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COSTS OF PLANT OILS ENCAPSULATION USING EXTRUSION SND PROCESS[6]

Abstract

Plant oils are important not only for human nutrition, but also for cosmetic industry, pharmaceutical industry and alike. Within plant oils, there is an increasing interest for production and use of grape seed oil as a type of high-quality plant oil. Nevertheless, grape seed oil should be treated (through the process of encapsulation) in order to protect its active ingredients. Therefore, the goal of this research is to analyse the costs of a new and original approach to grape seed oil encapsulation, which is called submerged-nozzle dispersion (SND) for oil encapsulation in alginate. After determining necessary investments in equipment, total production costs were calculated (as well as average costs per unit of product). Authors also discussed fixed and variable costs per kilogram of encapsulates for different levels of capacity use. Risk analysis was performed by applying sensitivity analysis and assuming different scenarios for market prices of the most important inputs. It was determined that average production costs of encapsulates significantly vary depending on production level, while prices of grape seed oil and sodium alginate also play an important role. Costs also depend on some technological factors, such as encapsulation efficiency and load of active compound. The results offer an insight in the effects of future investments in food industry.

Key words: *grape seed oil, encapsulation, extrusion, costs, input prices, sensitivity analysis*

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JEL classification: *O3, Q12, Q16*

ТРОШКОВИ ИНКАПСУЛАЦИЈЕ БИЉНИХ УЉА УПОТРЕБОМ ЕКСТРУЗИОНОГ СНД ПРОЦЕСА

Сажетак

Биљна уља су важна не само за људску исхрану, већ и за козметичку индустрију, фармацеутску индустрију и слично. У оквиру биљних уља, постоји растући интерес за производњу и употребу уља из семена грожђа као врсте висококвалитетног биљног уља. Ипак, уља из семена грожђа морају се третирати (процесом инкапсулације) да би се заштитили њихови активни састојци. Зато је циљ овог истраживања анализа трошкова новог и оригиналног приступа инкапсулацији уља семенки грожђа, који се назива дисперзија помоћу потопљене млазнице (СНД) за инкапсулацију уља у алгинату. Након утврђивања неопходних улагања у опрему, израчунати су укупни трошкови производње (као и просечни трошкови по јединици производа). Аутори су такође разматрали фиксне и варијабилне трошкове по килограму инкапсулата за различите нивое употребе капацитета. Анализа ризика је извршена применом сензитивне анализе и под претпоставком различитих сценарија за тржишне цене најважнијих инпута. Утврђено је да просечни трошкови производње инкапсулата значајно варирају зависно од његовог обима производње, док цене уља из семенки грожђа и натријум алгината такође имају важну улогу. Трошкови такође зависе од одређених технолошких фактора, као што су ефикасност инкапсулације и садржај активног једињења. Резултати пружају увид у ефекте будућих инвестиција у прехрамбену индустрију.

Кључне речи: *уље семенки грожђа, инкапсулација, екструзија, трошкови, цене инпута, сензитивна анализа*

Introduction

Plant oils are one of the most important groups of food products widely used as sources of active compounds necessary for human metabolism such as polyunsaturated fatty acids, polyphenols, tocopherols, monoterpenes, etc. Besides food applications, plant oils are also important for cosmetic and pharmaceutical industry. Analysing economic aspects of investment in “essential oils production” from medical plants Nastić et al. (2024) concluded that such investments are economically justified. Nevertheless, this research is primarily devoted to grape seed oil, and its use. Duba and Fiori (2019) discussed economic effects of extracting grape seed oil, concluding that the observed process “can produce high-quality seeds oil at a cost-effective price”. Dabetic et al. (2020) discussed and compared quality of grape seed oils from white grape varieties (two out of six varieties were autochthonous Serbian). Authors concluded that oil quality scores indicated similar results for the observed varieties, “although Smederevka stands out as the most potent one". Importance of grape seed oil production and discussion of its quality parameters was performed by other authors, as well (Pardo et al., 2009; Abd El-Hack et al., 2024; Martin et al., 2020; Gitea et al., 2023).

