EVALUATION THE EFFECTS OF ARABIC GUM AND SODIUM CASEINATE ON THE QUALITY OF MEDIUM CHAIN TRIGLYCERIDES POWDER

MOHAMAD AMIR BIN AWANG

A project report submitted in fulfilment of the
requirements for the award of the degree of
Master of Science

School of Chemical and Energy Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

AUGUST 2022

DEDICATION

Every difficult task necessitates both self-effort and the guidance of elders, particularly those close to our hearts. My humble effort is dedicated to my loving mother, wife, family members and friends whose support and prayers enable me to continue this journey. Along with all the hardworking and respected lecturers, particularly my supervisor, without whose unending support, guidance, knowledge shared, and motivation, this entire journey would not be possible. To everyone who shone brightly on this journey, this study is dedicated to you.

ACKNOWLEDGEMENT

First and foremost, praises and thanks to the almighty Allah S.W.T, for His blessings throughout completing my research work successfully. I would like to express my sincere gratitude to Universiti Teknologi Malaysia (UTM) specifically Institute of Bioproduct Development (IBD) for the opportunity given to me in carrying out my research and I have managed to successfully complete my research with the guidance and encouragement of various parties.

Secondly, I am deeply thankful to Ts Dr. Harisun Yaakob, the supervisor of my research, for giving me the opportunity to do my research and offering invaluable guidance and advice throughout my journey in finishing this thesis. I was influenced profoundly by his dynamism, vision, honesty, and motivation. She taught me the proper methodology as clearly as possible in conducting this research work. Studying under his supervision was a pleasure and honour. For what he has given me, I am deeply thankful.

Finally, I am immensely thankful to my parents for their love, unconditional prayers, continuous care, and sacrifices for preparing me for my future. Also, I would like to thank my wife and kid very much for their affection, understanding and valuable support to complete the research work.

ABSTRACT

Medium-chain triglycerides (MCT), sourced from good fat in virgin coconut oil is increasing in demand due to its potential substitute for source of energy compared to energy sourced from simple carbohydrates foods which leads to many diseases. MCT powder can be used as a strategy to encourage diet high in good fat in daily life. Most of MCT powder in the market contains maltodextrin which was reported contribute bad side effects to human health. Wall material like prebiotic (arabic gum) and protein (sodium caseinate) able to replace maltodextrin in the MCT powder formulation as well as giving a good human health benefits and potential to improve the quality of MCT powder. However, the effect of both ingredients on the quality of MCT powder was not fully reported. Therefore, this study aimed to evaluate the effects of arabic gum and sodium caseinate as formulation ingredients on the quality of MCT oil powder produced by spray drying method. The formulation ingredients consisted of MCT oil, arabic gum and sodium caseinate with different concentration. The quality of MCT powder were characterized with regards to its solubility, wettability, antioxidant activity, probiotic growth and sensory evaluation. From this study, it was found that the formulation F1 (70% of MCT oil, 20% of arabic gum and 10% of sodium caseinate) met all the required assessment with the highest yield, moderate antioxidant activity, overall sensory evaluation acceptability and promote the probiotic growth over the commercialize sample. As a conclusion, the alternative formulation ingredients (Arabic gum and sodium caseinate) was found affect the quality of MCT oil powder in terms of physical, chemical and biological characteristic.

