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"Plant-based Multifunctionals"

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Abstract

The increasing consumer demand for natural and sustainable cosmetic products has driven the search for plant-based ingredients that offer broad-spectrum antimicrobial activity and additional functionalities. However, challenges remain with the stability, color, odor, and efficacy of these ingredients. This study investigates the potential of a novel combination of plant-derived compounds to provide effective antimicrobial protection in oil-in-water (O/W) emulsions, alongside chelating and antioxidant properties, contributing to formulation stability and overall product quality.

Keywords: Multifunctionality, Plant-based Ingredients, Cosmetics

1. Introduction

Broad-spectrum antimicrobial agents are essential for ensuring the safety and extending the shelf life of cosmetic formulations. Consumer preference for naturally derived ingredients has created a demand for plant-based alternatives for product preservation. However, the inherent characteristics of many plant extracts, such as chemical instability, undesirable color or odor profiles, and insufficient antimicrobial efficacy, often limit their practical application.

This study explores the development of a stable and effective 100% plant-based solution capable of providing comprehensive product protection and multiple beneficial functionalities. The goal is to address the limitations of traditional synthetic preservatives and some previous attempts at plant-based preservation.

2. Materials and Methods

The antimicrobial activity of the test ingredients was evaluated in oil-in-water (O/W) emulsions, a prevalent type of cosmetic formulation. Standardized formulations were subjected to antimicrobial efficacy testing (challenge tests) according to the European Pharmacopoeia and ISO 11930 guidelines. Briefly, the emulsions were inoculated with representative microbial strains, including *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Candida albicans*, and *Aspergillus brasiliensis*. Inoculated emulsions were incubated under controlled conditions (22°C ± 2°C). Microbial growth was monitored over a four-week period, and the log reduction of each microorganism was determined at specified time intervals (2, 7, 14, and 28 days).

The chemical antioxidant capacity was determined by using the ABTS-Assay, which is a cell free in vitro test for the evaluation of the chemical AOX capacity. The assay principle is based on the reduction and involved de-colorization of the green colored cationic radical 2,2'-Azino-bis (3-ethylbenzothiazoline 6-sulfonic acid) (ABTS+) by antioxidants. The de-colorization was measured photometrically at 734 nm.

The test was performed in 96-well microplates with a microplate reader. The samples were incubated for 10 min at 30°C with the 2,2'-Azinobis-(3-ethylbenzothiazoline- 6-sulfonate (ABTS) radical cation obtained by chemical conversion of ABTS with potassium persulfate ($K_2S_2O_8$). As a positive control Trolox (water soluble Vitamin E derivative) was used. Results were averaged from 2 independent experiments performed in quadruple technical replicates.

An assay kit was used to investigate the chelating capacity using free cupric and ferrous ions. Substances that were able to form complexes with the ions lower the ion concentration, decreasing the colored complex concentration which results in a loss of absorbance. Disodium EDTA served as standard.

a) Ferrous

Ferrozine (Dinatrium-4-[3-pyridin-2-yl-6-(4-sulfonatophenyl)-1,2,4-triazin-5-yl]benzosulfonat) is able to form a complex with free ferrous ions resulting in a chormophore with strong absrobance at 562nm.

Fe(II) + Ferrozine → Ferrozine * Fe(II) (highly colored)

Fe(II) + Chelator + Ferrozine → Chelator * Fe(II) + Ferrozine (less color)

b) Cupric

Pyrocatechol Violet is able to form a complex with free cupric ions (Cu(II)) resulting in a chorompophre with strong absorbance at 632nm.

