Poster presentations

Functionality of Multicomponent Systems

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pMC-1

Influence of the incorporation of curcumin-loaded solid lipid microparticles on the characteristics of mixed whey protein isolate-xanthan gum gels

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Simultaneous reduction of the lipid content and the incorporation of bioactive compounds is an interesting approach to obtain healthier food products, and can be carried out by producing emulsion filled gels. This study aimed to produce and characterize heat-set mixed protein (WPI)-polysaccharide (xanthan gum) gels filled with solid lipid microparticles (SLM) encapsulating curcumin. The gels were produced with WPI (12 % w/w) and xanthan gum (0.2 % w/w) at the condition of 90 °C/ 30 min and pH 6.5, varying salt concentration, hydrated by water or SLM. Two formulations of SLM were produced with babacu (*Orbignyia speciosa*) oil (2.8 % w/w) and tristearin (1.2 % w/w), with different surfactant (mixtures of tween 60 and span 80) concentrations, 2 % (SLM-2%) or 4 % (SLM-4%), encapsulating 0.03 % w/w of curcumin. Nine formulations of gels were produced with different salt concentration (no salt; 0.1 M NaCl and 0.1 M $CaCl_2$) hydrated by deionized water, incorporating both SLM-2% and SLM-4%. Gels were characterized by texture profile (TPA), water holding capacity (WHC), scanning electron microscopy (SEM), confocal laser scanning microscope (CLSM) and rheology. TPA results showed that presence of salt and SLM dispersions had low influence in the parameters investigated. Mixed gels filled with SLM had higher water holding capacity (average WHC of 42%) than no-filled gels (average WHC of 27%). SEM and CLSM micrographs showed particulate and very porous gels, with a homogeneous distribution of the solid lipid microparticles in the biopolymer network, and xanthan gum formed fine filaments linking the protein aggregates. For small amplitude oscillatory tests (1% shear) G' and G'' changed linearly with frequency sweep. The addition of 0.1 M NaCl, or filling the gels with SLM-4% (in the absence of salt) promoted reinforcement of the structure of the gels. Presence of 0.1 M $CaCl_2$ decreased the gel force in all samples. It was possible to conclude that filled gels were particulate and porous, and that SLM were homogeneously distributed in the structure, and the presence of salt and SLM modified significantly the structure of the mixed gels in some formulations.

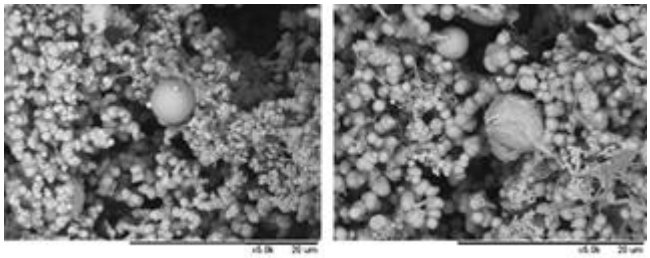

Figure 1: Micrographs obtained by scanning electron microscopy of the mixed gels filled with solid lipid microparticles.

pMC-2

Factors of influence on cold set gelation of mixed gels produced with soy protein isolate and locust bean gum

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Soy protein isolate (SPI) is an important ingredient in food industry due to its nutritional value and functional properties, as the ability to form gels. Although thermal gelation of globular proteins is the technique most commonly applied, cold set gelation has been also studied, in order to obtain final products with a differentiated quality. The gelling capacity of the proteins is influenced by the protein structure, characteristics of the environment (pH, temperature and ionic strength) and interactions with other ingredients in food. The presence of polysaccharides, for example, can contribute to a better structure and stabilization of protein gels. In this context, the objective of this study was to evaluate the effect of concentration of SPI (5, 10 and 15% (w/v)), $CaCl_2$ (0, 5 and 15 mM) and locust bean gum (LBG) (0, 0.1, 0.2, 0.3 %(w/v)) on cold set gelation of commercial SPI (obtained from Marsul, Brazil). Samples of SPI, with and without LBG, were hydrated, had the pH changed to 7 and were heated up to 80° C for 30 minutes. Afterwards the samples were cooled to room temperature and diluted with $CaCl_2$ solutions to reach the desired concentrations. The samples were kept at 5°C overnight and evaluated by appearance, texture profile analysis (TPA) and water-holding capacity (WHC). Sustainable gels were obtained in samples with 15% of SPI, in presence of $CaCl_2$ and in all concentrations of LBG tested (0-0.3% (w/v)). In all formulations, the high concentration of protein was important to increase the hydrodynamic interactions among the molecules, which can lead to a viscoelastic behavior and the presence of $CaCl_2$ was important to reduce electrostatic repulsion and form salt bridges among the protein molecules. The increase of salt concentration in gels without LBG increased the springiness, cohesiveness and hardness and decreased the WHC. The addition of LBG increased springiness, cohesiveness and hardness but did not change the WHC. In samples with LBG the increase of polysaccharide concentration did not interfere in springiness, cohesiveness and WHC, but decreased hardness, and the increase of salt concentration did not interfere in WHC, springiness and cohesiveness, but increased hardness.

pMC-3

Physico-chemical and structural characterization of multilamellar curcumin-loaded liposomes obtained by hydration of proliposomes

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This study aimed to investigate the physico-chemical stability and structure of curcumin-loaded multilamellar liposome dispersions. The liposomes were produced by the method of hydration of proliposomes, obtained by coating of micronized sucrose (Elhissi et al., 2011). Different combinations of polysaccharides were tested as thickeners to stabilize the dispersions, as in less than 48 h in the absence of stabilizers the multilamellar liposomes (average diameter 940 nm) destabilized. The polysaccharides tested were (% m/m): mixture of guar gum and xanthan gum (0.01% xanthan gum and 0.09% guar gum); mixtures of guar gum, xanthan gum and inulin (0.01% xanthan gum, 0.09% guar gum, 2.5% inulin); mixtures of xanthan gum and locust bean gum (0.01% xanthan gum and 0.09% LBG). The liposomes were produced by hydration of 20 g proliposome/L with deionized water using ultra-agitation at 13,000 rpm for 15 min. Afterwards the hydrocolloids were added to the liposome dispersion under magnetic stirring at room temperature (Toniazzo et al., 2014). The presence of curcumin in the liposomes decreased their hydrodynamic diameter in approximately 30%, in comparison to empty vesicles. Regarding liposomes stabilized with xanthan and guar gums, the average diameter was in the range of 700 – 900 nm, the same range of average diameters for the liposomes stabilized with mixtures of these gums and inulin. The systems stabilized with mixtures of xanthan gum and LBG presented higher average diameters, between 2600 and 3600 nm, and destabilized completely after 30 days of storage. In the case of this mixture, the increased size can be due to partial adsorption of the gums on the surface of the liposomes. Encapsulated curcumin was quantified in all systems, and in the liposomes stabilized with xanthan gum and LBG, after 30 days 40% of the initial amount of curcumin was preserved, whereas for the two systems containing guar and xanthan gums after 60 days 63% of the initial amount of curcumin was not degraded. SAXS (small angle X-ray scattering) measurements indicated the inulin did not act as a thickener, but formed nanoagglomerates, and that curcumin did not alter significantly the structure of the phospholipid bilayers of the liposomes.

