# THESIS OF DOCTORAL (PhD) DISSERTATION

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# Characterization and Green Extraction of Plant Bioactives: Encapsulation of Roselle Extract for Functional Dairy Dessert Development

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## 1. Introduction

Interest in polyphenols for functional food applications is rising due to their health benefits and industrial advantages. Notably, polyphenols are recognized for their antioxidant capabilities, which enable them to mitigate diseases linked to oxidative cell damage. In this study, coffee (*Coffea arabica*) and roselle (*Hibiscus sabdariffa* L.) calyx were selected for polyphenol extraction because of their high polyphenol content, especially due to the abundance of chlorogenic acid (CGA). Determining the exact concentration of phenolic compounds in plant extracts is a critical step. Therefore, a high-performance liquid chromatography (HPLC) combined with a photo-diode array (PDA) detection method was applied to quantify CGA in the above plant extracts in addition to certain spectrophotometric methods (e.g., total phenolic content—TPC, total flavonoid content—TFC, antioxidant activity).

Enhancing the bioavailability of polyphenols is challenging, necessitating the development of technologies that preserve polyphenols during digestion. One effective method is encapsulation (ENC), which involves entrapping active ingredients in food-grade, biodegradable materials to protect them and improve their delivery in foods. Selecting an appropriate solvent is crucial before ENC to maximize phenolic yield and activity. Being non-toxic, biodegradable, and effective at dissolving various phenolic compounds, natural deep eutectic solvents (NADESs) allow extracts to be used directly in food or pharmaceutical applications without complex removal processes, and hence, was selected as the extraction solvent in this study. The main objective was to develop an ENC

method for polyphenol-rich roselle calyx extract and apply it to a dairy-based functional food. Addressing gaps in existing research on encapsulating NADES extracts of roselle calyx, focusing on heat-sensitive phenolics, this study developed a freeze-drying ENC method for roselle calyx phenolics extracted with glucose and lactic acid-based NADES.

Objectives

1. To develop and optimize an HPLC-PDA method for the analysis of CGA in roselle calyx and coffee extracts.
2. To optimize the ENC parameters for a NADES-based roselle calyx extract with phenolic compounds
3. To develop a dairy-based functional food that contains encapsulated polyphenols
4. To analyze the antioxidant properties of the developed functional food occupying 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging approach

## 2. Methodology

### 2.1. Extraction of roselle calyx phenolics with ethanol

Roselle extracts were prepared using 1 g dehydrated flower per 100 mL solvent in triplicate, following a $3^3$ factorial design to test the effects of solvent (25%, 50%, 75%), pH (2.0, 4.5, 7.0), and extraction time (20 min, 40 min, 60 min) on 5-CQA yield. pH was adjusted with specific buffer solutions, and samples were heated under reflux at boiling for set times. A response surface model (RSM) using a box-Behnken design was employed to evaluate the relationship between the three independent

variables and the dependent variable—area of the 5-CQA peak in the chromatogram.

### 2.2. Extraction of phenolics from green coffee beans and roselle calyx with NADESs

Green coffee beans were dehydrated at 40-45˚C for 6 hours, ground to 400-500 μm, then extracted using a NADES solvent—glucose-glycerin (Glu-Glyc) (1:1 M)—at a 1:20 (w/w) solid-to-solvent ratio. Extraction was performed at 30±2˚C and 150 rpm for 30, 60, or 90 min, and also at 50±2˚C for 30 min. After extraction, samples were centrifuged at 6000 rpm for 10 min, supernatant was diluted fivefold, filtered (0.22 μm hydrophilic filter), and analyzed. Solvent and dilution volumes were optimized in pre-trials. Comparative extracts were prepared using water and 50% (v/v) aqueous ethanol under the same conditions.