It should be taken into account that many oils' compounds are unstable and can undergo chemical transformations that change their metabolic properties and reduce their nutritional value. Hence, the protection of oil's active compounds is a challenge for many industrial processes and food practices. One of the strategies that can be used for oil protection is encapsulation (Rodríguez et al., 2016). Modern consumers require food products that, besides energy and basic nutrients, provide additional healthy components. One of the approaches in the delivery of healthy compounds is to protect them using encapsulation and apply encapsulates in food products formulations. For example, Stajić et al. (2018) used encapsulated flaxseed oil to improve nutritional value of the fermented sausages. Also, encapsulation could be used for masking unpleasant sensorial properties of active compounds in food products (Choudhury et al., 2021). However, some encapsulation processes require complex formulations of carrier material to achieve good protection of active compounds (Strobel et al., 2020). Apart from food processing industry, encapsulation could be used in various fields of agriculture an aquaculture, such as delivery of bio stimulants in agriculture (Jíménez-Arias et al., 2022) or delivery of bioactive agents in aquaculture (Masoomi Dezfooli et al., 2019). Also, the encapsulated nutrients could be included into animal feed, which may positively influence productivity and animal health (Ariaeenejad et al., 2024; Fontana et al., 2025).

Encapsulation is a process of protection of an active ingredient by forming a protective layer of carrier material that serves as a barrier against external factors such as oxygen, light, moisture or high temperatures (that may change grape seed oil chemical properties). Encapsulation methods such as spray drying, freeze drying, coacervation and extrusion are commonly used for protection of plant oil (Rodríguez et al., 2016; da Silva et al., 2022). Extrusion (which will be discussed in this research) is the encapsulation method that utilizes polysaccharides, proteins or their mixtures as carrier materials for entrapment of active compound. Depending on extrusion method, encapsulates in various shape and size could be obtained. Usually, spherical shape is preferable, while encapsulate size could be in the range from ~50µm to above 2 mm (Đorđević et al., 2015). Encapsulation of oils and generally hydrophobic compounds (e.g. liquid aromas) using an extrusion method, is described in details by Lević et al. (2015). Recently, Lević et al. (2024) presented a new extrusion method i.e., submerged-nozzle dispersion (SND) for oil encapsulation in alginate. By using SND method, it is possible to achieve high oil load and encapsulation efficiency.

Economic sustainability of encapsulation process depends on many factors. Generally, the costs of encapsulation primarily include the cost related to necessary equipment as well as costs of materials, labor and energy. In some cases, the costs of encapsulation could become very high, limiting the usage of encapsulated active compound (Strobel et al., 2020). However, if the encapsulation is the only way to stabilise or deliver active compound, then the encapsulation and its costs must be taken into consideration. This is particularly obvious in the case of expensive active compounds. Namely, according to Popplewell (2001) the expensive active compounds are more suitable for encapsulation because the costs of encapsulation have less influence on the overall price of final product i.e. encapsulate. Also, the costs of encapsulation process depend on capacity use (production volume) while revenues are related to selling price of products, as well (Dimitrellou et al., 2019). Observing the development of encapsulation technology, Timilsena et al. (2020) mentioned that an "innovative food-grade encapsulants are being explored to reduce the production costs" while at the same time they should meet "consumer expectations".

Serbian market is dominated by imported encapsulated food products such as food additives and supplements. Development of domestic encapsulation capacities can increase competiveness of our food sector, especially when food sector is oriented towards more healthy food products. It requires entrepreneurial initiative, which is (according to Janošik et al., 2024) related not only to personal characteristic of an entrepreneur but also to a number of other factors (economic, technological and socio-cultural). Nikitović et al. (2023) explained the impact of training on employees' performance in an entrepreneurial environment in Serbia. Authors stated that "without a systematic investment in increasing the knowledge and skills of employees, organizations may find themselves in a position of losing a competitive edge". When it comes to potential level of foreign direct investments in Central and Eastern Europe (according to Zarić, S., 2022), it is closely linked to "cheap resources and increased efficiency", meaning that "the availability of skilled labour and low labour costs have emerged as significant determinant".

Having that in mind, the goal of this research is to discuss the costs of the new approach to encapsulation technology (extrusion SND process), as well as factors influencing the costs. The main research question is how to determine the level of costs related to innovative encapsulation technology in the expected Serbian business environment, and to examine behaviour of encapsulation costs in risky circumstances.

Material and methods

Grape seed oil encapsulation in alginate using SND process is a new technology which is described in details by Lević et al. (2024). This study is focused on the production of wet encapsulates that could be used in the variety of food products, such as food additives and supplements.