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pMC-4

Formation of micro- and nano-sized gel particles of calcium alginate via the Leeds Jet Homogenizer

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Microgels of alginates with particle sizes less than 300 nm were synthesized using the Jet Homogenizer developed by University of Leeds. Unlike many homogenizers that involve a pre-mixing step, this confined impinging jet method has two separate feed streams that allows in situ gelation as the 2 streams come in contact at extremely high velocities and exit through a small orifice (diameter typically 0.5mm). Highly turbulent flow is generated, with Reynolds numbers exceeding 10^4. Thus if one stream is alginate and the other $CaCl_2$, small 'particles' of calcium alginate gel are formed. There were many ways to control particle size, e.g., by altering the viscosity of the alginate, changing the velocity (homogenization pressure), electrostatic stabilization of particles as they form with lactoferrin, plus ultrasonication. Higher viscosity and lower stream velocity generated larger particles. Particles formed in the presence of lactoferrin (a positively charged protein) were also reduced in size, suggesting lactoferrin was electrostatically adsorbed at the surface of the (negatively charged) gel particles, at least to some extent. There was a tendency of gel particles to form aggregates as they exited from the jet homogenizer and some particle size reduction could also be achieved through sonication to break down the aggregates. Various SEM techniques revealed gel particles of size below 50 nm forming clusters into microregions of size of 200-300 nm and upwards (depending on the preparation conditions). These gel particles were utilized to encapsulate a water soluble food dye (erioglaucine) and water insoluble particles of flavonoids (rutin and tiliroside). Due to the flavonoids' ability to fluorescence, confocal microscopy (CLSM) was employed to examine the entrapment of gel particles with rutin and tiliroside. The CLSM images provide solid evidence that Ca-alginate gel particles can successfully encapsulate such materials via this extremely simple and effective technique.

pMC-5

Exploration of the effect of liquid anti-solvent precipitation production parameters on colloidal protein particle properties

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Food-grade colloidal delivery systems have already been successfully developed for the encapsulation of lipophilic bioactive components. The design of similar systems for the stabilization of hydrophilic components in food matrices has proven to be much more challenging[1]. In this regard, colloidal protein particles are considered to be very promising systems. Indeed, proteins are presumed to interact with hydrophilic bioactive molecules through several interaction types, including hydrophobic, steric and hydrogen interactions. By reducing the exposure to harsh conditions in the food matrix, protein particles are believed to protect the encapsulated active and often unstable ingredients[2]. In addition, proteins are known to form dense particles and are usually easily digested within the human gastrointestinal tract[3].

In this study, protein particles were assembled from whey protein isolate using liquid anti-solvent precipitation (LAS). This production strategy involves the self-assembly of protein particles upon decreasing the solvent power of the medium in which the proteins are dissolved. By adding the protein solution to an anti-solvent phase, the proteins start to unfold which eventually results in the formation of particles by aggregation and precipitation of the molecules[4]. However, lack of knowledge of the effect of the production parameters during LAS on the properties of the final particles hampers their efficient production. The purpose of this study was therefore to examine the effect of different production parameters on the final particle diameter. Hereto, a statistical model was designed which enabled the prediction of the final particle diameter (distribution) based on a well-defined set of pre-chosen parameters. The particle diameter as well as its variability were measured by dynamic light scattering.

The results showed that the protein concentration, the mixing time, the solvent/anti-solvent ratio and the addition order can be considered as the main factors determining the diameter of particles produced using LAS. The designed model can be considered a useful tool in order to rationalize, promote and speed up the design and production of dense protein particles within the Food Science Field, which in a next step can be used for the entrapment of hydrophilic molecules.

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pMC-6

Influence of pH on the emulsifying properties of aqueous extract of *Rhyncophorus phoenicis* Larvae.

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Today, edible insects are evaluated for their potential functional properties to be used as food ingredient (Akopssan et al, 2014; Yi et al, 2013). The larvae of *Rhyncophorus phoenicis* (Rp), edible insect eaten in Central and Western Africa, are a good source for proteins and unsaturated lipids (Womeni et al, 2012). They can now be farmed which could be the opportunity for sufficient production for small-scale transformation and formulation industries. In the present work, the emulsifying properties of aqueous extract of *Rhyncophorus phoenicis* larvae were studied. Aqueous extracts were prepared at pHs from pH 3.0 to 10, their protein and lipid contents quantified, their molecular weight profiles investigated by SDS PAGE and fatty acid composition determined by gas chromatography. Emulsions of the aqueous extracts (protein concentration adjusted to 1mg/mL) and peanut oil in the ratio 90:10 (wt/wt) were prepared by sonication. Their droplet size distribution was determined by laser diffusion and mean surface diameter ($d_{3,2}$, µm) has been calculated. Droplet flocculation was assessed by optical microscopy. The protein content of the aqueous extracts increased from 0.84 ± 0.07 at pH 3.0 to 4.56 ± 0.48 g protein per 100 g fresh insect at pH 10. The molecular weight distribution differed according to pH indicating that different groups of proteins were extracted depending on pH. Lipids were present in the aqueous extracts whatever the pHs, the highest concentrations being found at pH 9.0 and 10. From pH 5.0 to 8.0, free fatty acids were obtained mostly, whereas at pH 9.0 and 10, it was triacylglycerol's. Monoacylglycerol's were also present with low proportions. At pH 5.0 to 8.0, the droplets size distributions were polydisperse with floc and very large oil droplets (> 10µm) leading to creamed emulsions in less than 30 min after emulsification. At pH 9 and 10, the $d_{3,2}$ of emulsions were less than 1 µm, the emulsions being stable for more than a week with no flocculation as shown by optical microscopy. In conclusion, aqueous extracts of *Rhyncophorus phoenicis* larvae obtained at pH 9.0 and 10 can be used as emulsifiers to form stable emulsions and then could be used in industry formulation.

