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AGRICULTURE AND LIFE SCIENCES

Institute of Food Science and Technology

INVESTIGATION ON THE EMULSIFICATION AND MICROENCAPSULATION OF OLIVE OIL

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1. INTRODUCTION AND OBJECTIVES

Olive oil has been considered as a culinary for its excellent organoleptic properties due to presence of ketones, alcohols, aldehydes, hydrocarbons, esters, furans, etc. It also has a great importance for biopharmaceutical formulation because it prevents the risks of several chronic and acute metabolic disorders (type 2 diabetes, obesity, cancer, rheumatoid arthritis, Alzheimer's disease, and cardiovascular diseases). Olive oil is enriched with monounsaturated fatty acids (ω-6 and ω-3 fatty acids), phenolic antioxidants (hydroxytyrosol and oleuropein), flavonoids, secoiridoids, vitamin E and vitamin K. Unfortunately, oxidative deterioration of fatty acids in olive oil provides short shelf-life, responsible for undesirable organoleptic properties and reduced biological activities. Therefore, microencapsulation of olive oil is considered as a promising approach to preserve its quality and biological activities. Microencapsulation is an emerging technology, which has been received interest in food, biopharmaceutical, and cosmetic industries. It is used to protect bioactive compounds within surrounding layer (coating) and control their release in environment. In this process, a small droplet of liquid or solid particle is surrounded by a thin film, known as a wall material or matrix. The matrix could act as a barrier and it may protect the encapsulated bioactive compound against oxygen, water, light and contact with other ingredients. For microencapsulation of vegetable oils, several emulsification technologies have been used. It has been reported that

the size and shape of microcapsules depend on the characteristics of wall material, method, and technology of emulsification and dehydration. Presently, membrane emulsification (ME) has come to the forefront, and it is considered as an emerging emulsification technology. In the platform of “process intensification”, membrane emulsification is a low energy consuming technique with lower equipment footprint. ME is carried out using a microporous membrane. One of its realization options is crossflow design. In this case, to reach dispersed droplets, the dispersion phase is forced through the membrane pores under pressure, resulting in droplets on the membrane surface. The droplets are sheared off by the flow of the continuous phase running parallel to the fine pore membrane. They are detached from the surface of the membrane to form emulsified drops.

During my work, I analysed the methods and possibilities of olive oil microencapsulation by varying emulsification and dehydration methods as well as the formulation of the wall materials. I have done a comprehensive literature research related mainly to the present status of the microencapsulation of olive oil and its possible applications in food, pharmaceutical and cosmetic industries. I designed my experiments along three main lines.

1.1. Effect of change of emulsification method and wall materials composition on microencapsulation of olive oil

The objective of this part of my PhD work was to investigate the microencapsulation of extra virgin olive oil by freeze drying (FD) to increase its stability and application area. The effect of homogenization methods in terms of rotor stator homogenisation (RSH) and cross flow membrane emulsification (CFME) and the effect of wall materials composition were examined on the physical properties of olive oil microcapsule. Maltodextrin (MD), carboxymethylcellullose (CMC) and gum arabic (GA) were used as wall materials and microencapsulation was carried out in a laboratory type freeze dryer. Concentrations of CMC and MD (with DE 5) were varied; however, the concentration of GA was constant. CMC and MD (DE 5) are considerable hydrophobic which influences the detachment of oil droplets (hydrophobic nature) from membrane pores due to surface tension (hydrophobic-hydrophobic interaction). Related tasks include:

- Emulsion production by RSH and CFME process with different wall material compositions,
- Investigating emulsions' stability, droplet size and span.
- Emulsion dehydration by FD,
- Investigating powders' moisture contents, particle size and span and encapsulation efficiency (EE).
- Studying the surface morphology of produced microcapsules by a field emission scanning electron microscope (FESEM).
- Define optimal parameters,

- Establish the significant differences between different groups by SPSS (statistics software).