The prices of equipment and necessary materials were obtained on the international and domestic market during the period June-July 2024. All the prices are expressed in EUR using exchange rates established by the National Bank of Serbia. It was estimated that one appropriately trained (full time) employee can successfully operate the equipment. The costs of the depreciation were obtained by applying straight-line method, based on the useful life of fixed assets (which is expected to be 8 years). An average yearly cost of interest is calculated on the basis of 8% interest rate. It was assumed that the purchase of all the equipment is financed by external funds (bank loan).

Apart from determining cash outlays necessary for equipment purchase, authors calculated total costs of SND encapsulation process. Besides that, fixed, variable and total costs (per unit) for various levels of production capacity use were determined. Cost behaviour in risky circumstances was discussed by applying sensitivity analysis for different levels of market prices for the most important elements of material costs. Various scenarios (the most probable, optimistic and pessimistic) were also discussed.

Results and Discussion

The research was based on the idea of using equipment which is not expensive to provide effective way for protection of active compounds from grape seed oils. Annual production capacity of equipment discussed in this research (Table 1) is 6.750 kg of wet encapsulates per year.

Table 1. Equipment for the production of wet encapsulates

Equipment	**Amount (EUR)**
Air compressor	4,000.00
Encapsulation unit/custom made	1,000.00
Homogenizer	7,000.00
Supporting equipment	2,000.00
Total	**14,000.00**

Source: Authors` research

By using such equipment for SND encapsulation process, material costs presented in Table 2 were obtained. They are dominated by the costs of sodium alginate (as the most expensive type of material) and grape seed oil (as the material which is encapsulated).

Table 2. Material costs for the SND encapsulation

Material	**Unit**	**Cost per unit (EUR)**	**Material for the production of 1 kg of wet encapsulates**	**Amount of produced wet encapsulates (kg, annually)**	**Total cost of material (EUR)**
Sodium alginate	Kg	400	0.015	6,750	40,500.00
Calcium chloride	Kg	10	0.09	6,750	6,075.00
Cold pressed grape seed oil	L	30	0.20	6,750	40,500.00
Distilled water	L	0.133	15.00	6,750	13,466.25
Total					**100,541.25**

Source: Authors` research

Beside materials costs, there are other costs such as energy cost (electricity costs), labor costs, depreciation, interest and costs of equipment maintenance. Variable costs are estimated on the base of using overall production capacity for SND encapsulation process. Analysis showed that material costs are the most important element of total costs, while labor costs are also significantly contributing to the overall cost of SND encapsulation process (Table 3). As can be seen, the other costs individually contribute with less than 3% in total costs (total participation of costs other than material and labor costs is 4.98%). This is in line with findings presented by Nastić et al. (2024) who determined that processing costs of medical plants (essential oils production) are dominated by material costs, while labor costs are usually second important type of costs (depending on the production year). Considering all costs necessary for annual production (6,750 kg of wet grape seed oil encapsulates), it is determined that the production cost per one kilogram of encapsulates is 18.20 EUR (average production costs per kilogram).

Table 3. Total costs of SND encapsulation process

Item	Costs (EUR)	Contribution (%)
Materials costs	100,541.25	81.83
Energy costs	3,600.00	2.93
Labor costs	16,200.00	13.19
Depreciation	1,750.00	1.42
Interest	630.00	0.51
Maintenance costs	140.00	0.11
Total costs	**122,861.25**	**100.00**

Source: Authors` research

At the same time, it should be taken into account that average production costs depend not only on the capacity use, but also on the potential variation of input market prices. Sodium alginate and grape seed oil are considered as the most influential inputs in this analysis. Assuming 100% use of production capacities, authors considered variation of input market prices within the range from -30% to +30%. In such a way production costs were calculated for different combinations of sodium alginate and grape seed oil prices (Table 4). It could be noticed that production costs per one kilogram of wet encapsulates vary from minimal 14.60 EUR/kg (presenting the most optimistic scenario for input market prices) to 21.80 EUR/kg (reflecting the most pessimistic combination of input market prices).