ABSTRAK

Trigliserida rantaian sederhana pendek (MCT), yang diperolehi daripada lemak yang baik dalam minyak kelapa dara semakin meningkat dari segi permintaan pengguna kerana potensinya sebagai pengganti sumber tenaga yang lebih baik dari sumber tenaga yang diperolehi daripada karbohidrat ringkas yang membawa kepada banyak penyakit. Serbuk MCT boleh digunakan sebagai strategi untuk menggalakkan diet yang tinggi lemak baik dalam kehidupan seharian. Kebanyakkan serbuk MCT di pasaran mengandungi maltodextrin yang dilaporkan menyumbang kepada kesan sampingan yang buruk kepada kesihatan manusia. Bahan penyendat seperti prebiotik (gam arab) dan protein (sodium casienat) mampu menggantikan maltodextrin dalam formulasi serbuk MCT, memberikan manfaat dan potensi kesihatan manusia yang baik malah mampu meningkatkan kualiti serbuk MCT. Walau bagaimanapun, kesan kedua-dua bahan pada kualiti serbuk MCT tidak dilaporkan sepenuhnya. Oleh itu, kajian ini bertujuan untuk menilai kesan gam arab dan sodium casienat dalam formulasi, terhadap kualiti serbuk minyak MCT yang dihasilkan menggunakan kaedah pengeringan sembur. Bahan-bahan formulasi terdiri daripada minyak MCT, gam arab dan sodium casienat dengan kepekatan yang berbeza. Kualiti serbuk MCT dicirikan dengan kelarutan, kebolehbasahan, aktiviti antioksidan, pertumbuhan probiotik dan penilaian deria rasa. Dari kajian ini, didapati bahawa formulasi F1 (70% minyak MCT, 20% gam arab dan 10% sodium casienat) memenuhi semua penilaian yang diperlukan dengan hasil tertinggi, aktiviti antioksidan sederhana, kebolehterimaan penilaian deria keseluruhan dan mampu menggalakkan pertumbuhan probiotik berbanding sampel komersial. Kesimpulannya, bahan formulasi alternatif seperti gam arab dan sodium casienat didapati mempengaruhi kualiti serbuk minyak MCT dari segi ciri fizikal, kimia dan biologi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	-	Analysis of variance
AG	-	Arabic Gum
EC_{50}	-	Half maximal effective concentration
FAME	-	Fatty acid methyl esters
GCFID	-	Gas Chromatography with Flame Ionization Detection
GI	-	Glycaemic Index
HPLC	-	High-performance liquid chromatography analysis
LCFA	-	Long-chain fatty acids
LDL	-	Low-density Lipoprotein
MCT	-	Medium-chain triglycerides
MRKSO	-	Microencapsulated refined kenaf seed oil
SCFA	-	Short chain fatty acid
UV–Vis spectrophotometer	-	Ultraviolet-visible (UV-Vis) spectrophotometer
VCO	-	Virgin coconut oil

LIST OF SYMBOLS

cm	-	Centimetre
m^3/hr	-	Cubic metres per hour
◦C	-	Degree Celsius
g	-	Gram
g/g	-	Gram per gram
g/ml	-	Gram per millilitre
h	-	Hour
M	-	Molarity
Mpa	-	Megapascal
µL	-	Microlitre
µL/min	-	Microlitre per minute
µm	-	Micrometre
mg	-	Milligram
mg/mL	-	Milligram per millilitre
mm	-	Millimetre
mL	-	Millilitre
mL/min	-	Millilitre per minute
min	-	Minutes
nm	-	Nanometre
rpm	-	Revolutions per minute
m^3/hr	-	Cubic metres per hour
%	-	Percentage
psig	-	Pounds per square inch gauge
s	-	Second
w/v	-	Weight per volume
v/v	-	Volume per volume
p	-	Probability
n	-	Number of samples

CHAPTER 1

INTRODUCTION

1.1 Research Background

Food is a necessity for sustaining life. Due to modern lifestyles and unhealthy eating habits, coronary heart disease, obesity, diabetes, hypertension, and other health problems are on the rise. Obesity is associated with heart disease, diabetes etc (Stanislav et al., 2018). However, doctors and nutritionists have found that regular consumption of a balanced diet containing certain components helps to reduce the risk of diseases of civilization. It helps to shape the intestinal microbiota for better digestibility and lower risk of colon cancer (De Almeida et al., 2019). According to Abdel-Salam (2010), functional foods have a positive effect on single or multiple body functions simultaneously to improve health and/or minimize the risk of disease. The development of functional foods by fortification with some bioactive ingredients is increasing (Mudgil et al., 2012). The demand for nutrient-rich and healthy fats in cosmetic, food, and pharmaceutical industries is increasing because of their multifunctional benefits. Most dietary fats are usually long-chain fatty acids (LCFA). However, LCFA tends to induce negative effects on insulin balance and glucose level, as well as in body weight and adipose tissue mass gain. This urge the need for an alternative fat as an alternative energy source in the most convenient form to be incorporated in daily meals to encourage healthy eating among Malaysians.