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pMC-7

Rheology of emulsions stabilized by the electrostatic interaction between pectin and whey protein concentrate with ultrasound application

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Colloidal systems such as mixtures of proteins and polysaccharides have been used in food processing in various applications; furthermore, the addition of polysaccharides, even at low concentrations can generate large differences in the structure and rheological properties of foods. Most of these applications involve an emulsification step. The objective of this study was to evaluate the rheological behavior at constant shear of oil-in-water emulsions (O/W) stabilized by the electrostatic interaction of whey protein concentrate (WPC) with high-methoxyl pectin (PEC), at pH 3.5, with WPC:PEC proportions of 1:1 and 4:1, with ultrasound application, and with varied oil contents. The rheological behavior was also correlated with results of optical microscopy and stability of the emulsions. The emulsions were prepared through soybean oil dispersion (5, 10 and 15 %) in the protein suspension using Ultra Turrax at 15000 rpm for 4 minutes, followed by addition of the polysaccharide dispersion, stirring for further 4 minutes, and sonication for one minute at 20 kHz and 120 W. After preparation, the samples were transferred to test tubes and left at rest for 48 hours. The rheological behavior was determined in a rheometer AR-2000EX using serrated parallel plate geometry, 300 µm gap, at 25 °C. Flow curves were obtained during the descendant (100 to 0.1 s^{-1}) and ascendant (0.1 to 100 s^{-1}) shear rate ramps and the Newton model was fitted. The microstructure was evaluated through optical microscopy and stability by visual assessment and creaming index (CI). The Newton model could be well fitted to the data with R^2 = 0.99, and the emulsions exhibited Newtonian behavior for the two WPC:PEC proportions in all oil contents, which is a characteristic behavior of stable emulsions. The visual evaluation and CI analysis indicated stable systems without phase separation (no creaming) for all oil contents. Microscopy showed small droplets, possibly due to sonication. The population of droplets increased with increasing oil content; additionally, it was stable over the course of seven days. Emulsions based on WPC:PEC interactions were stable systems, allowing possible use as fat substitutes, reducing the level of fat in industrialized products and making them healthier.

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pMC-8

Rheological behavior of emulsions stabilized by the electrostatic interaction between sodium alginate and whey protein concentrate subjected to sonication

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Mixtures of biopolymers which result in phase separation are useful to create new structures and the role of protein:polysaccharide interactions regarding their functionalities in multiphase systems, such as dispersions and emulsions, are still a subject worth of study. The objective of this study was to evaluate the rheological behavior of oil-in-water emulsions (O/W) stabilized by the electrostatic interaction of whey protein concentrate (WPC) with sodium alginate (ALG), at pH 3.5, with WPC:ALG proportions of 1:1 and 4:1, with ultrasound application, and with varied oil contents. The rheological behavior was also correlated with results of optical microscopy and stability of the emulsions. The emulsions were prepared through soybean oil dispersion (15, 20 and 25 %) in the protein suspension using Ultra Turrax at 15000 rpm for 4 minutes, followed by addition of the polysaccharide dispersion, stirring for further 4 minutes, and sonication for one minute at 20 kHz and 120 W. After preparation, the samples were transferred to test tubes and left at rest for 48 hours. Rheological tests were performed on AR-2000EX rheometer, using serrated parallel plate geometry, 500 µm gap, at 25 °C. Flow curves were obtained along the descendant (100 to 0.1 s^{-1}) and ascendant (0.1 to 100 s^{-1}) shear rate ramps, in addition to frequency sweeps (0.1 - 100 $rad.s^{-1}$) that were performed at WPC:ALG 4:1 with 0.4 % strain. The microstructure was evaluated through optical microscopy and stability by visual assessment and creaming index (CI). The power law model fit the data well (R^2 = 0.99), indicating pseudoplastic behavior in all systems; the consistency index (K) increased with increasing proportion of protein and oil content. The mechanical spectra showed G'> G'' in the frequency range applied, indicating a structured material; the modules were intensified as oil content increased. Visual evaluation and CI indicated phase separation and creaming, with CI varying from 59 to 84.9 %. Microscopy showed an increase in the number of drops with increasing oil content. Emulsions based on WPC:ALG complexes were unstable systems, but the creams formed have interesting textural and rheological characteristics and may allow creation of new structures and specific applications.

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pMC-9

Behaviour of soy protein isolate/high-methoxyl pectin complexes as affected by pH and protein concentration

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The formation of complexes between proteins and polysaccharides with opposite charges is a colloidal phenomenon involved in the structuring of several biological systems. There has been increasing interest in complexes formed by these biopolymers recently due to their potential applications in the food industry, being used as stabilizers in milk-based beverages, emulsifiers, foam stabilizers, fat replacers, besides being used in encapsulation, enzymes immobilization and recuperation, and protein separation processes (Dong et al., 2015). In this context, the aim of this study was to characterize the soy protein isolate and high-methoxyl pectin biopolymers at different pHs through solubility and charges, besides characterizing the complex formed by the pair at different proportions and pHs, evaluating turbidimetry and morphology. Through tests for characterization of the biopolymers, it was observed that high-methoxyl pectin was completely soluble, disregarding the pH of the solution and that negative charges increased as pH increased until they reached a plateau (above pH 5.0). The soy protein isolate showed low solubility, around 10%, at its isoelectric point (between pH 4.0 and 5.0) which increased in alkaline solutions, until it reached 100% at pH 11.0. Besides, positive charges below the isoelectric point and negative ones above this point were found. For the systems in which the biopolymers were present at different concentrations, as solutions became more alkaline, the absorbance reading values became lower, which suggests a lower attractive interaction between them and lower complex formation. For the same pH, the increase in proportion of soy protein isolate was followed by an increase in the absorbance reading value, which leads to the conclusion that a higher complex formation occurred, mainly in more acid solutions. Through images obtained from optical microscopy, it was possible to observe the morphology of the systems at different proportions for the studied pHs, confirming the results obtained through turbidimetry tests. Based on these remarks, solutions at pH 3.5 were considered ideal for an attractive interaction and complex formation between the studied biopolymers to happen, being suitable to elaborate stable food systems, such as acidic beverages based on protein or emulsions.