Three glucose-based NADESs (Glu-Glyc—1:1 M, glucose-citric acid (Glu-CA)—1:1 M, glucose-lactic acid (Glu-LA)—1:5 M) were tested for extracting phenolics from roselle calyx. Extractions were done at 30±2˚C and 50±2˚C for 30 min with shaking (150 rpm), using a 1:20 (w/w) solid-to-solvent ratio. After extraction, samples were centrifuged at 6000 rpm for 10 min, supernatants were diluted 5-fold with deionized water and analyzed by spectrophotometry and HPLC after filtration through a 0.22 μm hydrophilic filter. As controls, 80% (v/v) aqueous ethanol and 80% (v/v) ethanol with 0.1% (v/v) HCl were used.

### 2.3. HPLC-PDA analysis of CGA in roselle calyx and green coffee bean extracts

To quantify 5-CQA in NADES extracts, a calibration curve (y=7364x-3495) was prepared by plotting peak area at 325 nm versus 5–50 μg/mL 5-CQA standards. Separation and quantification used an InertSustain Phenyl column (5 μm, 3×150 mm) at 35˚C, with 7% (v/v) acetonitrile and 93% (v/v) water (0.1% (v/v) phosphoric acid) as mobile phase, at 1.2 mL/min flow rate and 2 μL injection volume. Quantification of 3-CQA and 4-CQA was accomplished by multiplying the respective isomer concentration as calculated with the 5-CQA standard curve (*Conc.* $_{isomer}$) by the respective molar extinction coefficients ($\varepsilon$) (5-CQA=1.95, 3-CQA=1.84, 4-CQA=1.80) using Eq. 1. The elution order was identified with literature.

$$Concentration\ of\ CQA\ isomer = \frac{Conc._{isomer}}{1.95} \times \varepsilon\ of\ CQA\ isomer \qquad \text{Eq.1}$$

To quantify 5-CQA in ethanolic extracts of roselle calyx, separate 5-CQA calibration curves were developed based on the separation performed using two HPLC columns: InterSustain Phenyl column and Synergi Polar column, following a predetermined isocratic procedure (similar to the above method).

### 2.4. HPLC-PDA analysis of caffeine in green coffee bean extracts

To quantify caffeine concentration in green coffee extracts, a calibration curve (y=38153x) was prepared by plotting peak area at 275 nm versus 5–100 μg/mL caffeine standards. Separation and quantification used an InertSustain Phenyl column (5 μm, 3×150 mm) at 35˚C, with 7%

(v/v) acetonitrile and 93% (v/v) water (0.1% (v/v) phosphoric acid) as mobile phase, at 1.2 mL/min flow rate and 10 µL injection volume.

### 2.5. Analysis of phenolic compounds in plant materials extracted with NADES using spectrophotometric methods

#### 2.5.1. TPC of green coffee beans and roselle calyx

A 100 µL sample was mixed with 1.5 mL water, 2.5 mL 10% (v/v) Folin-Ciocalteu reagent, and 2 mL sodium carbonate (7.5 g/100 mL). After incubating 90 min at room temperature, absorbance was measured at 725 nm versus a blank. TPC was calculated using a gallic acid standard curve ($y=1.2929x+0.011$, $R^2=0.999$) and expressed as mg gallic acid equivalents per gram dry plant material (mg GAE/g).

#### 2.5.2. Total flavonoid content (TFC) of roselle calyx

A 500 µL sample was mixed with 1.5 mL of methanol, 100 µL of 10% (v/v) aluminum chloride, 100 µL of 1 M sodium acetate, and 2.8 mL of deionized water. After standing in the dark for 30 min at room temperature, absorbance was measured at 415 nm against a sample blank (no aluminum chloride). TFC was calculated using a quercetin standard curve ($y=0.0088x+0.003$, $R^2=0.999$) and expressed as mg quercetin equivalents per gram dry roselle (mg QE/g).