1.2. Effect of change of the drying method and wall material composition on the microencapsulation of extra virgin olive oil

The objective of this part was to understand the effects of wall material and method of drying for the encapsulation of extra virgin olive oil. MD and whey protein isolate (WPI) were considered as matrix for the microencapsulation of olive oil. In the first stage, emulsions were prepared with aqueous solutions of MD (DE 19) and WPI with olive oil. Different ratios of MD and WPI were considered to prepare emulsion. Tween 20 was used as an emulsifier. Five wall systems were tested consisting of WPI alone, MD alone and three different combinations of them. In later exercise, emulsion was considered to prepare olive oil microcapsule by drying technology. Two different drying technologies, spray drying (SD), and FD were adopted. Emulsion was characterized by stability, viscosity, and liquid droplet size. Furthermore, olive oil microcapsules were characterized by EE, particle size, moisture content and surface morphology. In the literature, very few publications can be found, which would expressly design food products based on ME. For this reason, in the framework of process intensification, I aimed at developing an olive oil powder by CFME. In any case, a higher efficiency of encapsulation and protective capacity against oxidation were the goals. My target was to use the optimal composition of ingredients (olive oil and wall materials).

Related tasks include:

- Determination of optimum manufacturing parameters (wall materials composition and dehydration method) for the preparation issued by RSH method,
- Powder production using the specified parameters by CFME,
- Investigating moisture contents and EE of the produced microcapsules,
- Oxidative stability of the produced powders,
- Morphology of the produced powders.

1.3. Microencapsulation based emulsification/ external gelation technique

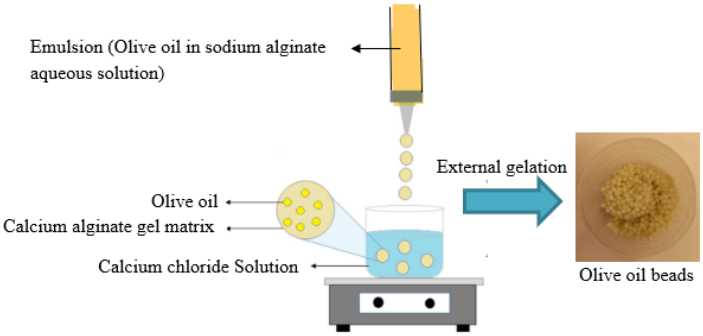

Figure 1: Schematic representation of the process of emulsification/external gelation.

The overall aim of this part of my PhD was to encapsulate olive oil in Ca-alginate beads to produce beads containing a higher oil content. One of the most common methods of encapsulation is the ionic gelation with formation of alginate gels by ionic cross-linking with multivalent cations. The process of encapsulation is affected by various factors such as sodium alginate and olive oil concentrations and the homogenization rate of the rotor stator homogenizer. Design of expert (DOE) is a technique that quantifies the effects of various factors on a response and optimizes them in well-defined experimental areas. This technique consists of the organization of a series of tests by manipulating the factors to describe the method making it possible to obtain an optimal response. The response surface methodology (RSM) is part of the design of experiments used for optimization. Box-Behnken designs (BBD) is among the most used types of RSM. Related tasks include:

- Establishing the BBD design based on the different variables,
- Optimization of the process parameters for preparation of capsules with high oil phase content,
- Determining crucial operating parameters from the mathematical model.

2. MATERIALS AND METHODS

2.1. The ingredients of the emulsions and their preparation

For making emulsions, I used commercially available olive oil and distilled water and wall materials. Maltodextrin (MD, DE=5) was procured from Applichem panreac itw companies, Gum arabic was purchased from Bi-Bor Kft, carboxymethylcellulose (E466) was procured from Gréta- tortadekoracio- hunguary. Maltodextrin (MD, DE= 19) and whey protein isolate (WPI 90) were purchased from Buda Family Kft., Austria. Tween 20 and tween 80 (Sigma Aldrich, France) were used as stabilizers. Tween 80 is an artificial additive made from sorbitol, oleic acid, and ethylene oxide. In the food industry, it is known as E433 as an emulsifier. The maximum daily intake volume is 25 $mg.kg^{-1}$. Sodium alginate food additive E401 was purchased from Naturguru Kft Hungary. Sodium alginate powder was dispersed in distilled water under magnetic stirring at 65°C for 15 minutes, to produce alginate solutions of desired concentrations 0.5%, 1% and 1.5 %. The solutions were left standing for 24h to disengage bubble before use.