Cu(II) + Pyrocatehol Violet (PV) → PV * Cu(II) (highly colored)

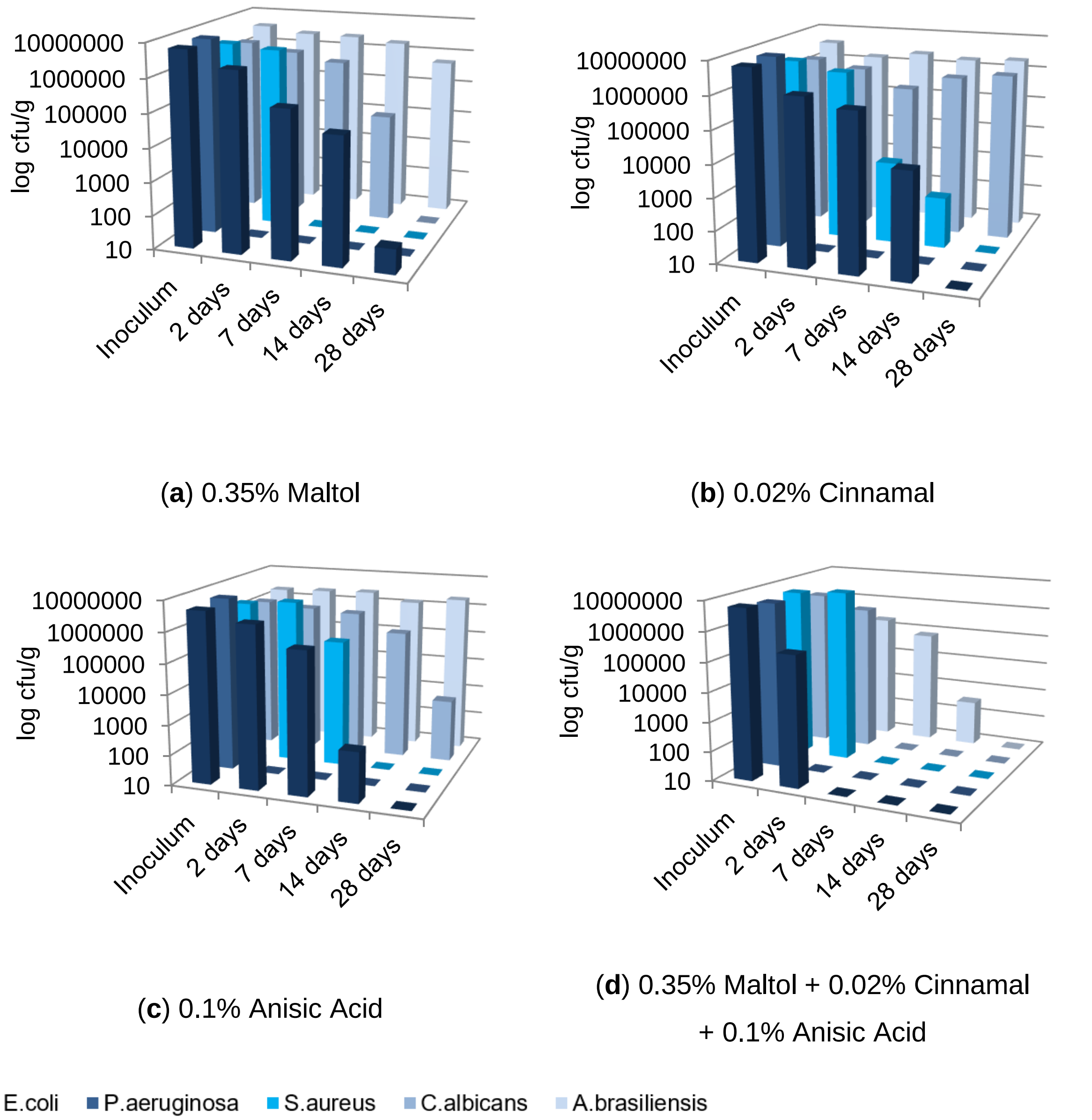
Cu(II) + Chelator + PV → Chelator*Cu(II) + PV (less color)

The ability to stabilize o/w emulsions was determined via oil droplet size measurements by laser diffraction (Malvern Mastersizer 3000) and analytical photocentrifugation (Lumisizer). For the test a model emulsion was used. Evaluation was performed by using the mean value (volume based, Dv [4,3]). (Mie Scattering Model). The LumiSizer device was used to assess the dispersion stability of the emulsion. Test parameters were 3000rpm rotation speed, 40°C for 4 hours. The instability Index is a dimensionless number between 0 and 1. The higher the instability index the lower the stability. It´s calculated by the clarification at a given separation time, divided by the maximum clarification. Clarification is quantified by the increase in transmission due to phase separation. [1]

3. Results

1.1. Product protection

The single ingredients (a-c) failed in preservative , whereas the combination of different plant-based ingredients (d) passed the requirements (Criteria A for ISO norm and Criteria B for Ph.Eur).