#### 2.5.3. Total monomeric anthocyanin (TMA) content of roselle calyx

A 0.5 mL sample was diluted with 4.5 mL of sodium acetate buffer (0.4 M, pH 4.5) and potassium chloride buffer (0.025 M, pH 1.0), respectively, and then incubated for 30 min. Absorbance was measured at

520 and 700 nm against deionized water. Absorbance difference (A) was calculated using Eq. 2.

$$A = (A_{520nm} - A_{700nm})_{pH\ 1.0} - (A_{520nm} - A_{700nm})_{pH\ 4.5} \quad \text{Eq.2}$$

Anthocyanin concentration was calculated using Eq. 3 and expressed as mg delphinidin-3-sambubioside equivalents per gram dry material (mg DSE/g), using $\varepsilon$=26,900 L/mol/cm and *MW*=597.5 mg/mol. *DF* and *L* are the dilution factor and path length.

$$Anthocyanin\ pigment\ concentration\ \left(\frac{mg}{L}\right) = \frac{A \times MW \times DF \times 1000}{\varepsilon \times L} \quad \text{Eq.3}$$

### 2.5.4. DPPH radical-scavenging activity of roselle calyx

A diluted extract of 100 µL was mixed with 3 mL 0.1 mM methanolic DPPH solution and kept in the dark for 30 min at room temperature. Absorbance was measured at 517 nm against a blank (100 µL methanol+3 mL DPPH). The % inhibition was calculated using Eq. 4.

$$\%\ Inhibition = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad \text{Eq.4}$$

DPPH % inhibition value of each extract was compared to an ascorbic acid standard curve (y=0.0046x-0.0023, $R^2$=0.999). Antioxidant activity was reported as mg ascorbic acid equivalents per gram dry material (mg AAE/g).

### 2.6. ENC of NADES extract of roselle calyx

Glu-LA (1:5M) based roselle calyx extract with 1:20 solid-to-solvent ratio was prepared, following incubation at 50±2˚C and 150 rpm for 30 min. For ENC, MD, and GA (excipients) were combined in five ratios: A (1:0), B (1:3), C (1:1), D (3:1), E (0:1). Each 10 g mixture of excipients was dissolved in 6 g deionized water (45–50˚C), mixed with 4 g roselle

extract and 0.14 g aerosil, and then stirred until smooth. Mixtures were first pre-frozen at −25˚C for 12 h, then freeze-dried: 90 mT and −80˚C for 24 h. Dried materials were ground to powder and stored at ~4˚C. Each combination was evaluated for ENC efficiency, drying yield, and moisture content.

### 2.6.1. Determination of ENC Efficiency, drying yield and moisture content of encapsulates

ENC efficiency was calculated as the percentage of total anthocyanin encapsulated versus surface anthocyanin (Eq. 5).

$$ENC\ Efficiency\ \% = \frac{Total\ Anthocyanin - Surface\ Anthocyanin}{Total\ Anthocyanin} \times 100 \qquad \text{Eq.5}$$

Drying yield was calculated (Eq. 6) from the final dry weight of encapsulated powder ($DW_{final}$) and total initial solids ($WI$).

$$Drying\ Yield\ \% = \frac{DW_{final}}{WI} \times 100 \qquad \text{Eq.6}$$

Moisture content was calculated by heating a known weight of encapsulated powder ($W_i$) at 105˚C for 30 min until constant weight ($W_f$), then expressing the loss of weight as percent moisture.

### 2.6.2. Determination of functional properties of encapsulated powder

The treatment that demonstrated the highest ENC efficiency was further analyzed for TPC, TMA, and DPPH radical-scavenging activity, following the methods described in Section 2.3. To improve the accuracy, total and surface measurements were taken and their difference was considered.

### 2.6.3. Determination of powder properties and solubility of encapsulates

Bulk density was measured by filling a 10 mL graduated cylinder with 5 g of powder and dividing mass by volume. Tapped density was measured after tapping 120 times. Carr index and Hausner ratio were calculated as below.

$$Carr\ Index = \frac{Tapped\ density - Bulk\ density}{Tapped\ density} \times 100 \qquad \text{Eq.7}$$

$$Hausner\ Ratio = \frac{Tapped\ density}{Bulk\ density} \times 100 \qquad \text{Eq.8}$$

Solubility was determined as the average time to completely dissolve 2 g powder in 50 mL deionized water at 30±2˚C with magnetic stirring.