Medium Chain Triglycerides (MCT) have played a role in the food industry for years, but their use has increased as consumers attracted to healthy fats for diets with bioactive lipids that are associated with weight loss. The emphasis on low-carbohydrate diets has also driven the growth of MCT in the beverages and food industry. MCTs are metabolized more quickly than any other fatty acids and supply energy without being stored as fat. The high concentration of MCT in coconut oil

encourages many media articles to promote its uses for weight loss (Lockyer and Stanner, 2016). Many studies also reported that MCT can reduce food intake and increase satiety upon consumption (Van Wymelbeke et al., 2001). Its mechanism of action which do not cause a spike in blood sugar level and insulin secretion, in addition giving satiety and feeling full longer is favourable for weight management, attracting attention of ketogenic diets, obese, diabetic type-2 and patient with insulin resistance issue to incorporate MCT in their daily diet.

1.2 Problem Statement

The addition of maltodextrin in the powder formulation able to enhance the quality of the product such as MCT powder in terms of physical appearance, poor wettability, solubility, and sensory acceptance. Regardless of many MCT powdered formulation in the market, there's limited improvement about the formulation ingredients as the current formulation in the market usually include maltodextrin as their main ingredients which was reported giving a negative side effect on the human health such as might cause a spike in blood glucose level due to its high glycaemic index, subsequently not recommended for diabetics with insulin resistance issue and for weight management.

Due to high awareness and health conscious among Malaysian, finding an alternative to maltodextrin for wall material in formulation ingredients is important for better health. The addition of prebiotic ingredient as a wall material such as Arabic Gum (AG) and protein, sodium caseinate able to replace maltodextrin and may improve the physicho characteristic, biological activity as well as add values to MCT powder. However, the effect of these ingredients on the physicochemical and biological activity of MCT powder are still not reported. Therefore, the evaluation on the effect of both ingredients in the formulation of MCT oil powder was carried out to tackle the above-mentioned problem as well as improve its quality. The quality of MCT oil powder was assessed in terms of yield, solubility, wettability, antioxidant activity, and its effect on probiotic growth that able to assist future commercialization.

1.3 Research Objectives

To determine the effects of formulation ingredients on the nutritional quality of MCT oil powder.

1.4 Research Scopes

To achieve the objective of this research, the following scopes are outlined:

i. Screening of formulation ingredients range of MCT oil, Arabic gum and sodium caseinate for high yield.
ii. Identification of the effects of formulation ingredients on physicho characteristics like its solubility, wettability, antioxidant activity, and sensory evaluation of MCT oil powder.
iii. Identification of the effects of formulation ingredients on probiotic growth using *In Vitro* Probiotic Analysis.

1.5 Significant of Study

In the past decades, spray drying technology has been studied and developed for the development of functional products with numerous ingredients and using various wall materials. In order to maximize the encapsulation's efficiency, it is important to choose the wall material to protect the core material (active ingredients) from volatilization, chemical interactions and oxidation (Fernandes et al., 2014). Due to cost effective, acceptable neutral taste and aroma, low viscosity at high sold concentration, maltodextrin is widely used to give high protection against oxidation (Fernandes, 2014). However, because maltodextrin has the highest glycaemic index (> 130), it can lead to unhealthy effects on human health.

The replacement of maltodextrin wall with healthy wall materials may help to solve this problem. Therefore, Arabic gum & sodium caseinate were chosen as better choice wall materials as it exhibits dual functions, both as healthier wall materials and prebiotic source. This study discovered its effects towards quality of MCT oil powder for future commercialization.