(**a**) 0.35% Maltol

(**b**) 0.02% Cinnamal

(**c**) 0.1% Anisic Acid

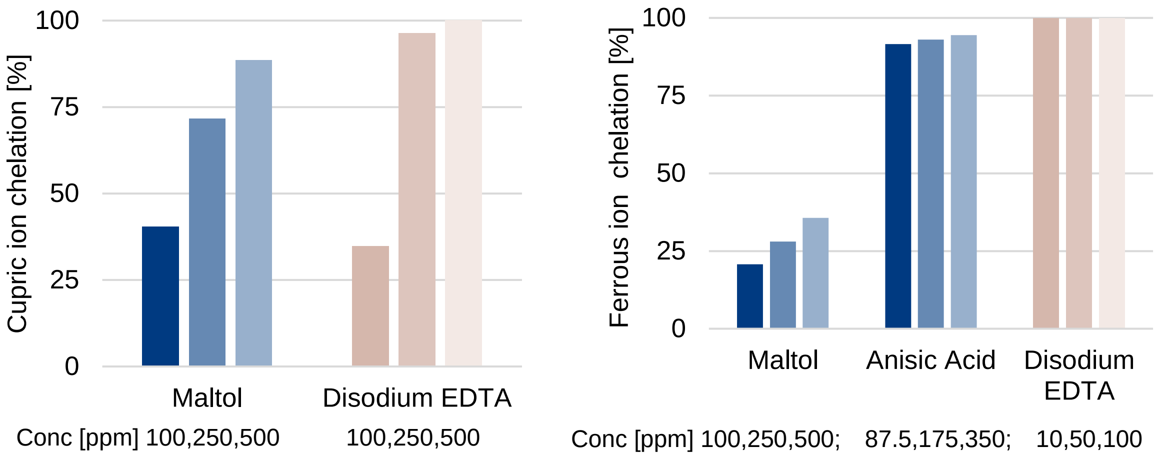
(**d**) 0.35% Maltol + 0.02% Cinnamal + 0.1% Anisic Acid

Figure 1. Antimicrobial efficacy in anionic oil in water (o/w) emulsion

For all ingredients additional benefits e.g. chelating, antioxidative, soothing or emulsion stabilizing could be identified.

1.2. Chelating properties

Test for chelating properties revealed the capability of Maltol and Anisic Acid to chelate Cupper and Ferrum. For Cupper Maltol shows similar results compared to Disodium EDTA which is a well known chelator (Figure 2).