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pMC-10

Encapsulation of iron for fortification of plant protein-based structured foods

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A promising solution to reduce meat consumption is to shift towards alternative sources of proteins, such as meat replacers [1]. Unfortunetely, most consumers do not see such plant proteins sources as potential substitutes for meat yet [2]. This has been one of the biggest challenges that researchers working on this topics had to face: how to make meat substitutes not only of high nutritional value, but also attractive and eco-friendly. Previous results have already been obtained in creating anisotropic structures with shearing device using calcium caseinate [3,4] and blends of soy protein nutrients such as iron, fibers and bioactive compounds (3.g. vitamins) that are commeonly present in meat. In case protein isolates are used as main ingredients in a meat substitute it would be opportune to consider fortification with such nutrients, for instance iron to turn meat substitutes into healthier alternatives to conconsumers. Since iron has a prooxidant activity, encapsulation techniques should be consider to avoid sensory defects and loss in nutritional quality. Till now, the use and stability of iron encapsulates in plant protein-based structured foods has not been studied. Therefore, the aim of this work is the production and characterization of iron encapsulated particles for fortification of structured plant-based products. In addition, it will be investigated the behaviour of encapsulates during structuring process, considering thermal-mechanical treatment. For this purpose different encapsulation systems such as spray drying, liposome and double emulsions will be tested.

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pMC-11

Incorporation of solid lipid nanoparticles (SLN) in protein gels: Impact on water holding capacity and rheological properties

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Filling gels with emulsions or suspensions may change their network structure. It is known that gel characteristics are altered compared to non-filled gels[1]. Droplet- or particle-sizes as well as the concentration of filler materials affect the properties of these gels[2]. In the present study, we investigate the impact of the incorporation of solid lipid nanoparticles (SLN) on the characteristics of cold set β-lactoglobulin gels. In this contribution we present experimental results for different SLN concentration (0 %, 1.5 %, 2.5 %, 4.7 % w/v) and time of SLN addition (before or after protein denaturation). After thermal denaturation, the formation of the network was induced by reducing the pH-value. The gels were characterized with respect to their water holding capacity, rheological properties and gel strength.

Both in the presence and absence of SLN, the gels showed viscoelastic properties and thixotropic behavior. The water holding capacity and the gel strength increased with increasing SLN concentration. The time at which the SLN were added to the protein solution had a smaller impact on the gel characteristics than the nanoparticle concentration. No differences in storage modulus and water holding capacities between gels containing SLN that were incorporated before or after heat denaturation of the protein were found.

SLN in β-lactoglobulin gels act as active filler and influence the characteristics of the gel. This study will help in understanding better the behavior of nanoparticles during network formation and their influence in complex food structures, the latter being a prerequisite for prospective applications.

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pMC-12

Foam-mat Freeze-drying of blackcurrant juice: anthocyanin survival and drying analysis

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It is known that polyphenols impart stability properties to colloidal systems due to their interaction with proteins. One of the main problems of foam dehydration is the intrinsic instability of foams. Blackcurrant juice has a high polyphenol content, in particular of anthocyanins. Studies have suggested anthocyanin protection against oxidation is given by proteins. The aims of this study were to freeze-dry blackcurrant foams which can maintain a solid-like structure before and during dehydration, to analyse the drying rates of foamed and non-foamed blackcurrant juice and to analyse if proteins protect anthocyanins during foaming. Blackcurrant juice and acidified-sugared water (both pH 2.7) were foamed and analysed for drainage and overrun at 12°C. Blackcurrant juice and foam were freeze-dried at -50 °C for 24 h and at 0.04 mbar. Freeze-dried samples were reconstituted and digested with pepsin (0.32%) at low pH, and free anthocyanin content determined. Results showed slower drainage in blackcurrant foam compared to acidified-sugared water. Overrun in blackcurrant foam was 990% while acidified-sugared water was 610%. A 70% reduction in the drying time and a faster decrease in the percentage water loss were obtained in the blackcurrant foam compared to non-foamed juice in equal volumes. However, a lower production yield was obtained in dried foam than in the dried juice. This coupled with the higher overrun (reduction of the freeze-drier load), the energy needed to foam the juice and the expenses of the foaming agents and manpower, means that foamed juice is more complicated and probably more expensive to freeze-dry than non-foamed juice. Finally, it was found that the protein does not have a complete protective effect on anthocyanin degradation when juice was foamed: only 67% of the original anthocyanin content was recovered, whereas non-foamed samples registered no losses.

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pMC-13

Solvency Effects on Biopolymer Interactions

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Low-methoxyl (LM) pectin is widely used in food industry for its capability to form gels in presence of calcium ions. In the product, the polymer will be exposed and interact with other ingredients such as sugars, polyols, proteins, etc. to obtain a desired products. The aim of this study is to investigate the interactions that occur between polymer, water, co-solvents and calcium and their effect on the gelation process. Characterization of these interactions were investigated by using bulk shear rheology and laser scattering techniques for examination of pre-gel aggregate formation and fluctuations in gel microstructure.

Firstly, LM pectin gels and their mechanical characteristics were studied by varying concentrations of (i) co-solvents such as glucose, fructose and glycerol; (ii) calcium chloride ($CaCl_2$) combined with sodium hexametaphosphate $(NaPO_3)_6$; (iii) pectin concentration. Secondly, long-term aging on selected gels was investigated by varying the concentration of calcium. Thirdly, short-term aging on selected pectin gels were investigated. By evaluating the storage modulus *G'*, varying a type of sugar and its concentration, pectin solutions formed gels with different characteristics. During a long-term aging of selected gels, significant changes occurred in *G'*. As a result of the work conducted so far, we are reaching a better understanding of the dynamics of gel formation and their microstructural evolution in these more complex solution conditions.

pMC-14

Proteins characterization of sparkling cider and study of their foam behaviour

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Foam is one of the most important sensory parameters of a cider and it is one of the first attribute that consumer perceive. Indeed, in cider, as in sparkling wine, foam of good quality is predictive of other sensory parameters such as taste and aroma (Picinelli Lobo, 2005). The factors responsible for the formation of cider foam are proteins that act as surfactants, lowering surface tension and favoring bubbles formation. Proteins characteristics play a key role in foam quality when they have a high number of hydrophobic residues, are flexible, small in size and capable of establishing interactions with other macromulecules, allowing the formation of protein films with good viscoelastic properties (Blanco-Gomis, 2010). In this research, proteins of a sparkling cider were separated by FPLC, according to their molecular weight, and the four protein fractions obtained were used to study the foaming behavior by sparging method (Vincenzi et al, 2012). Protein fractions were studied by SDS-PAGE to determine their molecular weight and the presence of glycosylation. The results showed that glycosilated proteins with the highest molecular weight (100-150 KDa, F1) form foams with greater expansion and stability compared to the total unfractionated fraction, at the same protein concentration. After 20 sec of observation, while the total fraction showed a residual foam height of about 30%, F1 showed a residual foam of about 45%. The other FPLC protein fractions showed intermediate behavior. In conclusion, the molecular weight of proteins and the presence of glycosylation affect the foaming behavior of cider, indicating that cider foam expansion and stability depend on the contribution of the single protein fractions.