2.2. Emulsification technology apparatus

The emulsions were produced using either a rotor stator homogenizer DLAB D-160 or a laboratory ME apparatus designed and constructed in the Department of Food Process Engineering at Hungarian University of Agriculture and Life Sciences, Faculty of

Food Science. The device is a continuous, crossflow device, as illustrated in Figure 2, by designating the main units. The basic materials of this experiment are the dispersion phase measuring vessel (25 ml) and the continuous phase container (1000 ml). To improve the emulsion quality in terms of droplet size distribution and stability, a mechanical device, named turbulence static promoter, was inserted to the membrane module. The static promoter was made of stainless steel (SS316), it is a double helix-shaped-ribbon reducer (helix reducer) (Figure 4) with the width of 5.8 mm, thickness of 1.6 mm and the length of one complete turn in the spiral was 24 mm.

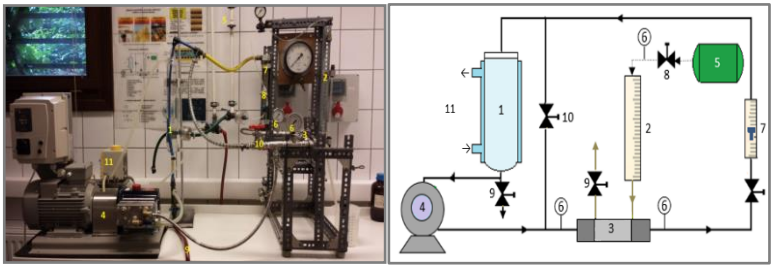

Figure 2: Membrane emulsification apparatus (1. continuous phase tank, 2. scaled dispersed phase tank, 3. membrane module, 4. compressor, 6. pressure gauge, 7. rotaméter, 8. pressure regulator, 9. valve, 10. valve, 11. thermostat connection)

The dispersed phase pressure was guaranteed by compressed air with compressor, and it was injected from the outer surface of the membrane. The peristaltic pump and recirculation channel were fitted to recirculate the continuous phase. A rotameter was placed at

the exit side of the membrane for measuring the flow rate of continuous phase. Microcapsules were prepared by tubular ceramic porous membrane, pore size l.4 μm (PALL Austria Filter GmbH). The membrane material was α alumina and the active membrane surface area was 50 cm2. The flux of the dispersed phase was examined during the emulsion preparation, and the time of the dispersion phase of the oily phase was measured by a stopwatch from the dispersion phase measuring vessel.

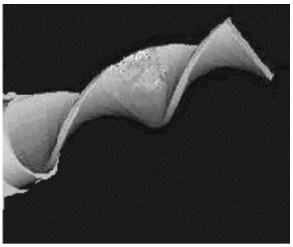

Figure 3: Helix reducer geometry

2.3. Emulsion dehydration (ED)

Two methods were used for the dehydration of emulsions: The first one is the SD method. The spray dryer used in this PhD work is a laboratory-scale spray dryer (LabPlant SD-05, Hungary) equipped with a 0.5 mm diameter nozzle. The pressure of the compressed air was adjusted to 3.6 bars. The inlet and outlet air temperatures were maintained at 190±2°C, 100±4°C respectively. The air flow rate was adjusted to 74 m3/h. Emulsions were prepared during the spray drying process and were continuously stirred by a magnetic stirrer

throughout. The microcapsules were collected from the collecting chamber and stored in darkness until analysed. The second method of dehydration is FD method. The emulsions were kept in the freezer for 24 hours at -40 °C and then lyophilized in a freeze-dryer (ScanVac, coolsafe, Hungary).

2.4. Methods and tested parameters of emulsions

Immediately after the emulsion preparation, stability of emulsions was measured by transferring 25 mL aliquots of each sample to graduated cylinders, sealed, stored at room temperature and the volume of the upper phase was measured after 24 h. During the analysis of the emulsions, the particle size and distributions were examined by either by Fritsch Analysette 22 or by Bettersize ST and Delta Optical Genetic Pro Bino Microscope Instruments. Viscosity was measured using a controlled-stress Physica MCR92 rheometer.