Table 4. Production cost of encapsulates (EUR/kg) at 100% capacity use

Change of input price	**Sodium alginate**						
Grape seed oil	**-30%**	**-20%**	**-10%**	**0%**	**+10%**	**+20%**	**+30%**
-30%	14.60	15.20	15.80	**16.40**	17.00	17.60	18.20
-20%	15.20	15.80	16.40	**17.00**	17.60	18.20	18.80
-10%	15.80	16.40	17.00	**17.60**	18.20	18.80	19.40
0%	**16.40**	**17.00**	**17.60**	**18.20**	**18.80**	**19.40**	**20.00**
+10%	17.00	17.60	18.20	**18.80**	19.40	20.00	20.60
+20%	17.60	18.20	18.80	**19.40**	20.00	20.60	21.20
+30%	18.20	18.80	19.40	**20.00**	20.60	21.20	21.80

Source: Authors` research

Nevertheless, the table above describes the only situation in which production capacity is fully used, which is very demanding in terms of organization in practice. To make an analysis more detailed, i.e. to predict more possible outcomes, authors analysed various scenarios for certain levels of production volume (Table 5).

Table 5. Production cost of encapsulates (EUR/kg) for different levels of capacity use

Capacity use	Scenario		
	Optimistic	**Most probable**	**Pessimistic**
10%	39.56	43.16	46.76
50%	17.38	20.98	24.58
90%	14.91	18.51	22.11
100%	14.60	18.20	21.80

Source: Authors` research

The analysed scenarios are the optimistic, the most probable and the pessimistic one (which is a usual approach according to Ivanović and Marković, 2018). The most probable scenario uses input prices which were common at the time when the analysis was performed. On the other hand, the optimistic scenario reflects the best option (the lowest prices of sodium alginate and grape seed oil), while the pessimistic scenario represents the highest prices of the observed inputs.

The results of this research showed a lower price of oil encapsulates compared to Strobel et al. (2020) (in most cases). According to the same authors, the cost of encapsulation of fish oil in alginate using extrusion external gelation process was estimated at 37.98$. Further, they tried to calculate the costs of encapsulates if the gelling process is modified by decreasing the mass ratio between emulsion and gelling solution. The lowest price of encapsulates of 24.32$ was achieved when this ratio was equal (which is closer to the price of wet oil encapsulates that is obtained in this study). SND process can operate successfully when emulsion and gelling solution ratio is 1:2 or 1:3. This is significantly lower compared to other extrusion processes that usually use at least up to five times more gelling solution than SND encapsulation process. Also, according to the same research, the decreasing in the required amount of gelling solution leads to decreasing of investment in gelling vessels and other equipment. This can explain the lower prices of SND encapsulates that we calculated in this study.

It should be pointed out that the prices of encapsulates presented by Strobel et al. (2020) also include the costs of encapsulates drying, which contributed to the higher prices of final encapsulates. On the other hand, we discussed the production of wet encapsulates as more convenient for application if food products with higher water content. Considering the SND process, it provides high encapsulation efficiency with high load of active compound (Lević et al., 2024). As efficiency and load of active compound increase, encapsulate production is more economically sustainable (Popplewell, 2001). According to Xu et al. (2024), challenges and limitations of encapsulation technology are not only “pollution and energy consumption” related to it but also “high preparation costs” and issues concerning the encapsulation rate.

Conclusion

Encapsulation of plant oils (grapes seed oil in this case) protects their active ingredients against external factors that may change oil chemical properties. Therefore, production of encapsulates offers good opportunity to increase competitiveness in food production and other sectors related to healthy products. Having in mind that encapsulated food products are in majority of cases imported in Serbia, it is necessary to develop domestic production of encapsulated plant oils. The information about encapsulation costs is useful for the calculation of prices of food products that contain encapsulates. Besides, this study provided economic analysis that could help the investors to calculate their own prices of encapsulated active compounds.

The research enabled an insight into the relation between production costs of encapsulates and some important factors (such as the capacity use of installed equipment and the prices of key materials). Encapsulation efficiency with high load of active compound proved to be the most important technological factor. The results of this study have practical implication on managerial decisions regarding future investments in food processing industry. Future research in this field in Serbian conditions should be primarily directed towards the economic efficiency of encapsulates drying in order to decrease the level of water content. Therefore, future research steps require determination of investments in additional equipment necessary for the drying of wet encapsulates (e.g. lyophilization process) and discussion of associated costs. There is also a possibility of paying to other specialized companies to dry encapsulates (instead of investing in specialized equipment) which should be explored in future research, as well. In such a way, an extent to which the lyophilization increases the costs of encapsulates production and economic efficiency of this process could be determined.