This study concluded that the bioproduct development of MCT oil powder has a huge potential as an exceptional value-added product of derived VCO as it would receive wide acceptance in terms of colour, flavour, taste, and texture. The nutritional benefits of the product were also interesting in term of health point of view as it contains high medium chain triglycerides (good fat) with prebiotic effects for human gut health and general well-being, improving the nutritional status of the country. The long-term storage capability of the product makes it commercially lucrative. Biochemical and sensory attributes of the formulated MCT oil powder were either superior or comparable to existing MCT oil powders. This study will assist future research and product development of healthy powdered drinks to replace Malaysian's sugary breakfast drinks.

REFERENCES

Abdel-Salam, A.M. Functional foods: Hopefulness to good health. American Journal of Food Technology 2010, 5, 86-99, https://doi.org/10.3923/ajft.2010.86.99.

Aluko, R. Bioactive lipids. In: Functional foods and nutraceuticals. Springer: New York 2012; pp. 23-36, https://doi.org/10.1007/978-1-4614-3480-1.

Antolovich, M.; Prenzler, P.D.; Patsalides, E.; McDonald, S.; Robards, K. Methods for testing antioxidant activity. Analyst 2002, 127, 183–198.

Babayan VK. Medium chain triglycerides and structured lipids. Lipids. 1987;22(6):417-20.

Babiker, R., Merghani, T.H., Elmusharaf, K., Badi, R.M., Lang, F., Saeed, A.M., 2012. Effects of gum Arabic ingestion on body mass index and body fat percentage in healthy adult females: two-arm randomized, placebo controlled, double-blind trial. Nutr. J. 11, 1-7.

Bach AC and Babayan VK (1982). Medium-chain triglycerides:an update. American Journal of Clinical Nutrition 36:950–962.

Bloch R (1974). Intestinal absorption of medium-chain fattyacids. Zeitschrift fur Ernahrungswissenschaft 13: 42–49.

Calame, W., Weseler, A.R., Viebke, C., Flynn, C., Siemensma, A.D., 2008. Gum arabic establishes prebiotic functionality in healthy human volunteers in a dose-dependent manner. Br. J. Nutr. 100 (6), 1269–1275.

Carmona, P.A.O.; Garcia, L.C.; de Aquino Ribeiro, J.A.; Valadares, L.F.; de FigueiredoMarçal, A.; de França, L.F.; Mendonça, S. Effect of Solids Content and Spray-Drying Operating Conditions on the Carotenoids Microencapsulation from Pressed Palm Fiber Oil Extracted with Supercritical CO2 . Food Bioprocess. Technol. 2018, 11, 1703–1718.

Carneiro, H.C.F.; Tonon, R.V.; Grosso, C.R.F.; Hubinger, M.D. Encapsulation Efficiency and Oxidative Stability of Flaxseed Oil Microencapsulated by Spray Drying Using Different Combinations of Wall Materials. J. Food Eng. 2013, 115, 443–451.

Chew, S.C.; Tan, C.P.; Nyam, K.L. Microencapsulation of Refined Kenaf (Hibiscus cannabinus, L.) Seed Oil by Spray Drying Using β-Cyclodextrin/Gum Arabic/Sodium Caseinate. J. Food Eng. 2018, 237, 78–85.

Chuyen, H.V.; Roach, P.D.; Golding, J.B.; Parks, S.E.; Nguyen, M.H. Encapsulation of Carotenoid-Rich Oil from Gac Peel: Optimisation of the Encapsulating Process Using a Spray Drier and the Storage Stability of Encapsulated Powder. Powder Technol. 2019, 344, 373–379.

Comunian, T.A.; Favaro, L.F.; Thomazini, M.; Pallone, E.M.J.A.; do Amaral Sobral, P.J.; de Castro, I.A.; Favaro-Trindade, C.S. Echium Oil with Oxidative Stability Increased by Emulsion Preparation in the Presence of the Phenolic Compound Sinapic Acid Followed by Dehydration by Spray and Freeze-Drying Processes. J. Food Sci. Technol. 2019, 56, 1155–1164.

