSIONS

- The main assumptions of the project have been fulfilled.
- Both formulation and optimization of homogenization process are essential for the development of stable and appealing nut-based milk alternatives.
- The use of low homogenization pressure caused a decrease in the instability index of almond-based milk alternatives.
- The promising formulas of almond-based milk alternatives with the longest TPDS duration appear to be the variants of samples with addition of xanthan and lecithin as food emulsifiers.
- The insights gained contribute to better understanding of emulsion dynamics in nut-based milk alternatives and offer practical recommendations for the commercial production of almond and coconut milk products with improved stability and shelf life, as evidenced by obtained low values of an instability index ≤ 0.4 as well as a creaming rate ≤ 20 µm/s, while maintaining stable emulsions throughout a minimum 9-month shelf life at temperatures between 5°C and 25°C.
- The effect of the project implementation is the introduction of process and product innovation to the local market.

Literature

[1] Reyes-Jurado, F. et al. Food Rev Int. 2021, 39(4), 2320–2351
[2] Sethi, S. et al. J Food Sci Technol. 2025, 53, 3408–3423
[3] McClements, D.J. Foods 2020, 9, 421
[4] Wilde, P. Adv Colloid Interface Sci. 2004, 108, 63-71

witpol

Investigation conducted by WITPOL Sp. z o.o. on improving emulsion stability in plant-based nut beverages, focused on reducing fat separation as part of the FEMA.01.01-IP.01-023Q/24-00 project.

Fundusze Europejskie dla Mazowsza
Rzeczpospolita Polska
Dofinansowane przez Unię Europejską
Mazowsze. serce Polski