2.5. Methods and tested parameters of olive oil microcapsules

Microcapsules characterisation was assessed by measuring the efficiency of encapsulation. EE is the most important parameter to consider for optimizing the manufacturing of olive oil microcapsules process. For that, 15 ml of hexane were added to 1.5 g of microcapsules in a glass jar with a lid, which was shaken by hand for the extraction of free oil, for 2 min, at room temperature. The solvent mixture was filtered through a Whatman filter paper n° 1 and the powder collected on the filter was rinsed three times with 20 mL of hexane. Then, the solvent was left to evaporate at room temperature

and after at 60 °C, until constant weight. The non-encapsulated oil (surface oil) was determined by mass difference between the initial clean flask and that containing the extracted oil residue. Total oil was assumed to be equal to the initial oil, since preliminary tests revealed that all the initial oil was retained, which was expected, since olive oil is not volatile.

Moisture contents were measured using moisture analyser by heating the powder at 70 °C until reaching constant weigh. Powder particle size was assessed either by Fritsch Analysette 22 or by Bettersize ST.

Microcapsules morphology was observed by a field emission scanning electron microscope (FESEM) (Model: JSM 5500 LV).

2.6. Preparation of olive oil beads by emulsification/external gelation method

Emulsions prepared with the corresponding concentrations of sodium alginate and olive oil were homogenized at the corresponding rate and dripped from a specified height into a 2% $CaCl_2$ solution using a graduated burette like it was shown in the Figure 1. The gelling solution was stirred using a magnetic stirrer during the whole period of encapsulation. After that the gel beads were held for a further 30 min in the gelling solution for hardening to achieve the required mechanical stability. Figure 1 shows the process of emulsification/external gelation. The beads obtained were further dried at room temperature for 24 hours. To screen the effect of various formulations and process variables on formulation of beads, various concentrations of sodium alginate and olive oil and

homogenization rates were tested employing the Box-Behnken design (BBD) using design of expert software version 13.

The retention capacity of the beads was evaluated by determining the amount of oil phase in the gelling solution after the washing of the capsules with distilled water. In a cylinder with a volume of 250 cm^3, the gelling solution was poured and after a brief retention the quantity of the oil phase separated in it was determined. After that, 100 cm^3 of distilled water were used to wash out the surface oil phase of the capsules separated from the gelling solution by a metal sieve. The washing water was also put into a measuring cylinder and after retention the oil phase amount was recorded.

3. RESULTS

The major concept of this dissertation is to investigate the encapsulation of extra virgin olive oil by sequential technologies, such as preparation of emulsion (oil in water with polymeric carbohydrate) and subsequently, freeze drying and /or spray drying or external gelation of emulsion. In this investigation, polymeric carbohydrates, such as MD, CMC, GA, WPI and sodium alginate were used as matrix. The preliminary study showed that CFME is an effective method to perform stable emulsions with narrow droplet size using CMC, MD, and GA as wall materials. The addition of CMC to MD and GA mixture of wall materials resulted in a stability of the emulsion two times greater than emulsion containing MD and GA alone and into a monodisperse emulsion with a span value of 0.398.

At the first stage, the effects of emulsification technologies in terms of RSH and CFME and the composition of wall materials were studied in a judicious way. Two different formulations by changing the concentrations of MD with DE5 (dextrose equivalent 5) and CMC were considered for emulsion preparation; however, the amount of emulsifiers, such as GA and Tween 80 were fixed. The stability of emulsion was higher when emulsion was prepared by RSH. Emulsion droplet diameter D_{32} was lowered in case of RSH compared to CFME. After emulsions freeze drying, the highest EE

(EE 68.86%) was found when CFME was used. Considering higher EE, the most effective wall material composition to produce olive oil microcapsules is MD 15 g, CMC 5 g and GA 15 g. The freeze-dried powder micrographs showed irregularly shaped particles which were due to the drying process.