References

Abd El-Hack, M. E., Khafaga, A. F., Abu-Hiamed, H. A., Almarkhan, W. D., Alharbi, N. A., Alhassani, W. E., Alkholy, S.O., Khalifa, N.E., Khojah, H., Moustafa, M., Al-Shehri, M. & Ismail, I. E. (2024). Grape seed oil: health benefits and useful impacts on livestock performance and products quality–a review. *Annals of Animal Science*, *24*(3), 749-765. DOI: 10.2478/aoas-2023-0094

Ariaeenejad, S., Zeinalabedini, M., Sadeghi, A., Gharaghani, S., & Mardi, M. (2024). Enhancing nutritional and potential antimicrobial properties of poultry feed through encapsulation of metagenome-derived multi-enzymes. *BMC Biotechnology*, 24, 76. https://doi.org/10.1186/s12896-024-00904-y

Choudhury, N., Meghwal, M., & Das, K. (2021). Microencapsulation: An overview on concepts, methods, properties and applications in foods. *Food Frontiers*, 2, 426-442. https://doi.org/10.1002/fft2.94

da Silva, L.C., Castelo, R.M., Cheng, H.N., Biswas, A., Furtado, R.F., Alves, C.R. (2022). Methods of microencapsulation of vegetable oil: principles, stability and applications – A minireview. *Food Technology and Biotechnology,* 2022, *60 (3)*, 308-320. (DOI: https://doi.org/10.17113/ftb.60.03.22.7329)

Dabetic, N. M., Todorovic, V. M., Djuricic, I. D., Antic Stankovic, J. A., Basic, Z. N., Vujovic, D. S., & Sobajic, S. S. (2020). Grape seed oil characterization: A novel approach for oil quality assessment. *European Journal of Lipid Science and Technology*, *122*(6), 1900447. DOI: 10.1002/ejlt.201900447

Dimitrellou, D., Kandylis, P., Lević, S., Tanja Petrović, Ivanović, S., Nedović, V., & Kourkoutas, Y. (2019). Encapsulation of Lactobacillus casei ATCC 393 in alginate capsules for probiotic fermented milk production. *LWT-Food Science and Technology*, 116, 108501. https://doi.org/10.1016/j.lwt.2019.108501

Đorđević, V., Balanč, B., Belščak-Cvitanović, A., Lević, S**.,** Trifković, K., Kalušević, A., Kostić, I., Komes, D., Bugarski, B., & Nedović, V. (2015). Trends in encapsulation technologies for delivery of food bioactive compounds. *Food Engineering Reviews*, 7**,** 452-490. DOI: https://doi.org/10.1007/s12393-014-9106-7

Duba, K., & Fiori, L. (2019). Supercritical CO2 extraction of grape seeds oil: scale-up and economic analysis. *International Journal of Food Science & Technology*, *54*(4), 1306-1312. doi:10.1111/ijfs.14104

Fontana, L.B., Henn, G.S., Dos Santos, C.H., Specht, L., Schmitz, C., de Souza, C.F.V., & Lehn, D.N. (2025). Encapsulation of Zootechnical Additives for Poultry and Swine Feeding: A Systematic Review. *ACS Omega*, 10, 7, 6294-6305. https://doi.org/10.1021/acsomega.4c08080

Gitea, M. A., Bungau, S. G., Gitea, D., Pasca, B. M., Purza, A. L., & Radu, A. F. (2023). Evaluation of the phytochemistry–therapeutic activity relationship for grape seeds oil. *Life*, 13(1), 178. https://doi.org/10.3390/life13010178

Gogić. P. (2014). Teorija troškova sa kalkulacijama u proizvodnji i preradi poljoprivrednih proizvoda. Poljoprivredni fakultet, Beograd – Zemun.

Ivanović, S., & Marković, T. (2018). Upravljanje investicijama u agrobiznisu. Univerzitet u Beogradu, Poljoprivredni fakultet. Beograd – Zemun.

Janošik, M., Vukotić, S., & Milenkovski, L. (2024). Analysis of possible impact factors on the development of the entrepreneurial initiative. *Ekonomika*, 70(1), 65-78. DOI: 10.5937/ekonomika2401065J

Jíménez-Arias, D., Morales-Sierra, S., Silva, P., Carrêlo, H., Gonçalves, A., Ganança, J. F. T., Nunes, N., Gouveia, C.S.S., Alves, S., Borges, J.P., & Pinheiro de Carvalho, M. Â. (2022). Encapsulation with natural polymers to improve the properties of biostimulants in agriculture. *Plants*, 12(1), 55. https://doi.org/10.3390/plants12010055