### 2.6.4. Determination of color stability (by spectrophotometric absorbance) at varying pH levels

0.1 g of powder was dissolved in 10 mL buffers at pH 1.0, 2.0, 4.5, and 6.8, respectively. Spectrophotometric absorbance at 535 nm was measured over three hours. At pH 6.8, the degradation rate constant ($k$) was calculated using Eq. 9, where $t$ is time, $C_0$ is initial, and $C_t$ is final concentration.

$$k = \frac{1}{t} ln \times (C_0/C_t) \qquad \text{Eq.9}$$

## 2.7. Developing a dairy dessert (Túró Rudi) incorporating freeze-dried encapsulated powder of roselle

A 250 g portion of curd was creamed and mixed with 50 g of icing sugar, 1 teaspoon of vanilla extract, 8 g of vanillin sugar, the grated zest of one medium-sized lemon. Encapsulated roselle extract powder was added at three levels (2%, 5%, 9%, w/w) calculated based on the combined

weight of the curd basis and the respective mass was replaced with the encapsulated powder. Mixtures were homogenized, shaped into bars with 2 cm thickness and 4 cm length, frozen for 1–2 hours, then coated with melted dark chocolate (54.5% cocoa, plus sunflower oil) and stored at −18˚C. Túró Rudi (composed of both the coat and core) was first defatted by extraction with n-hexane at a solid-to-solvent ratio of 1:10, centrifuged for 10 min at 6000 rpm, and the supernatant with fat was removed. Washing the sample with n-hexane was repeated for the second time, and the remaining solid product was oven-dried at 40˚C for 45 mins. Defatted Túró Rudi (0.75 g) was extracted with 80% (v/v) ethanol at a solid-to-solvent ratio of 1:20 (g/mL) and shaken-incubated (150 rpm, 30±2˚C) for 30 min to measure TPC, TMA, and antioxidant activity.

Moisture, salt, protein, fat, and total solids of the curd base of Túró Rudi were measured by a near-infrared rapid food analyzer. Sensory properties were assessed by 20 semi-trained panellists in terms of visual assessment (9-point hedonic scale), comparison with control (herbal flavor, pink/redness, and texture), and overall preference.

## 3. Results and Discussion

### 3.1. Optimization of the extraction conditions and quantification of 5-CQA in ethanolic extracts of roselle calyx

Roselle extraction experiments with RSM model revealed that the highest 5-CQA yields were achieved using 25% ethanol at pH 7 with a 20-minute heat treatment. This optimized method produced 1.43 mg and 1.48 mg 5-CQA per gram of dried hibiscus as tested with an InertSustain Phenyl column and a Synergi Polar column, respectively.

### 3.2. NADES for the extraction of phenolics from green coffee beans

The study found that Glu-Glyc-based NADESs are effective alternatives to water and ethanol for extracting phenolic compounds from green coffee beans, yielding the highest TPC at 48.7±0.6 mg GAE/g at 30˚C after 30 min of extraction, which remained nearly unchanged at 90 min (48.6±0.6 mg GAE/g), and was significantly higher ($p<0.05$) than 50% ethanol and water at the same extraction times. For CGA, the highest 5-CQA yield was 41.5±0.5 mg/g using 50% ethanol at 30˚C for 30 min, while NADES at the same conditions gave 38.9±0.9 mg/g and water yielded 34.3–34.8 mg/g. Total CGA was also highest in ethanol extracts at 30˚C for 30 min (52.4±0.6 mg/g). TPC in NADES was similar at 30˚C and 50˚C ($p>0.05$). Overall, NADES at both 30˚C and 50˚C for 30 min is optimal for TPC, while extended extraction times (60 or 90 min) are ideal to improve CGA yields extracted from green coffee beans.