Daoub, R.M.A.; Elmubarak, A.H.; Misran, M.; Hassan, E.A.; Osman, M.E. Characterization and Functional Properties of Some Natural Acacia Gums. J. Saudi Soc. Agric. Sci. 2018, 17, 241–249.

Dauqan, E. and Abdullah, A. Utilization of Gum Arabic for Industries and Human Health. Am. J. Appl. Sci. 2013, 10, 1270–1279.

De Almeida, C.V.; de Camargo, M.R.; Russo, E.; Amedei, A. Role of diet and gut microbiota on colorectal cancer immunomodulation. World Journal of Gastroenterology 2019, 25, 151-162.

Decker, E.A.; Elias, R.J.; McClements, D.J. Oxidation in foods and beverages and antioxidant applications: management in different industry sectors. Elsevier: USA 2010.

Domian, E.; Sułek, A.; Cenkier, J.; Kerschke, A. Influence of Agglomeration on Physical Characteristics and Oxidative Stability of Spray-Dried Oil Powder with Milk Protein and Trehalose Wall Material. J. Food Eng. 2014, 125, 34–43.

Dos Santos Vaucher, A.C.; Dias, P.C.M.; Coimbra, P.T.; Dos Santos, I.M.C.; Marreto, R.N.; Dellamora-Ortiz, G.M.; De Freitas, O.; Ramos, M.F.S. Microencapsulation of Fish Oil by Casein-Pectin Complexes and Gum Arabic Microparticles: Oxidative Stabilization. J. Microencapsul. 2019, 36, 459–473.

Edris, A.E.; Kalemba, D.; Adamiec, J.; Pi ˛atkowski, M. Microencapsulation of Nigella sativa Oleoresin by Spray Drying for Food and Nutraceutical Applications. Food Chem. 2016, 204, 326–333.

Eun, J.B.; Maruf, A.; Das, P.R.; Nam, S.H. A review of encapsulation of carotenoids using spray drying and freeze drying. Critical Reviews in Food Science and Nutrition 2019, 1-26, https://doi.org/10.1080/10408398.2019.1698511.

Fernandes, R.V.B., Borges, S.V., Botrel, D. A., 2014. Gum arabic/starch/maltodextrin/inulin as wall materials on the microencapsulation of rosemary essential oil. Carbohydr. Polym. 101, 524-532.

Fernandes, R.V.B., Borges, S.V., Silva, E.K., da Silva, Y.F., de Souza, H.J.B., do Carmo, E.L., de Oliveira, C.R., Yoshida, M.I., Botrel, D.A., 2016. Study of ultrasound assisted emulsions on microencapsulation of ginger essential oil by spray drying. Ind. Crops Prod. 94, 413-423.

Gharsallaoui, A.; Roudaut, G.; Chambin, O.; Voilley, A.; Saurel, R. Applications of Spray-Drying in Microencapsulation of Food Ingredients: An Overview. Food Res. Int. 2007, 40, 1107–1121.

Hogan, S.A.; McNamee, B.F.; O'Riordan, E.D.; O'Sullivan, M. Emulsification and Microencapsulation Properties of Sodium Caseinate/Carbohydrate Blends. Int. Dairy J. 2001, 11, 137–144.

Ixtaina, V.Y.; Julio, L.M.; Wagner, J.R.; Nolasco, S.M.; Tomás, M.C. Physicochemical Characterization and Stability of Chia Oil Microencapsulated with Sodium Caseinate and Lactose by Spray-Drying. Powder Technol. 2015, 271, 26–34.

K.G. Nevin, T. Rajamohan, Virgin coconut oil supplemented diet increases the antioxidant status in rats. Food Chemistry 99 (2) (2006) 260-266.

Kha, T. C., Nguyen, M. H., Roach, P. D., and Stathopoulos, C. E. 2014. Microencapsulation of Gac Oil by Spray Drying: Optimisation of Wall Material Concentration and Oil Load Using Response Surface Methodology. Drying Technology. 32(4): 385-397. DOI: 10.1080/07373937.2013.829854.