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pMC-15

Rheology of heat-induced egg yolk gels as affected by phenolic compounds

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Hen egg yolk is a traditional ingredient used in a wide variety of food thanks to its high technological functionality. Besides its excellent emulsifying properties, the gelling capacity upon either heat or acidic treatments is crucial in determining the rheological and structural properties of many common foods like bakery products and sauces. It has been evidenced that proteins are able to form complexes with polyphenols leading to changes in the structural, functional and nutritional properties of both compounds. To date, most of the studies have been focusing on milk proteins while very scarce are the information on the effect of phenolic compounds on egg yolk proteins functionality which, thus, represented the aim of the present work.

To this purpose diluted egg yolk solutions were added with increasing amounts of either a polyphenol-rich olive extract or oleuropein and submitted to rheological measurements by using a rotational rheometer equipped with a plate/plate measuring system. Protein gelling was favoured by heating (30 °C – 90°C, 5°C/min) and cooling (90°C-30°C, 10°C/min) at a constant strain of 0,1% and 1 Hz of frequency. Frequency sweep tests were then carried out in dynamic conditions, from 0,1 to 40 Hz at 30 °C, and a constant strain of 1% was applied. The experimental data obtained by the frequency sweep tests were then modeled with the power law equation by Gabriele et al., (2001) in order to get the coordination number z and the proportional coefficient A, which describe the network extension and its strength.

The presence of polyphenols affected the gelation behaviour as well as the rheological properties of the gel network. The addition of phenolic compounds induced a shift of the gel point towards lower temperatures, showing a dose-dependent behaviour. As far as the rheological properties of the gel network are concerned, polyphenols significantly increased both the A and z parameters, as a consequence of a more structured network.

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pMC-16

Fostering biopolymer interactions for developing novel satiating ingredients

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Foods that generate strong satiety sensations have obvious benefits for weight management and are one of the approaches which can be followed trying to counteract the tremendous impact that obesity has on health and economy. Konjac glucomannan (KGM) is a dietary fibre with extraordinarily high water-holding capacity which has demonstrated to have a positive effect on body weight reduction in the context of an energy-restricted diet (1, 2). However, direct addition of KGM to food products in the amounts required to exert this claimed benefit is not possible due to technological issues related to the high viscosity it develops in solutions. The present work reports on the investigation of pH-sensitive interpenetrating hydrocolloid networks based on blends of KGM with chitosan. The aim of the study was to understand the physical interactions between both biopolymers which can be promoted, so that the binary systems display a low viscosity in aqueous solutions, but that are able to develop a high viscosity when exposed to acidic environments such as the ones found at the gastric level. The effect of chitosan molecular weight (low, medium, high), the ratio between both biopolymers (25:75, 50:50, 75:25 and 90:10 KGM:chitosan) and the effect of the hydration media (water, pH7 buffer and pH3 simulated gastric fluid) in the extent of interactions and subsequent pH-dependent behaviour were studied through FTIR, SAXS, swelling and rheological experiments. The results showed that while the molecular weight of the chitosan used only slightly affected the swelling of the systems, the biopolymer ratio and the neutralization of the blends using cationic solutions were key for the development of the potentially satiating biopolymer-based novel ingredients. As an example, Figure 1 shows the different swelling behaviour of various KGM-chitosan blends as a function of pH.

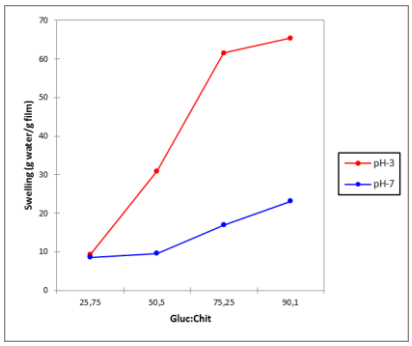

Figure 1. Swelling of different blends of KGM and chitosan as a function of pH

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pMC-17

Controlled release of water soluble vitamined in high-solid polysaccaharides with co-solutes

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The work dealt with the diffusional mobility of water soluble vitamins embedded in two high-solid carbohydrate matrices containing (i) ascorbic acid/high methoxy pectin/polydextrose and (ii) thiamine/κ-carrageenan/glucose syrup. Thermomechanical analysis in the form of small-deformation dynamic oscillation in shear was utilised. Structural properties of the high-solid preparations were assessed within a temperature range that induced a rubber-to-glass transformation. Colorimetric methods were employed to monitor the diffusion processes of vitamins from the high-solids matrices to diffusion mediums. The relationship between mechanical properties of the carbohydrate matrices and vitamin mobility were assessed *via* the application of the combined framework of free volume and predictions of the reaction rate theory. Results argue that the transport of the micronutrients is governed by the structural relaxation of the high-solid matrices. These were further treated with the concept of Fickian diffusion coefficient to provide the rate of the bioactive compound motility within the present experimental settings.

pMC-18

Effect of Biopolymers Structural Relaxation on Governing Dynamic Diffusion of Fatty Acid in Polysaccharide/Co-Solute System

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Identification of theoretical mechanisms governing molecular diffusion of unsaturated fatty acids (oleic and α-linolenic acids) in high solid matrices was carried out on two polysaccharide matrices of high-methoxy pectin and κ-carrageenan in the presence of co-solute, i.e. glucose syrup and polydextrose, respectively. Physicochemical analysis of this system utilised modulated DSC, dynamic oscillation in shear, ESEM, FTIR and WAX diffraction. The carbohydrate matrices were conditioned through an extensive temperature range to induce changes in molecular morphology and identify the network glass transition temperature calculated using mathematical modelling of combined WLF and Modified Arrhenius equations. Structural consistency during glassy state of biopolymers is taken as a limitation parameter on molecular rearrangements and entrapment small molecule. Thermally induced variation in phase morphology was employed to rationalise the transportation patterns of the bioactive compound within the high-solid preparation. Thus, experimental observations from UV-vis spectroscopy exhibit the diffusion kinetics to document the mobility arresting effect of the matrix vitrification on the micro-constituent. Results argue that within the glass transition region, a free volume theory is the molecular process governing structural relaxation. Further, Less Fickian diffusion follows well the rate of molecular transport of the fatty acids as a function of time and temperature of observation in the condensed matrices.

pMC-19

Gelation of WPI (Whey Protein Isolate) Aggregates in the Sodium Caseinate Matrix: Kinetics and Structure of the Gels

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Texture is an important characteristic of a food product influencing its organoleptic perception by consumers, its integrity during storage and transportation, and the storage life. The most commonly used thickeners and gelling agents are polysaccharides such as guar (E 412) and xanthan (E 415) gums, carrageenan (E 407) and modified starches (E 1400 – E 1500). However, consumers in Europe are becoming more demanding for the composition of the foods they buy giving the preference for the additive-free products with simple wholesome ingredients ('clean label' or 'store cupboard' ingredients).