### 3.3. NADES for the extraction of phenolics from roselle calyx

Extraction of bioactive compounds from roselle calyx was compared across various solvents, with a focus on NADESs. Glu-LA consistently outperformed other NADES and conventional solvents in extracting phenolics and anthocyanins. At 50˚C. Glu-LA yielded the highest TPC at 22.96±1.06 mg GAE/g, outperforming other NADES and conventional solvents. Glu-LA also achieved strong TMA content (8.13±0.43 mg DSE/g) and notable antioxidant activity (13.9±0.80 mg AAE/g). Glu-LA remained competitive with aqueous ethanol in CGA and flavonoid extraction. These results highlight Glu-LA’s efficiency as a green solvent

for maximizing antioxidant-rich phenolic compound recovery from roselle calyx, particularly when extraction is performed at elevated temperatures.

### 3.4. ENC efficiency, drying yield, moisture content, visual properties and functional properties of encapsulated powder

The ENC of roselle calyx extract using freeze-drying with MD and GA mixtures was thoroughly evaluated, with the 3:1 MD:GA ratio (treatment D) selected for its optimal balance of properties. This mixture offered the highest ENC efficiency (99±0.02%), moderate drying yield (90±0.01%), and low moisture content (5–6%), resulting in a stable powder (Figure 1).

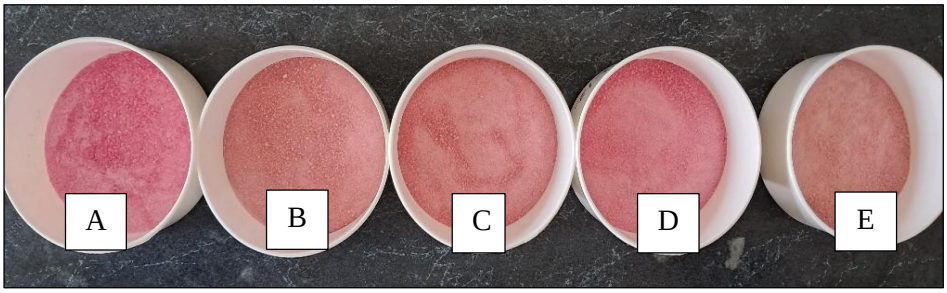


**Figure 1** NADES extracts of roselle calyx after freeze-drying ENC

The encapsulated powder contained 2.50±0.08 mg GAE/g total phenolics, 0.36±0.03 mg DSE/g TMA, and 0.36±0.04 mg AAE/g antioxidant activity, which, though lower than raw extract due to dilution, indicate effective stabilization of bioactives. Powder properties were excellent, with a Carr index of 10 ±0.00% and Hausner ratio of 1.11±0.00, reflecting outstanding flowability and low compressibility, while complete solubility was rapid (51±1.41 s). The encapsulated anthocyanins were highly unstable at neutral pH ($k$=1.087/hr at pH 6.8), but much more stable and suitable for controlled release in acidic conditions (pH 1.0–2.0), as

supported by a release exponent (n=1.02) indicating potential swelling- and erosion-driven release. These findings suggest the 3:1 MD:GA encapsulated roselle powder is well-suited for use in acidic foods or applications requiring targeted release, with prospective vigorous physical and functional characteristics for industrial use.

### 3.5. Characteristics of Túró Rudi with roselle encapsulated powder

The study on Túró Rudi fortified with roselle encapsulated powder revealed that TPC significantly increased at the 9% addition level (T3) (4.50±0.03 mg GAE/g), owing to the natural richness of roselle calyx in polyphenols such as protocatechuic acid, hibiscus acid, quercetin, CGA, and catechin. The substantial TPC boost in Túró Rudi compared to the encapsulated powder likely to have an impact of ingredients in the dark chocolate. TMA content in Túró Rudi remained low but increased at the 9% fortification, with MD and GA-based wall materials effectively protecting anthocyanins from degradation at higher pH levels. However, TMA dropped compared to the encapsulated powder, likely due to anthocyanin binding to milk proteins. Antioxidant activity exhibited a significant increase from the 5% fortification level (T2), reaching 1.31±0.01 mg AAE/g in T3, compared to the control's 0.87±0.01 mg AAE/g, underscoring synergistic effects between dairy proteins, roselle extract, and chocolate phenolics. The 3:1 MD to GA wall matrix provided efficient protection of bioactives throughout the Túró Rudi making process, ensuring high TPC and antioxidant activity despite reduced TMA levels.