Kriangkrai, W., Sararuk, P., Tothong, T., Khumpirapang, N. and Wittaya-Areekul, S., 2022. *Formulation Optimization and Characterization of Spray-Dried Medium Chain Triglycerides-Rich Oil.*

Li, K.; Woo, M.W.; Patel, H.; Selomulya, C. Enhancing the Stability of Protein-Polysaccharides Emulsions via Maillard Reaction for Better Oil Encapsulation in Spray-Dried Powders by PH Adjustment. Food Hydrocoll. 2017, 69, 121–131.

Limketkai BN and Zucker SD. Hyperammonemic encephalopathy caused by carnitine deficiency. J Gen Intern Med. 2008;23(2):210-3.

Liu, Y.; Xue, C.; Zhang, Y.; Xu, Q.; Yu, X.; Zhang, X.; Wang, J.; Zhang, R.; Gong, X.; Guo, C. Triglyceride with medium-chain fatty acids increases the activity and expression of hormone-sensitive lipase in white adipose tissue of C57BL/6J mice. Bioscience, Biotechnology, and Biochemistry 2011, 75, 1939–1944, https://doi.org/10.1271/bbb.110321.

Lockyer S and Stanner S. (2016) Nutritional Bulletin 41, 42–54.

Matsumoto, N., Riley, S., Fraser, D., Al-Assaf, S., Ishimura, E., Wolever, T., Phillips, G.O., Phillips, A.O., 2006. Butyrate modulates TGF-β1 generation and function: potential renal benefit for Acacia(sen) SUPERGUM (gum Arabic)? Kidney Int. 69 (2), 257–265.

McClements, D.J. Design of nano-laminated coatings to control bioavailability of lipophilic food components. Journal of Food Science 2010, 75, R30-R42, https://doi.org/10.1111/j.1750- 3841.2009.01452.x.

Mirghani, Mohamed & Elnour, Ahmed & Kabbashi, Nassereldeen & Alam, Md & Musa, Khalid Hamid & Abdullah, Amina. (2018). Determination of antioxidant activity of gum Arabic: An exudation from two different locations. ScienceAsia. 44. 179. 10.2306/scienceasia1513-1874.2018.44.179.

Mudgil, D.; Barak, S.; Khatkar, B.S. Process optimization of partially hydrolyzed guar gum using response surface methodology. Agro Food Industry Hi Tech 2012, 23, 13-15.

Mumme K and Stonehouse W. Effects of medium-chain triglycerides on weight loss and body composition: a metaanalysis of randomized controlled trials. J Acad Nutr Diet. 2015;115(2):249-63.

Munin, A.; Edwards-Lévy, F. Encapsulation of Natural Polyphenolic Compounds; A Review. Pharmaceutics 2011, 3, 793–829.

Nandi S, Gangopadhyay S and Ghosh S (2005). Production of medium chain glycerides from coconut and palm kernel fatty acid distillates by lipase-catalyzed reactions. Enzymeand Microbial Technology 36: 725–728.

Niro Atomizer Ltd (Denmark) Dairy Research Group (1978). Analytical methods for dry milk products. 4th ed. Copenhagen, Denmark: A/S Niro Atomizer. pp 26–33.

Okonogi, S.; Duangrat, C.; Anuchpreeda, S.; Tachakittirungrod, S.; Chowwanapoonpohn, S. Comparison of antioxidant capacities and cytotoxicities of certain fruit peels. Food Chem. 2007, 103, 839–846.

Pang, S. F., Yusoff, M. M., & Gimbun, J. (2014). Assessment of phenolic compounds stability and retention during spray drying of Orthosiphon stamineus extracts. Food Hydrocolloids, 37, 159–165.

Papamandjaris AA, MacDougall DE, Jones PJ. Medium chain fatty acid metabolism and energy expenditure: obesity treatment implications. Life Sci. 1998;62(14):1203-15.

Patel, S. and Goyal, A., 2015. Applications of natural polymer gum Arabic: a review. Int. J. Food Prop. 18, 986–998.