Lević, S., Lijaković, I.P., Đorđević, V., Rac, V., Rakić, V., Knudsen, T.Š., Pavlović, V, Bugarski, B., & Nedović, V. **(**2015). Characterization of sodium alginate/D-limonene emulsions and respective calcium alginate/D-limonene beads produced by electrostatic extrusion. *Food Hydrocolloids*, 45, 111-123. DOI: https://doi.org/10.1016/j.foodhyd.2014.10.001

Lević, S.M. Rac, V.A., Rakić, V.M.; Salević-Jelić, A.S., Hovjecki, M.R.; Malićanin, M.V., Rabrenović, B.B.; Antić, M.P., & Nedović, V.A. (2024). Cold-Pressed Grape Seed Oil Encapsulation Using a Submerged Nozzle Dispersion Encapsulation Process. *Processes*, 12, 1628. https://doi.org/10.3390/pr12081628

Martin, M. E., Grao-Cruces, E., Millan-Linares, M. C., & Montserrat-De la Paz, S. (2020). Grape (Vitis vinifera L.) seed oil: A functional food from the winemaking industry. *Foods*, 9(10), 1360. doi:10.3390/foods9101360

Masoomi Dezfooli, S., Gutierrez-Maddox, N., Alfaro, A., & Seyfoddin, A. (2019). Encapsulation for delivering bioactives in aquaculture. *Reviews in aquaculture*, 11(3), 631-660. https://doi.org/10.1111/raq.12250

Nastić, L., Jeločnik, M., & Subić, J. (2024). Processing of medicinal herbs: Economic analysis. International Symposium *Agriculture Economy and Rural Development – Trends and Challenges "Agriculture and rural economy between tradition, innovation and sustainability", 15th Edition, November 2024, Bucharest*, Romania, pp. 15-23. https://symposium.iceadr.ro/wp-content/uploads/2023/03/Volum-simpozion-1.pdf#page=15

Nikitović, Z., Penjišević, A., & Somborac, B. (2023). The impact of training on employees' performance in an entrepreneurial environment in Serbia: empirical and statistical findings. *Anali Ekonomskog Fakulteta u Subotici*, *59*(49), 51-65. https://doi.org/10.5937/AnEkSub2200003N

Pardo, J. E., Fernández, E., Rubio, M., Alvarruiz, A., & Alonso, G. L. (2009). Characterization of grape seed oil from different grape varieties (Vitis vinifera). *European journal of lipid science and technology*, 111(2), 188-193. DOI 10.1002/ejlt.200800052

Popplewell, M.L. (2001). Evaluating Encapsulation Economics. Perfumer & Flavorist, 26.

Rodríguez, J., Martín, M.J., Ruiz, M.A., & Clares, B. (2016). Current encapsulation strategies for bioactive oils: From alimentary to pharmaceutical perspectives. *Food Research International,* 2016, *83*, 41-59. (DOI: https://doi.org/10.1016/j.foodres.2016.01.032)

Stajić, S., Stanišić, N., Lević, S., Tomović, V., Lilić, S., Vranić, D., Jokanović, M., & Živković, D. (2018). Physico-chemical characteristics and sensory quality of dry fermented sausages with flaxseed oil preparations. *Polish Journal of Food and Nutrition Sciences*, 68(4), 367-375. https://doi.org/10.2478/pjfns-2018-0006

Strobel, S.A., Knowles, L., Nitin, N., Scher, H.B., & Jeoh, T. (2020). Comparative technoeconomic process analysis of industrial-scale microencapsulation of bioactives in cross-linked alginate. *Journal of Food Engineering*, 266, 109695. https://doi.org/10.1016/j.jfoodeng.2019.109695

Timilsena, Y.P., Haque, Md.A. & Adhikari, B. (2020). Encapsulation in the Food Industry: A Brief Historical Overview to Recent Developments. *Food and Nutrition Sciences*, 11, 481-508. https://doi.org/10.4236/fns.2020.116035

Xu, Y., Yan, X., Zheng, H., Li, J., Wu, X., Xu, J., ... & Du, C. (2024). The application of encapsulation technology in the food Industry: Classifications, recent Advances, and perspectives. *Food Chemistry:* X*,* 21, 101240. https://doi.org/10.1016/j.fochx.2024.101240

Zarić, S. (2022). Determinants of foreign direct investment in Central and Eastern Europe: panel data analysis results. *Anali Ekonomskog Fakulteta u Subotici*, *58*(48), 35-49. https://doi.org/10.5937/AnEkSub2248035Z