At a second stage, olive oil microcapsules were produced by RSH method using MD with DE 19 and WPI as matrix by comparing two dehydration methods, SD and FD. Characteristics of emulsion were influenced by the proportions of matrix (proportions of MD and WPI). Droplet size in stable emulsion was lower and it is influenced by viscosity of emulsion. EE of microcapsules were influenced by stability of emulsion, ratio and characteristics of matrix, and dehydration method. The highest efficiency and the highest yields were observed 88.61 % and 52.25 % respectively when spray drying method was used and when the wall materials composition is 50 g whey protein isolate, 50 g maltodextrin and 1 g tween 20 emulsifier. Whereas freeze-dried emulsion containing only WPI as wall material, offers appreciable EE (40.64±0.03%). The size of microcapsules was higher at the highest proportions of WPI. The span value of microcapsules was higher with high concentration of WPI having lower value of Tg, which influences the agglomeration of the microcapsules. Microcapsules with higher concentration of MD contained higher moisture due to presence of low molecular weight of saccharides. Microcapsules produced by SD were spherical in shape and had smooth surface and free-flowing due to

the lower concentration of oil on the skin of microcapsules. The microcapsules produced by FD were agglomerated flat flakes with porous surface and irregular edges due to the disintegration of microstructure by FD and presence of high level of oil on surface of flat flakes. To intensify the process, cross flow membrane emulsification was applied for the optimal sample which contains equal proportions of MD and WPI. The obtained EE was improved from 88.61% ±1.64 to 91.16 % ± 0.27. Since olive oil is enriched with polyphenolic antioxidants, tocopherols, phytosterols and fatty acids, a quality assessment of encapsulated olive oil was performed through Rancimat accelerated test of oxidation. It was clear that the microencapsulated olive oil had a protective activity against oxidation comparing to bulk oil. Both RSH-SD and CFME-SD presents IP values which were 2.75 and 4.15 times respectively greater than the IP of bulk oil. Besides, the oxidative stability of the CFME-SD sample was higher due to its higher EE and low surface oils content compared to RSH-SD sample that had a lower protective function against oxidation. Microcapsules, produced by CFME-SD were spherical in shape and had smooth surface and free-flowing due to the lower concentration of oil on skin of microcapsules.

Finally, emulsification/external gelation method was investigated for high oil loading retention. The technology that I used looks suitable for industrial applications. Based on experimental data, mathematical models were established, and process optimization was carried out to determine crucial operating parameters: sodium alginate

concentration 1.13%, olive oil concentration 40.5% and homogenization rate 18000 rpm. It was concluded as well that further studies are needed to investigate the effect of incorporating optimized microcapsules in the composition of some selected food products. During my work, I was dealing with the possibilities of using the process of membrane emulsification in the food industry and its implementation. My research focused on the production of emulsions made using this technique, specifically for food industry use.

3.1. NOVEL SCIENTIFIC RESULTS – THESIS

1. The addition of carboxymethylcellulose to maltodextrin and gum Arabic mixture of wall materials resulted a stability of the emulsion two times greater than emulsion containing MD and GA and into a monodisperse emulsion with a span value of 0.398. Therefore, considering that adding CMC to the emulsion resulted in more monodisperse compositions, explains the acceptable viscosity of this mixture towards the crossflow membrane machine which implies resistance to the droplets movements and thus avoiding coalescence and resulting in smaller diameters.
2. As a result of the comparison of emulsification by cross flow membrane method and rotor stator homogenization method, I found that after drying using the freeze drier, a best efficiency 68.86% was achieved by cross flow membrane emulsification

method using emulsion formulation containing 15 g maltodextrin, 5 g carboxymethylcellulose and 15 g gum Arabic. The freeze-dried powder micrographs showed irregularly shaped particles which were due to the drying process.

3. By comparing different drying methods, I proved that spray drying technique was the most promising process to microencapsulate olive oil. The highest efficiency and the highest yields were observed 88.61 % and 52.25 % respectively when spray drying method was used and when the wall materials composition is 50 g whey protein isolate, 50 g maltodextrin and 1 g tween 20 emulsifier.
4. By intensifying the process using CFME coupled with spray drying for the optimum sample, the obtained EE was improved from 88.61% ±1.64 to 91.16 % ± 0.27. Microcapsules, produced by CFME-SD were spherical in shape and had smooth surface and free-flowing due to the lower concentration of oil on skin of microcapsules. The oxidative stability of the CFME-SD sample was higher due to the lower surface oil content on the skin of the capsules, while the RSH-SD sample had a lower protective function against oxidation.
5. In my attempts, to produce microcapsules with high olive oil loading, I opted to the microencapsulation method by emulsification/ external gelation which consists of dripping alginate/ oil emulsion into a calcium chloride solution. That enhances the ionic gelation with formation of alginate gels by ionic cross-linking with multivalent cations. Consequently, the