Globular proteins such as those found in the milk whey are known for their excellent functional properties and ability to form gels, and they need not to be indicated by another E number on the packaging.

On the other hand, their application in the food industry requires detailed understanding of the mechanism of their functionality. Many scientific publications on the subject deal with the mechanism of aggregation and the aggregate structure at different conditions. The process of gel formation through so-called 'cold gelation' has received much attention in the literature. However, few studies have focused on the process of gelation of globular protein aggregates within a complex food matrix, containing other dairy proteins such as caseins. It is important to understand because most dairy products consist of a mixture of different proteins that might in particular compete for calcium ions during gelation.

In our work we studied the calcium-induced cold gelation of whey protein isolate aggregates in the presence of sodium caseinate. The influence of the aggregate size, protein and calcium concentration on the gelation kinetics and gel structure has been investigated. It has been demonstrated that the size of the aggregates does not influence much the kinetics of gelation and the gel structure, while the increase of the protein and calcium concentrations speeds up the process dramatically. Yet the smaller aggregates form gels in a wider range of calcium ratios compared to the bigger ones. It has been shown that the addition of sodium caseinate to the mixtures slows down the process of gelation.

pMC-20

Effect of composition of outer water phase (w_2) on yield of double emulsions ($w_1/o/w_2$)

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Double emulsions ($w_1/o/w_2$) display a promising strategy to reduce oil content in foods. In foods, the matrix (w_2 phase) usually contains other ingredients, such as emulsifiers and polysaccharides. Interactions between the emulsifiers and/or polysaccharides can affect the yield (amount of w_1 remaining inside the oil droplets) of double emulsions.

In this study, we investigated the effect of various emulsifiers (whey protein isolate (WPI), Na-caseinate, and Tween 20), and thickeners (xanthan and pectin) added to the w_2 phase on the yield of double emulsions. The concentration of thickeners was varied to also investigate the effect of the viscosity of the w_2 phase on the yield of the emulsion. w_1 droplets were either gelled or non-gelled, as gelling of w_1 increases the yield. Oil droplet sizes were determined and yield was quantified using Differential Scanning Calorimetry (DSC).

The yield of double emulsions protein-stabilized could be increased by 20% by gelling of w_1. Double emulsions stabilized with small molecular weight surfactants (Tween 20) showed higher yields then protein-stabilized emulsions with similar oil droplet sizes. In contrast to protein-stabilized emulsions, gelation of w_1 did not increase the yield of Tween 20-stabilized emulsions, probably due to differences in adsorption kinetics. Proteins adsorb relatively slowly, and therefore, gelling of w_1 might have an additional positive effect to reduce coalescence between w_1 and w_2 phase, while Tween 20 quickly stabilizes the o/w_2 interface and therefore gelling does not have an additional positive effect on double emulsion yield. Pectin and xanthan increased the viscosity of w_2, decreasing the viscosity ratio between the (w_1/o) emulsion and w_2 phase. This facilitated oil droplet breakup and resulted in lower yields. We observed a competition of pectin and the emulsifiers at the o/w_2 interface resulting in an additional decrease in yield.

We conclude that the yield of double emulsions in complex systems is influenced by interfacial characteristics of the o/w_2 phase, oil droplet size and the viscosity of the outer water phase (w_2). This work contributes to the understanding of stability of double emulsions as fat replacers in more complex food systems.

pMC-21

Structure engineering of oil-filled protein microbeads to tailor release of hydrophobic compounds in gastric digestion

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Oil-soluble components can be encapsulated in an O/W1/W2 microsystem, in which they are dissolved in oil droplets dispersed in a gelled microbead (W1), which forms a barrier between the oil droplets and the aqueous continuous phase (W2). Different production methods of such beads give differences in bead morphology and gastric breakdown response. We investigated the rate and 19 mechanism of breakdown of protein microbeads in a simulated gastric system, and studied the influence of microbead protein concentration, gelling method (cold-set, slow and fast heat-set), and further processing (freeze-drying), on the breakdown process. Breakdown rate decreased with increasing protein content of the beads, for the same method of production. Due to the porosity of the slowly-heated heat-set beads, breakdown occurred evenly throughout the entire bead. Cold-set microbeads of 10% protein broke down slightly slower than the heat-set microbeads of 15%. The denser surface of the 10% beads slowed down the diffusion of the enzymes into the bead's interior, causing the beads to be broken down from the outside inward. All these beads broke down within one hour. Increasing the rate of temperature increase during the heating step dramatically slowed breakdown. There was no significant breakdown of rapidly heated beads within 138 minutes, even though no difference in microstructure between rapidly and slowly heated beads was visible with electron microscopy. Freeze-drying of the beads also slowed their breakdown. After 132 minutes more than half the measured particle volume were intact beads. Freeze-drying changed the microstructure of the beads irreversibly: rehydrating the dried beads did not result in a breakdown behaviour similar to that of unprocessed beads.

pMC-22

Insight into the mechanism of myofibrillar protein gel stability: Influencing texture and microstructure using a model hydrophilic filler

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Comminuted meat products such as frankfurters and bologna are made up of a dispersed fat phase embedded in a continuous, heat-denatured protein gel predominantly made up of salt-soluble myofibrillar proteins. Perhaps surprisingly, the precise mechanism(s) by which these systems are stabilized is not yet well understood,[1] however it has been proposed that the water phase is immobilized in the hydrated gel network via capillary forces. Furthermore, a recent study suggested that the capillary pressure of the aqueous phase is also responsible for maintaining the integrity of the fat phase during gelation (cooking).[2] In the present study we have characterized the influence of incorporating near-colloidal sized glass particles into a comminuted protein matrix at low filler volume fractions (ϕ_f =0 to 0.05) with no added fat. Water expulsion during gelation was rapidly reduced with increasing ϕ_f in an approximately linear fashion from ~20 wt% in unfilled gels to no expulsion at $\phi_f \geq 0.03$. Similarly, large deformation mechanical attributes improved with increasing filler addition, reaching a plateau when water expulsion was eliminated. For example, Hardness and Resilience increased from 4.3 N and 0.18, respectively in unfilled gels to ~11.3 N and ~0.36 at $\phi_f \geq 0.03$. Consistent with previous work,[3] SEM micrographs indicated the glass beads weakly interact with the protein network, leaving their hydrophilic surface exposed and available to interact with free/mobile water. Light micrographs showed that in the absence of filler particles the heat-treated myofibrillar gels contain an integrated network of water channels which decrease the continuity of the gel matrix. By incorporating the near-colloidal glass beads, the water channels were replaced with a meshwork of discrete, homogeneously distributed water pockets. NMR T_2 relaxation measurements confirmed that incorporating the glass beads already immobilized the free water prior to gelation. The dominant relaxation peak in the unfilled gels was centred around 125 µm prior to gelation, and shifted to ~64 µm after thermal treatment. Filled gels containing ϕ_f = 0.01 and 0.03 had peaks at approximately 96 and 65 µm prior to gelation, respectively. This work provides insight into the mechanism of myofibrillar protein gel stabilization during gelation and suggests the use of food-grade, hydrophilic colloidal particles may be of use in improving the stability and textural properties of comminuted meat products.