The incorporation of roselle encapsulated powder into Túró Rudi resulted in an increase in protein content from 14.66% (control) to 15.60% (T3), while fat content decreased from 6.38% to 5.15%, reflecting the substitution of fat-rich cheese curd with carbohydrate-based powder. Moisture content slightly decreased, and total solids increased significantly ($p<0.05$), contributing to a firmer texture, though salt concentration and moisture changes were not statistically significant ($p>0.05$).

Sensory tests showed no significant difference ($p>0.05$) in color preference (median scores—Reference: 7.0, T1: 7.0, T2: 6.5, T3: 7.5). In the comparison with control test, T3 showed an intense tartness, softness, and pink/redness, suggesting a potent effect of this treatment on both chemical (flavor) and physical (pigment and texture) properties. However, both the tartness and softness were not statistically significant ($p>0.05$) among the three treatments, while pinkness was significantly higher ($p<0.05$) in T2 and T3. Considerably higher pinkness demonstrates higher anthocyanin levels in T2 and T3. Although the overall likeliness among treatments was not significant significant ($p>0.05$), T2 showed a strong descriptive lead in preference. Overall, adding roselle encapsulated powder enhances the nutritional quality and appearance of Túró Rudi, though further taste balancing may be needed for higher fortification levels.

**New Scientific Results**

1. The optimal extraction parameters for roselle calyx were identified: The highest CGA yield from roselle calyx was achieved using an extraction pH of 7.0, 25% ethanol concentration, and 20 min extraction time when quantified by the HPLC-PDA method.
2. NADES solvent efficacy was defined for green coffee beans: Glu-Glyc-based NADES yielded competitive CGA (50.8±0.3 mg/g) and overall phenolic recovery (TPC: 48.7±0.6 mg GAE/g) to those of aqueous ethanol (CGA: 52.0±0.3 mg/g, TPC: 45.0±0.5 mg GAE/g), while offering superior sustainability and safety.
3. Superior green extraction was developed for phenolics from roselle calyx: Glu-LA-based NADES outperformed conventional ethanol in total phenolic yield (TPC: 22.69±1.06 mg GAE/g) and antioxidant activity (DPPH radical scavenging activity 13.9±0.80 mg AAE/g) at 50˚C, 30 min extraction, while resulting in comparable monomeric anthocyanins (TMA: 8.13±0.43 mg DSE/g;), and CGA (2.50±0.02 mg/g) yields, making it an effective, superior green solvent.
4. Advanced ENC method was developed: The freeze-drying ENC method utilizing a 3:1 blend of MD to GA yielded a 99% ENC efficiency for polyphenol-rich green extracts of roselle calyx. The resulting excellent powder properties (free-flowing: 10%±0.00 Carr index and 1.11±0.00 Hausner ratio) low moisture (5.31%±0.00), quick water solubility (51±1.14 s), and excellent colour stability at pH 1-2, ideal for functional food systems.

5. Túró Rudi fortification was achieved: A dairy dessert (Túró Rudi) was developed by incorporating the encapsulated roselle extract powder at 2%, 5% and 9% fortification (calculated based on the weight of curd basis). Higher level fortification (9%) resulted in 4.50±0.03 mg GAE/g of TPC, 0.05±0.04 mg DSE/g of TMA and 1.31±0.01 mg AAE/g of antioxidant activity.