optimum concentration of olive oil by using this process is 40.5 % which is higher than the oil concentration in the previous encapsulation methods. Additionally, based on the surface response methodology in this part, the optimal experimental conditions were as follows: sodium alginate concentration 1.13%, olive oil concentration 40.5% and homogenization rate 18000 rpm.

4. CONCLUSIONS AND SUGGESTIONS

My new scientific results have proved that CFME is an effective way to produce olive oil microcapsules in the presence of MD, GA and CMC. Microcapsules produced by FD were flat flakes with irregular surface due to the sublimation of water and disintegration of microstructure during FD. Therefore, further investigations are needed to understand the effects of the geometry of turbulent promoter, other formulation of emulsion and the quality of encapsulated olive oil during different times of storage.

The smooth surface of microcapsule was produced due to the presence of MD in formation. In this investigation, limited numbers of matrix (MD and WPI) and emulsion formulations were considered for the microencapsulation of olive oil. Further investigation will be performed to understand the effects of other formulations of emulsions and MD with different DE on EE, moisture content and Tg (glass transition temperature). Olive oil is enriched with polyphenolic antioxidants, tocopherols, phytosterols and fatty acids. In future, investigations will be performed to understand the quality of encapsulated olive oil during different storage times. Furthermore, the release of encapsulated olive oil from its matrix and fate of different functional compounds shall be investigated by the in vitro digestion protocol.

In the platform of process intensification, cross flow membrane emulsification was applied for the optimal sample from the previous

investigation.: optimum sample (50MD-50WPI) and the obtained EE was improved from 88.61% ±1.64 to 91.16 % ± 0.27. The microcapsules produced by CFME-SD were spherical in shape and had smooth surface and free-flowing due to the lower concentration of oil on skin of microcapsules. The quality assessment of encapsulated olive oil was performed through Rancimat accelerated test of oxidation. Consequently, the oxidative stability of the CFME-SD sample was higher due to its higher EE and low surface oils content compared to RSH-SD sample that had a lower protective function against oxidation.

From the point of view of maximising the oil load inside the capsules, emulsification/external gelation looks suitable for pharmaceutical applications such as nutraceuticals manufacturing. The crucial operating parameters for beads manufacturing are sodium alginate concentration 1.13%, olive oil concentration 40.5% and homogenization rate 18000 rpm.

Furthermore, studying the effect of incorporating optimized microcapsules in the composition of some selected food products may be promising.

LIST OF PUBLICATIONS RELATED TO THE DISSERTATION

Articles in journals with impact factor		
type	***year***	***publication***
journal	*2022*	***Chaabane, D.;*** *Yakdhane, A.; Vatai, G.; Koris, A.; Nath, A. (2022). Microencapsulation of Olive Oil: A comprehensive review. Periodica Polytechica Chememical Engineering, 66(3), 354–366, https://doi.org/0.3311/ppch.19587).*
journal	*2023*	***Chaabane, D****., Yakdhane, A., Ayari, E., Klosz, K., Albert, K., & Gáspár, I. (2023). Microencapsulation of extra virgin olive oil by sequential emulsification and freeze-drying processes: Effect of wall materials composition and emulsification method. Acta Alimentaria, 52(2), 235-244. https://doi.org/10.1556/066.2023.00004*
journal	*2021*	*Yakdhane, A., Labidi, S.,* ***Chaabane, D****., Tolnay, A., Nath, A., Koris, A., & Vatai, G. (2021). Microencapsulation of Flaxseed Oil—State of Art. Processes, 9(2), 295. https://doi.org/10.3390/pr9020295*
journal	*2023*	***Chaabane, D****., Mirmazloum, I., Yakdhane, A., Ayari, E., Albert, K., Vatai, G., Ladányi, M., Koris, A., & Nath, A. (2023). Microencapsulation of Olive Oil by Dehydration of Emulsion: Effects of the Emulsion Formulation and Dehydration Process. Bioengineering , 10(6), 657. https://doi.org/10.3390/BIOENGINEERING10060657*