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pMC-23

Structure-function relationships in roll-in shortenings

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The structural and rheological properties of commercial shortenings with similar physico-chemical characteristics but diverse functionality were characterized using x-ray scattering and oscillatory shear rheology. Particular attention was drawn to roll-in shortenings, characterized for having exceptional plasticity. All shortenings had similar polymorphic forms (β or β' or a mixture) as determined by wide-angle x-ray scattering , while the domain sizes were in the range of 300-400 Å as determined by small-angle x-ray scattering. Ultra-small angle x-ray scattering (USAXS) indicated that the aggregation of primary crystalline nanoparticles (CNPs) for laminating shortenings was either via diffusion limited-cluster aggregation or reaction limited cluster aggregation, while for the multipurpose shortening , the CNPs remained un-aggregated. All shortenings displayed low-frequency ω dependence, reminiscent of viscoelastic solids *G'>G"*, and comparable linear envelope γ_y=1-3 $\times 10^{-4}$. Linear elastic moduli G'=0.6-4.5 $\times 10^{6}$ Pa, and yield stress τ_y=46.4-593.9 Pa remained unremarkable, defying the prima facie assumption that specific ranges in these material properties lead to improved roll-in functionality (Haighton 1959). In contrast, nonlinear viscoelastic behavior of roll-in shortening differed considerably from all-purpose commercial shortening. Lissajous-Bowditch curves suggested less local intracycle strain stiffening and less average intercycle strain softening for roll-in shortenings than other shortenings. Likewise, their Fourier spectra indicated a gradual evolution of the leading-order third harmonic ($I_{3/1}$) into the nonlinear regime characterized by higher slopes *k*= 0.7-1.3. Third ($I_{3/1}$) and fifth ($I_{5/1}$) harmonics grew monotonically, and the third overtone levelled off and showed no stress decays unlike other samples, suggesting marked ability of roll-in shortenings to withstand deformation at high stresses. Moreover, roll-in shortening displayed enhanced thixotropic behavior supported by lower power law indexes (*n*= 0.08-0.10) and prompt structural rebuilding after steady shear cessation (64-71% within 20 s of rest). We believe that such rheo-structural signatures are critical to the functionality of roll-in shortenings.

pMC-24

Protein matrices ensure safe and functional delivery of marjoram (*Origanum majorana*) extracts

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To understand the interactions between carriers and functional ingredients is crucial when designing delivery systems, to maximize bioefficacy and functionality. In this study, protein nanoparticles were evaluated as means to protect marjoram extract. Casein micelles from fresh skim milk and soy protein isolate (SPI) were chosen as model protein nanoparticles. Extract obtained from marjoram leaves (*Origanum majorana*), containing 5 % of rosmarinic acid was obtained from pressurization of ethanol/water solvent (50:50, v/v) on grinded marjoram leaves for 10 min at 100 ºC. Protein dispersions of casein and SPI (0.5 % w/v) with or without marjoram extract (0.1-3 mg/mL) were prepared and homogenized using conventional homogenization at four passes and 450 kPa. The physicochemical characterization of size, charge and entrapment efficiency for loaded protein formulations were conducted. The results demonstrated that marjoram extract did not induce any alteration of the size and charge of the formulations, while the entrapment efficiency was highly dependent on the carrier itself. SPI formulations showed 20% more entrapment of marjoram extract when compared to casein formulations. To investigate the physiological behaviour of the marjoram –protein dispersions, human macrophages differentiated from THP-1 cells were employed. A non-specific inflammatory response of macrophages stimulated with bacterial lipopolysaccharide in the presence of marjoram formulations was conducted for 24h incubation time and TNF-α, IL-1β and IL-6 cytokine secretion was measured by ELISA. Both formulations ensured high bioefficacy of marjoram extract, and would suggest that these protein nanoparticles could be used as carriers for safe delivery of the such type of extracts. Nevertheless, the behavior and controlled release of the protein – bioactive dispersions during transition in the gut needs to be addressed.

pMC-25

Stabilising properties of whey protein covalently bonded with lactose via Maillard reaction

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The emulsion stabilizing properties of whey protein isolate (WPI) modified by lactose through Maillard complexation between the two, have been investigated in the O/W systems containing 30 vol. % sunflower oil at pH 4.6. The glycoprotein was prepared by dry-heating method at relative humidity (RH) 79% for 3 hours. The conjugation between WPI and lactose was confirmed by o-phthalaldehyde (OPA) test. The emulsions were made with glycoproteins as well as WPI alone (native), by passing through the Jet-homogenizer once, at pressure of 300 bar, and then stored in an incubator with controlled temperature of 30 °C. The stability of emulsions was determined by measuring the changes in average droplet-size over a storage period of 4 weeks. The unmodified (native) WPI was chosen as the reference stabiliser. The droplet–size distribution results show that the modified WPI has superior emulsion stabilizing properties than the native WPI under similar environmental conditions (pH 4.6, ionic strength 0.1M). The enhanced stabilizing properties of glycoprotein resulting from coupling with lactose are most likely due to the improved solubility of glycoprotein due to the presence of these additional lactose attachments.

pMC-26

Encapsulation of Liquorice Extract in Water-in-Oil-in-Water Multiple Emulsion

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Liquorice is known to contain glycyrrhizin, a triterpenoid saponin, which has numerous biological activities which are beneficial to human health, such as: antioxidant, anti-allergic, anti-hepatic and anti-inflammatory effects. The encapsulation of liquorice may prolong its shelf-life and increase its bioavailability for absorption by the body. In order to enhance the delivery of its health benefits, an attempt has been made to encapsulate liquorice extract via a novel multiple emulsion approach, using various types of primary emulsifiers (neocare, sunflower lecithin and PGPR 90) and symperionic as a secondary emulsifier. Initially, multiple emulsions were prepared with a ratio of 20 vol% primary emulsion-encapsulated with various concentrations of liquorice (0.4 – 1.5 wt%) and 80 vol% secondary aqueous phase. The stability of these emulsions was investigated over a storage period of 3 weeks. The time-dependent stability of multiple emulsions was investigated using particle size, rheological measurement, microscopy, visual assessment and encapsulation efficiency. At 2 wt. % emulsifier, symperionic was found to be capable of producing uniform droplets of the final W/O/W emulsions in size range of 10-25 µm. Neocare and sunflower lecithin emulsifiers were found to be more efficient primary emulsifiers in encapsulating liquorice in W/O/W multiple emulsions than the PGPR.

