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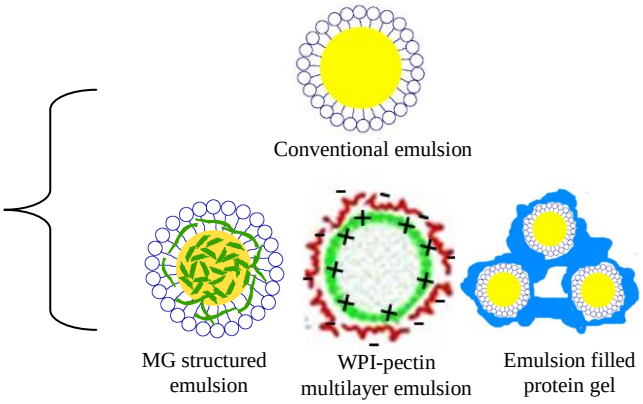
# Formulation and design of novel dairy ingredients based emulsions for bioactive nutrients delivery




## Key external stakeholders:

Dairy and beverage industry
Target-deliver food manufacturers
Academic and research institute

## Practical implications for stakeholders:

The outcome/technology or information/recommendation is……
We propose this research to develop novel dairy ingredients-based structured emulsions to encapsulate, protect and controlled release bioactive nutrients. The retention and release of nutrients in storage, reconstitution and conditions simulating human gastrointestinal system as well as absorption behaviours in vitro and in vivo will also be studied. This research undoubtedly will contribute to knowledge body of food nanotechnology and expertise for the design and production of novel foods with controlled targeted nutrient release. Furthermore, structured emulsions have almost every qualification for being the source of drug carriers without side-effects and potentially will break the bottleneck of high-efficient targeted drug delivery, lead to the accelerated development of the pharmaceutical industry and thus contribute to improved human health.

## Main results:

1. The initial droplet size and selection of emulsifiers (whey protein isolate, sodium caseinate, or tween 80) can significantly influence the emulsion stability (creaming and pH) and cellular uptake of encapsulated lipophilic components without passing through the GIT digestion;
2. Incorporation of monoglyceride (MG) into the oil phase of emulsions can significantly improve emulsion creaming stability, modify the emulsion properties (droplet size and distribution, and surface charge) in GIT digestion, and improve the bioaccessibility and cellular uptake of encapsulated lipophilic components after passing through GIT;
3. Interfacial compositions (emulsifiers) and initial droplet size can significantly influence the emulsion properties (droplet size and distribution, and surface charge) in the GIT digestion while the bioaccessibility and cellular uptake of encapsulated lipophilic components is mainly dependent on the selection of different emulsifiers (whey protein isolate, sodium caseinate, or tween 80), but not the initial droplet size;
4. Incorporation of konjac glucomannan (KGM) into the water phase of WPI-stabilized emulsions can significantly increase their viscosity, and improve their creaming, pH, and freeze-thaw stabilities;

## Opportunity / Benefit:

The present study provided useful information about different model O/W emulsions as delivery carriers for lipophilic components, and on how emulsion structures can be designed to modify the release of health-beneficial lipophilic components and improve their oral bioavailability, which could be important in developing functional foods with sustained release, or improved oral stability and bioavailability of functional ingredients entrapped in food matrixes.

## Collaborating Institutions:

University College Cork, Ireland



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**Teagasc project team:** Dr. Song Miao
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**External collaborators:** Prof. Alan Kelly (UCC)

## 1. Project background:

Instability and water-insolubility of many bioactive nutrients greatly limit their oral bioavailability and thus their health benefits. Therefore, the delivery of these compounds requires protective mechanisms. Emulsion-based delivery systems are becoming some of the most ideal microencapsulation carriers for these lipophilic bioactive components, and tailored structures of emulsions potentially contribute to a better control of the stability and bioavailability of instable and poorly water-soluble bioactive components.

## 2. Questions addressed by the project:

The main questions were whether novel structured emulsions are suitable to deliver bioactives, and how bioactive release can be modulated by just adjusting emulsion structures. We tried to correlate environmental stresses (e.g., pH, salt concentration, saliva) with food structures and then bioactives release. In the present study, model O/W emulsion based delivery systems with different oil phase, oil-water interface, and water phase, containing lipophilic bioactive nutrients (using β-carotene as an example) were prepared. A simulated in vitro GIT digestion model consisting of mouth, gastric, and intestinal phases combined with a cellular uptake test by enterocytes (Caco-2 cells) was employed to get a better understanding of the relationship between the emulsion structure and the oral absorption of encapsulated lipophilic components in an attempt to achieve a potential controlled release and improved bioavailability of these compounds by designing the structure of emulsion-based carriers.

## 3. The experimental studies:

The current study mainly investigated four model O/W emulsions with different initial droplet size, oil phase compositions, emulsifiers, and water phase compositions. A representative lipophilic bioactive nutrient, β-carotene, was encapsulated into these model emulsions. Emulsion properties, and the in vitro digestion, release, bioaccessibility and absorption by enterocytes of encapsulated β-carotene were investigated. Re-dispersible dry forms of these model emulsions containing β-carotene were also prepared, and their microstructures, re-dispersibility, and the properties of their reconstitutions were characterized.