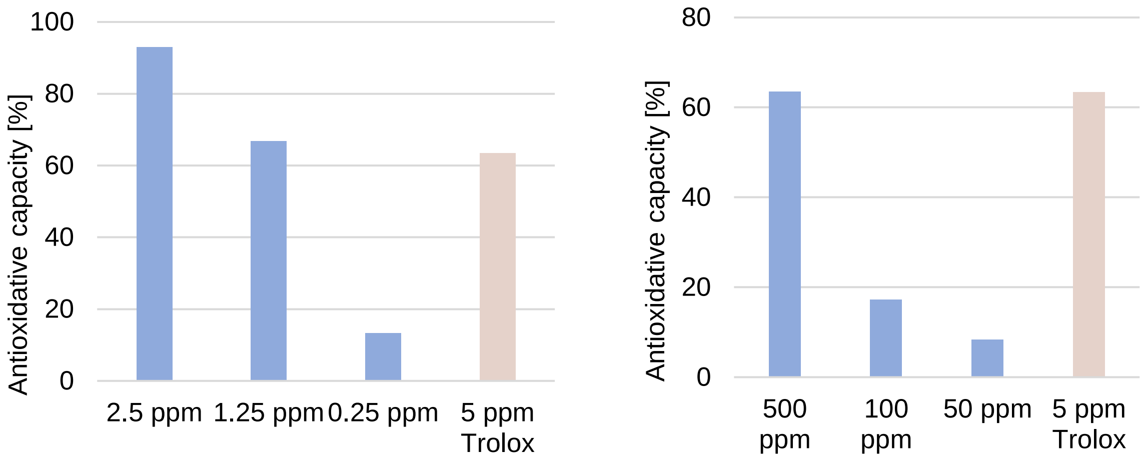


(a) Cupric Assay (**b**) Ferrous Assay

Figure 2. Chelating properties in comparison to Disodium EDTA (a) Cupric Assay, (b) Ferrous Assay

1.3. Antioxidant properties

Maltol and Cinnamal showed Antioxidant properties (Figure 3)



(**a**) Maltol (**b**) Cinnamal

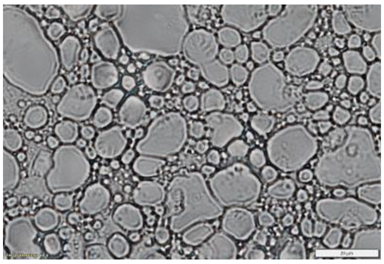
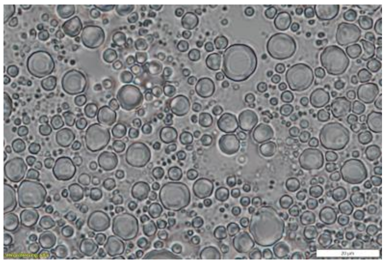
Figure 3. Antioxidant properties in comparison to reference Trolox (a) Maltol and (b) Cinnamal

1.4. Influence on emulsion properties

An o/w emulsion containing 0.3% Maltol was used to investigate the influence on emulsion stability.. The same emulsion without Maltol served as a reference.The oil droplet size of both emulsions weredetermined.

It could be clearly demonstarted that the addition of Maltol leads to smaller oil droplets in comparison to the reference sample. This effect was also supported by the results after photocentrifugation. (lower instability indices of Maltol containing emulsion.)

Table 1. Influence of Maltol on emulsion properties

	Reference	0.3% Maltol
Instability index	0.625	0.329
Oil droplet size [µm]	10.65	8.35
Microscopic images		

4. Discussion

Consumer demand for plant based and biodegradable cosmetic ingredients has led to the exploration of natural preservatives. While individual plant extracts may exhibit limited anti-microbial efficacy, a combination of Maltol, Cinnamal, and Anisic Acid in a specific ratio demonstrated effective broad-spectrum antimicrobial activity in O/W emulsions (Figure 1), fulfilling both ISO and Ph. Eur preservative criteria. The concentration of cinnamal was kept low (0.02%) to avoid undesirable odor contributions.

The chelating properties of Maltol and Anisic Acid are a further advantage (Figure 2), with Maltol exhibiting comparable copper chelation to EDTA. Although EDTA is a gold standard chelator, its low biodegradability is a concern, making Maltol and Anisic Acid attractive alternatives.

The antioxidant properties of Maltol and Cinnamal (Figure 3) are also advantageous, contributing to formulation stability. Maltol's co-emulsification behavior, demonstrated by the reduced oil droplet size and lower instability index (Table 1, Figure 4), further enhances emulsion stability.

Future research will investigate the potential of these ingredients in rinse-off cosmetic applications.

5. Conclusion

With the intensive work on the plant-based ingredients, it was possible to identify specific combinations, where naturality and performance are going hand in hand. Also with regard to stability, color and odor these ingredients meet the requirements.

They represent the start of a new, plant-based and innovative platform for natural born multifunctionals, which can be used as a toolbox, fulfilling the needs of modern product protection of various formulation types.

References

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