Peryam, D. R., & Pilgrim, F. J. (1957). Hedonic scale method of measuring food preferences. Food Technology, 11, 9–14

Ramirez M, Amate L and Gil A (2001). Absorption and distribution of dietary fatty acids from different sources.Early Human Development 65 (suppl.): S95–S101.

Rashidinejad A, Jameson GB, Singh H. The Effect of pH and Sodium Caseinate on the Aqueous Solubility, Stability, and Crystallinity of Rutin towards Concentrated Colloidally Stable Particles for the Incorporation into Functional Foods. Molecules. 2022 Jan 14;27(2):534.

Rosida, D.F.; Mulyani, T.; Septalia, L.R. A Comparative Study of Non-Dairy Cream Based on the Type of Leguminosae Protein Source in Terms of Physico Chemical Properties and Organoleptic. Agric. Agric. Sci. Proced. 2016, 9, 431–439.

Shi, L.; Beamer, S.K.; Yang, H.; Jaczynski, J. Micro-Emulsification/Encapsulation of Krill Oil by Complex Coacervation with Krill Protein Isolated Using Isoelectric Solubilization/Precipitation. Food Chem. 2018, 244, 284–291.

Sidossis LS, Stuart CA, Shulman GI, Lopaschuk GD and Wolfe RR(1996). Glucose plus insulin regulate fat oxidation by controlling the rate of fatty acid entry into the mitochondria. Journal of Clinical Investigation 98: 2244–2250.

Slavin, J., 2013. Fiber and prebiotics: mechanisms and health benefits. Nutrients 5 (4), 1417–1435.

Sosnik, A.; Seremeta, K.P. Advantages and Challenges of the Spray-Drying Technology for the Production of Pure Drug Particles and Drug-Loaded Polymeric Carriers. Adv. Colloid Interface Sci. 2015, 223, 40–54.

Stanislav, A.A.; Vassu-Dimov, T.; Iacob, M.M.; Botezatu, A.; Arsene, C.; Burlibasa, L.; Bodron, P.; Sarghie, L.; Cucu, N.; Alexandrescu, L. Investigation of fat mass and obesity associated (FTO) gene polymorphism in Romanian population. Biointerface Research in Applied Chemistry 2018, 8, 3710-3718.

Symersky T, Vu MK, Frolich M, et al. The effect of equicaloric medium-chain and long-chain triglycerides on pancreas enzyme secretion. Clin Physiol Funct Imaging. 2002;22(5):307-11.

Tavares G.M., Croguennec T., Carvalho A.F., Bouhallab S. Milk proteins as encapsulation devices and delivery vehicles: Applications and trends. Trends Food Sci. Technol. 2014;37:5–20. doi: 10.1016/j.tifs.2014.02.008.

Van WPymelbeke V, Louis-Sylvestre J and Fantino M (2001) American Journal of Clinical Nutrition 74, 620–30.

Yekdane, N.; Goli, S.A.H. Effect of Pomegranate Juice on Characteristics and Oxidative Stability of Microencapsulated Pomegranate Seed Oil Using Spray Drying. Food Bioprocess. Technol. 2019, 12, 1614–1625.

Yingngam, B.; Kacha, W.; Rungseevijitprapa, W.; Sudta, P.; Prasitpuriprecha, C.; Brantner, A. Response Surface Optimization of Spray-Dried Citronella Oil Microcapsules with Reduced Volatility and Irritation for Cosmetic Textile Uses. Powder Technol. 2019, 355, 372–385.

Yoo J.Y., Kim S.S. Probiotics and Prebiotics: Present Status and Future Perspectives on Metabolic Disorders. *Nutrients.* 2016;8:173. doi: 10.3390/nu8030173.

Zhang, Y.; Pan, K.; Zhong, Q. Eugenol Nanoencapsulated by Sodium Caseinate: Physical, Antimicrobial, and Biophysical Properties. Food Biophys. 2018, 13, 37–48.