## 4. Main results:

- A whey protein isolate (WPI) stabilized emulsion with small initial droplet size showed better creaming and pH stability and higher cellular uptake of β-carotene than that with large initial droplet size. After passing through the simulated gastrointestinal tract (GIT) digestion, initial droplet size significantly influenced the emulsion properties (e.g., droplet size and distribution and surface charge), but did not significantly affect the bioaccessibility and cellular uptake of β-carotene.
- Monoglycerides (MG) in the oil phase showed competitive absorption on the droplets surface with WPI, leading to reduced droplet surface charge. MG significantly increased the viscosity and creaming stability of WPI-stabilized emulsions. MG also significantly promoted the bioaccessibility and cellular uptake of β-carotene by Caco-2 cells ($p<0.05$).
- Emulsions stabilized with different emulsifiers of WPI, sodium caseinate, or tween 80, showed different droplet sizes, surface charges, creaming and pH stability, and cellular uptake of β-carotene without passing through the GIT. Selection of emulsifiers also significantly modified the emulsion properties when exposure to the GIT digestion, and the bioaccessibility and cellular uptake of β-carotene after the GIT digestion ($p<0.05$).
- Incorporation of KGM into the water phase of emulsions greatly improved the creaming and pH stability of WPI-stabilized emulsions, and significantly decreased the oiling-off of the emulsions during a freeze-thaw test. Emulsions containing KGM in the water phase showed a lower final release rate of encapsulated β-carotene then the emulsion without KGM ($p<0.05$), and the release rate decreased with increasing KGM content.
- Dried emulsions showed different morphologies and microstructures, depending on the drying method (spray-drying or freeze-drying), and the compositions of emulsions before drying. Dry emulsions showed fast re-hydration and good re-dispersibility in water. Compared with emulsions before drying, re-constituted spray-dried and freeze-dried emulsions showed shifted droplet size distribution to large and small size, respectively. Re-constituted emulsions containing KGM showed significantly decreased viscosity but increased creaming stability compared to emulsions before drying ($p<0.05$).



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## 5. Opportunity/Benefit:

Teagasc can provide expertise for the designing of bioactive component delivery system in dairy products or beverages to meet special requirement for customers. The techniques obtained in this research allow to test food bioactive ingredient release profile in different environmental conditions.

## 6. Dissemination:

### Main publications:


1. Lu, W., Kelly, A. L., & Miao, S.* (2020). Fabrication and characterization of highly re-dispersible dry emulsions, Food Hydrocolloids , (IF 5.839)
2. Lu, W., Kelly, A. L., & Miao, S.* (2017). Improved bioavailability of encapsulated bioactive nutrient delivered through a monoglyceride-structured O/W emulsion. Journal of Agricultural and Food Chemistry. 65(14):3048-3055. (IF 3.571)
3. Lu, W., Zheng, B., & Miao, S.*. (2018). Improved emulsion stability and modified nutrient release by structuring O/W emulsions using konjac glucomannan, Food Hydrocolloids , 81, 120-128. (IF 5.839)
4. Lu, W., Kelly, A. L., & Miao*, S. (2016). Emulsion-based encapsulation and delivery systems for polyphenols. Trends in Food Science & Technology, 47, 1-9. (IF 8.519)
5. Lu, W., Kelly, A. L., & Miao, S*. (2017). Bioaccessibility and Cellular Uptake of β-Carotene Encapsulated in Model O/W Emulsions: Influence of Initial Droplet Size and Emulsifiers. Nanomaterials, 7(9), 282. ( IF 4.034)
6. Lu, W., Kelly, A. L., Maguire, P., Zhang, H., Stanton, C., & Miao, S.* (2016). Correlation of Emulsion Structure with Cellular Uptake Behavior of Encapsulated Bioactive Nutrients: Influence of Droplet Size and Interfacial Structure. Journal of Agricultural and Food Chemistry, 64, 8659-8666. (IF 3.412)
7. Lu, W., Kelly, A.L., Maguire, P., Zhang H., Stanton, C., & Miao*, S. (2016). Correlation of emulsion structure with cellular uptake behaviour of encapsulated bioactive nutrients: Influence of droplet size. 18th World Congress of Food Science and Technology, August 21-25, 2016, Dublin, Ireland.
8. Lu, W., Kelly, A.L., Stanton, C., & Miao*, S. (2016). Influence of emulsion structure on cellular absorption of encapsulated bioactive nutrients in emulsions. 2nd International Congress on Food Structure Design, October 26-28, 2016, Antalya, Turkey, (Oral presentation).


### Popular publications:


1. Lu, W., Kelly, A. L., & Miao, S.* (2017). Improved bioavailability of encapsulated bioactive nutrient delivered through a monoglyceride-structured O/W emulsion. Journal of Agricultural and Food Chemistry. 65(14):3048-3055. (IF 3.571)
2. Lu, W., Zheng, B., & Miao, S.*. (2018). Improved emulsion stability and modified nutrient release by structuring O/W emulsions using konjac glucomannan, Food Hydrocolloids , 81, 120-128. (IF 5.839)
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5. Lu, W., Kelly, A. L., Maguire, P., Zhang, H., Stanton, C., & Miao, S.* (2016). Correlation of Emulsion Structure with Cellular Uptake Behavior of Encapsulated Bioactive Nutrients: Influence of Droplet Size and Interfacial Structure. Journal of Agricultural and Food Chemistry, 64, 8659-8666. (IF 3.412)
6. PhD Thesis entitled “Dairy Ingredients-based Emulsions and beta-Carotene Delivery” UCC 2018


## 7. Compiled by: Song Miao



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