Liquorice was successfully encapsulated within the internal aqueous phase of W/O/W multiple emulsions, having an encapsulation efficiency of >90%. Confocal laser microscopy confirms the formation of multiple emulsions with fairly monomodal distributions of droplets.

pMC-27

Characterization of Functionalized and Non-Functionalized Carvacrol-loaded colloids used to Inactivate *Escherichia coli* O157:H7 lux

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As the expansion of food processing, marketing and distribution around the world continues, the risk of food borne disease outbreaks has also increased. Simultaneously consumers' negative health perception towards synthetic preservatives has increased the interest on essential oils (EOs) as natural antimicrobials[1]. EO components, such as carvacrol, have shown to exert antibacterial effects against most common food borne pathogens, including *Escherichia coli* O157:H7[2]. However their low water solubility, volatile nature and tendency to bind with food components limit their use[3, 4]. To overcome those limitations, the use of nano-scale lipid-based delivery systems have been proposed[5]. In this study, the stability and antimicrobial activity against *E. coli* O157:H7 lux (in lab-media and in Romaine lettuce) of functionalized and non-functionalized carvacrol-loaded nanoemulsions produced by high-pressure homogenization was assessed.

Nanoemulsions (NE) formulation differed on lipid (coconut oil, CO; palm stearin, PS), surfactant (Tween 20, TW20; Ultralec lecithin, LU), and carvacrol concentration (0-50% w/w of lipid phase). To evaluate NE stability, average droplet diameter (Z-Ave), polydispersity index (PdI), and ζ-potential (ZP) were measured at various time points over 180 days. Most stable NEs contained LU and ≥ 2% w/w of carvacrol (Z-Ave approx.150 d.nm, PdI < 0.1, and ZP approx. -58 mV). Functionalized nanoemulsions were made in a second homogenization process by adding various concentrations of chitosan (CH: 0.005, 0.0125, 0.025, 0.0375 and 0.05% w/w), or polyethylene glycol (PEG: 0.5, 2.5, and 5.0 w/w) to a base formulations (CO/LU/C2%). The stability of the functionalized colloids was evaluated similarly.

Antimicrobial activity against *E. coli* O157:H7 lux of selected functionalized (CH 0.05% and PEG5.0%) and non-functionalized systems was tested in MSM at three carvacrol concentrations (500, 750, and 1000 ppm). Regardless of the colloid, treatments done with 750 ppm for 20 min, and 1000 ppm for more than 10 min showed a 5.5 log bacterial reduction. All colloids reached internalized bacteria in Romaine lettuce. CH-functionalized sample at 10000ppm of carvacrol had the maximum bacterial reduction, 1.7 log. Even though this value is too low compared to the inactivation achieved on lab-media, CH-functionalization proved to affect the interaction between the colloid's droplets and the bacterial membrane.

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pMC-28

Impact of type and concentration of cellulose derivatives on the rheological behavior of the batter of a model sponge cake

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Complex reaction like Maillard and caramelization reaction occur during baking of cereal products with a significant impact on the final nutritional and sensory quality. In this study, sponge cake was chosen as a good material for studying these reactions' pathways and kinetics. It is a soft product formed of a typical cellular structure with a relatively simple composition (flour, egg, sucrose). In order to analyze the impact of each ingredient, a non-reactive model mimetic of a sponge cake was developed. Reactive ingredients (i.e. egg, sucrose, and wheat flour protein) were replaced by non-reactive components providing equivalent functional properties (i.e. surfactant, thickening and gelling with increasing temperature). Two types of cellulose derivatives (HPMC and MC) were selected to be added to starch and water as ingredients of this model product. The starch/water ratio was kept constant and identical to that of the reference batter to allow the starch to swell identically as in the real sponge cake. HPMC and MC concentrations were adjusted to obtain a viscosity of 1.4 Pa.s for the model batter measured at 270 s^{-1} (maximum shear stress in the mixer). The foaming capacity was controlled by measuring the volume fraction of included air, and the cellular structure formed after baking was characterized by image analysis. Several HPMC/MC ratios made it possible to obtain a model batter viscosity of 1.4 Pa.s at 270 s^{-1}, but they developed different cellular structures after baking. In order to analyze the input of each molecule, G' and G" moduli and tan δ were measured on the solutions with different HPMC/MC ratios at room temperature and versus temperature, and compared to the density of the model batter after foaming and to the cellular structure of the model sponge cake after baking.

pMC-29

Evaluating the Digestive Fate of Coaxially Electrospun Starch Fibers for Oral Delivery of Bioactive Lipids

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Bioactive lipids such as fish or linseed oils are known to offer various beneficial bioactivities. Yet, the high costs of these oils and their challenging physicochemical stability maintain a need to develop cost-effective means for their successful delivery. This work evaluated the potential of coaxial electrospinning [1] of high amylose corn starch [2] as a shell and bioactive lipids as core to fabricate an effective delivery system. Three bioactive lipids were encapsulated: Extra Virgin Olive Oil (EVOO) composed of mainly 18:1 free fatty acids (FFAs), Hemp Seed Oil (HSO) composed primarily of 18:2 FFAs and Pomegranate Seed Oil (PSO) rich in 18:3 FFAs.

Encapsulation efficiency was examined along with structural characterization using optical and scanning electron microscope. Amount of oil in electrospun fiber mat was calculated to be around 50 wt. % for all the oils used. Images showed uniform tubular structure of the starch-based fibers filled with oil with diameter ranging from 3 to 5 microns.

The potential digestive fate of the encapsulating starch and the entrapped lipids was evaluated using a semi-dynamic in vitro digestion model based on the Infogest protocol, [3] and physiologically documented gastric pH gradients already applied in *in vitro* models [4]. Experimental results show that electrospun fibrous mat resists breakdown after 2h of gastric digestion and subsequent 1h of intestinal digestion. Altogether, this work demonstrates the great potential of coaxial electrospinning in generating matrices with high durability to upper gastro-intestinal digestion and suitability to entrap bioactive lipids.

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