International conference full text		
type	***year***	***publication***
conference full paper	*2019*	***Chaabane, D.,*** *Yakdhane, A., Koris, A. (2019). Present status of membrane emulsification and encapsulation by spray drying of vegetable oils with increased active ingredient content – A review. 3rd International Conference on Biosystems and Food Engineering. 3 June 2019.*
conference full paper	*2021*	***Chaabane, D.,*** *Yakdhane, A., Koris, A., Vatai, G. (2021). Microencapsulation using spray drying to protect olive oil against oxidation – a review. Proceedings of the 45th conference for students of agriculture and veterinary medicine with international participation, 52–62. Serbia. 18th Novenver 2021.*
conference full paper	*2020*	***Chaabane, D****., Yakdhane, A., Koris, A., Vatai, G. (2020). Membrane emulsification of olive oil: selection of the wall material. Proceedings of the 44th conference for students of agriculture and veterinary medicine with international participation, 173–182. Serbia. 15th December 2020.*
conference full paper	*2020*	*Yakdhane, A.,* ***Chaabane, D****., Nath, A., Koris, A. (2020). Preparation of food-grade oil-in-water emulsions using membrane emulsification technology - a review. Proceedings of the 44th conference for students of agriculture and veterinary medicine with international participation, 216-221. Serbia.15th December 2020.*

conference full paper	*2019*	*Yakdhane, A., Koris, A., Labidi, S., **Chaabane, D**., Nath, A. (2019). microencapsulation of flaxseed oil – a review. 3rd International Conference on Biosystems and Food. June 2019.*

International conference abstract

type	***year***	***publication***
poster presentation	*2018*	*Koris, A., Nath, A., Gáspár, I., Albert, K., Csighy, A., **Chaaben, D**., Vatai, G. (2018). Process intensification in food and biopharmaceutical industries. Conference "Biotechnology: A Paradigm Shift in Health and Agriculture" School of Biotechnology, Adamas University, Conference proceedings p. 14. 9 april 2018.*
poster presentation	*2018*	*András, K., Krisztina, A., **Donia, C.,** Kitti, M., Anita, T., Péter, K. (2018). Production of microcapsules containing active ingredient by a novel complex technology: characterization of wall materials and their mixtures. 11th Conference on Colloid Chemistry. Budapest, 28-30 May 2018.*
poster presentation	*2020*	***Chaabane, D.,** Yakdhane, A., Koris, A. Protection of olive oil from deterioration by spray drying microencapsulation - a review, 4 th SZIEntific Meeting of Young Researchers. 7th December 2020.*
poster presentation	*2022*	***Chaabane, D**., Yakdhane, Nath, A., Albert, K., Koris, A., Vatai, G. (2022). Microencapsulation of Extra Virgin Olive Oil by freeze Drying: Effect of Wall Materials Composition and Emulsification Method. 4th International Conference on Food Science and Technology. p. 72. Budapest*

poster presentation	*2022*	***Chaabane, D**., Yakdhane, Nath, A., Vatai, G., Albert, K., Koris, A. (2022). microencapsulation of extra virgin olive oil by spray- drying effect of wall materials composition. 5 Th Online International Conference on nutrition and nutraceuticals, USA, p. 30.*
poster presentation	*2021*	***Chaabane, D.,** Yakdhane, Zin, M., Nath, A., Koris,A, Vatai, G.(2021). Microencapsulation of olive oil by spray drying using membrane emulsification.4th International Conference on Biosystems and Food Engineering. 4th June 2021.*
poster presentation	*2022*	*Zin, M. M., **Donia, C.**, & Bánvölgyi, S. (2022). Concentrations of Beetroot Peel and flesh Extracts by reverse osmosis membrane. 30th Anniversary of Baku Eurasia University. 27-28 April 2022, pp. 342, ISBN – 978-625-7464-88-8.*