**List of publications**

**Journal articles (Peer-reviewed Indexed Journals)**

1. UR Chandimala, Zsolt Ajtony, Beatrix Sik (2024). Citrus flavonoids (naringin and hesperidin) as functional ingredients in dairy products, Bio Web of Conferences, 125, 02004. https://doi.org/10.1051/bioconf/202412502004
2. UR Chandimala, Zsolt Ajtony (2025). Application of chlorogenic acid in dairy product enrichment/fortification – a review, LWT-Food Science & Technology, 232. https://doi.org/10.1016/j.lwt.2025.118416 (D1)
3. UR Chandimala, Ottó Dóka (2026). Rheological analysis of dairy products: Instrumentation and Applications to Functional Dairy Products Enriched with Plant-based Ingredients, International Journal of Food Studies (Accepted to publish) (Q3)
4. UR Chandimala, Zsolt Ajtony, (2026). Green Extraction and Advanced Encapsulation of Roselle (*Hibiscus sabdariffa* L.) Phenolics: Harnessing Natural Deep Eutectic Solvents for Sustainable Nutraceutical Applications, Green Analytical Chemistry (Under review) (Q1)

**Journal articles (Peer-reviewed non-indexed Journals)**

1. UR Chandimala, Beatrix Sik, Zsolt Ajtony (2025). An Experimental Design for the Analysis of 5-Caffeoylquinic Acid (5-CQA) in Ethanolic Extracts of Hibiscus (*Hibiscus sabdariffa* L.) Flower, Georgikon for Agriculture, 29, 1-16. https://doi.org/10.70809/6561
2. UR Chandimala, Zsolt Ajtony (2025). Quantification of Caffeine and 5-Caffeoylquinic Acid (5-CQA) in Seven European Commercial Coffee (*Coffea arabica*) Types Using HPLC-PDA, Journal of Agro-Technology and Rural Sciences, 5(1), 1-5. https://doi.org/10.4038/atrsj.v5i1.71
3. UR Chandimala, Beatrix Sik, Zsolt Ajtony, (2026). The Potential of Natural Deep Eutectic Solvents for the Extraction of Phenolic Com-pounds and Caffeine from Green Coffee (*Coffea arabica*) Beans, Acta Agronomica Óváriensis, 67(1). https://doi.org/10.17108/ActAgrOvar.2026.67.1.90
4. UR Chandimala, Beatrix Sik, Zsolt Ajtony, (2026). Developing a dairy dessert (Túró Rudi) with freeze-dried encapsulated powder of roselle (*Hibiscus sabdariffa* L.) calyx, Advances in Food Sciences (accepted to publish)

**Conferences attended**

1. The 6th National Symposium on Agriculture, Eastern University, Sri Lanka, 2024.03.12-oral presentation on “A mini-review: incorporating encapsulated polyphenols in meat products”.
2. The 10th International Conference on Agricultural and Biological Sciences, Szechenyi Istvan University, 2024.07.25-oral presentation on “Citrus flavonoids (naringin and hesperidin) as functional ingredients in dairy products”.
3. XXXIV Keszthely Plant Protection Forum, MATE Georgikon Capus, 2025.01.16-oral presentation on “An Experimental Design for the Analysis of 5-Caffeoylquinic Acid (5-CQA) in Ethanolic Extracts of Hibiscus (*Hibiscus sabdariffa* L.) Flower”
4. International Symposium on Agro-Technology and Rural Sciences, University of Colombo, Sri Lanka, 2025.06.26-oral presentation on “Quantification of Caffeine and 5-Caffeoylquinic Acid (5-CQA) in Seven European Commercial Coffee (*Coffea arabica*) Types Using HPLC-PDA”
5. 40th óvár scientific day international conference, 2025.11.12-oral presentation on “Assessing the Potential of Natural Deep Eutectic Solvents (Glucose and Glycerin) for the Extraction of Phenolic Compounds and Caffeine from Green Coffee Beans”
6. Agriculture and Food conference, Bulgaria 2026.08.10-13-oral presentation on “A review: application of plant phenolics in meat products”.