International Journal of Pharmaceutical Drug Design (IJPDD)
Website: https://ijpdd.org/
ISSN: 2584-2897
Vol. 2, Issue 3, March, 2025
Page No.: 59-65

Research

A REVIEW ON MICROENCAPSULATION OF HERBAL EXTRACTS IN FOOD INDUSTRY

P. Prabhavathi[1], Y. Prapurnachandra[2], SK. Nasiha sulthana[3]

1Department of Pharmaceutical Chemistry, Ratnam Institute of Pharmacy, Pidathapolur (V), Muthukur (M), SPSR Nellore Dt.524346 A.P., India.

2Department of Pharmacology, Ratnam Institute of Pharmacy, Pidathapolur (V), Muthukur (M), SPSR Nellore Dt.524346 A.P., India.

3Ratnam Institute of Pharmacy, Pidathapolur (V), Muthukur (M), SPSR Nellore Dt.524346 A.P., India.

Corresponding Author:
Shaik. Nasina Sulthana

Email: *NA*

DOI: *10.62896/ijpdd.2.3.9*

Conflict of interest: *NIL*

Article History
Received: 03/01/2025
Accepted: 22/01/2025
Published: 10/02/2025

Abstract:
Modern microencapsulation techniques are employed to protect active molecules or substances such as vitamins, pigments, antimicrobials, and flavorings, among others, from the environment. Microencapsulation offers advantages such as facilitating handling and control of the release and solubilization of active substances, thus offering a great area for food science and processing development. For instance, the development of functional food products, fat reduction, sensory improvement, preservation, and other areas may involve the use of microcapsules in various food matrices such as meat products, dairy products, cereals, and fruits, as well as in their derivatives, with good results. The versatility of applications arises from the diversity of techniques and materials used in the process of microencapsulation. The objective of this review is to report the state of the art in the application and evaluation of microcapsules in various food matrices, as a one-microcapsule-core system may offer different results according to the medium in which it is used.

Key words: microencapsulation, fat substitute, sensory improvement, functional food, preservatives.

Introduction:

The microencapsulation process is used to entrap small particles of liquids, solids, or gases in one or two polymers. As presented in Fig. 1, the particle component is referred as the “core material”, and polymers are called variously such as “wall material”, “shell”, “coating”, “carrier”, or “encapsulant The purpose of microencapsulation is to protect the core material from environmental factors (such as light, moisture, temperature, and oxygen), to extend shelf-life , and to improve the release properties of compounds . Microencapsulation has been applied in the design of new materials not only for the food industry but also for pharmaceuticals, cosmetics, and textiles, where the stability, efficiency, and bioactivity of compounds are required.[1]

Microcapsules usually range between 0.2 to 5000 µm in diameter and consist of an encapsulating or wall-material that englobes a core containing the active substance. The final particle size depends on many factors, such as the processing method and the nature of the encapsulating material. Therefore, it is important to consider the type of wall-material that will be used in combination with a specific encapsulation process according to the function or destination of the microcapsule and the desired particle size; the wall material also leads to variation in encapsulation efficiency and stability summarizes.

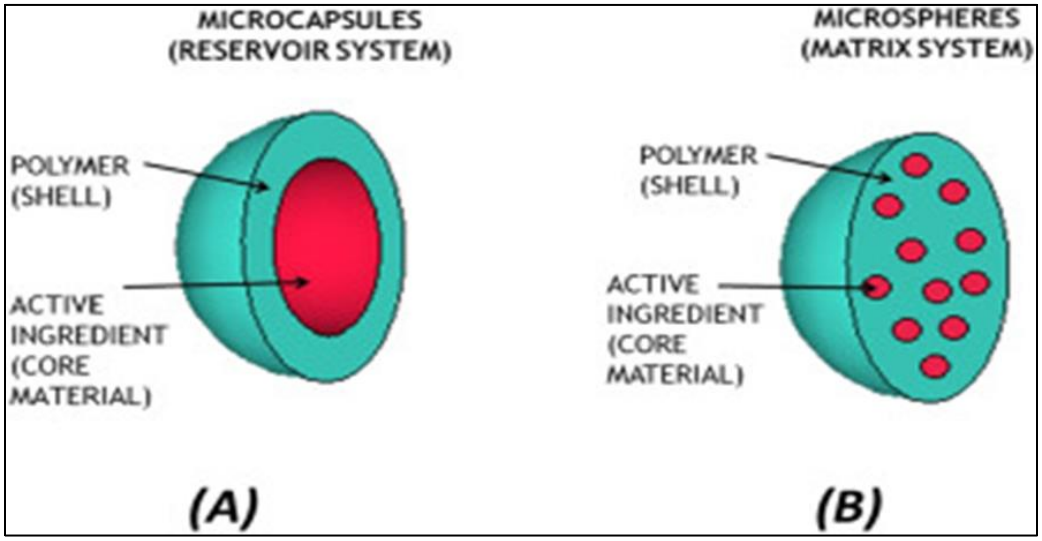

Figure-1: Schematic representation of core material and wall material

Microcapsules usually range between 0.2 to 5000 μm in diameter and consist of an encapsulating or wall-material that englobes a core containing the active substance. The final particle size depends on many factors, such as the processing method and the nature of the encapsulating material. Therefore, it is important to consider the type of wall-material that will be used in combination with a specific encapsulation process according to the function or destination of the microcapsule and the desired particle size; the wall material also leads to variation in encapsulation efficiency and stability summarizes.[2]

The use of microencapsulation in the food industry and its benefits have been extensively studied .The reasons why encapsulation techniques are used are numerous, here are some of them: (a) active compounds that are sensitive to external conditions to be protected from them; (b) to protect volatile compounds from straightening; (c) to disguise unpleasant aroma and taste; (d) to facilitate the use of liquids by turning them into a solid form; (e) for higher solubility of materials that do not dissolve well; (f) to obtain delivery of active substances to a specific site and their controlled release; and (g) to improve the efficacy of bioactive compounds .[3]

microencapsulation technologies, and varying the copolymer ratio, molecular weight of the polymer, etc., microcapsules can be developed into an optimal food ingredient device. Microcapsule-based systems increases the life span of food ingredients and control the release of food ingredients. Various properties of microcapsules that may be changed to suit specific ingredient applications include composition, mechanism of release, particle size, final physical form, and cost. Before considering the properties desired in encapsulated products, the purpose of encapsulation must be clear.[4]

Materials/Methods used for encapsulation materials:

Capsules:

capsules can be classified as per their size: macrocapsules (>5,000μm), microcapsules (0.2 to 5,000μm) and nanocapsules (. As far as their shape and development, capsules can be partitioned into two gatherings: microcapsules and microspheres. Microcapsules are particles comprising of an internal center, significantly focal, containing the dynamic substance, which is secured with a polymer layer establishing the case film. Mononuclear and polynuclear microcapsules can be recognized by whether the center is separated Interestingly, microspheres are grid frameworks in which the center is consistently scattered as well as broke up in a polymer arrange. Microspheres might be homogeneous or heterogeneous relying upon whether the center is in the subatomic state (broke down) or as particles (suspended), individually.[5]

Wall material:

The right decision of the wall material is vital in light of the fact that it infl uences the embodiment efficiency and dependability of the microcapsule. The perfect wall material ought to have the accompanying qualities: not receptive with the center; capacity to seal and keep up the center inside the case; capacity to give greatest insurance deeply against unfriendly conditions; do not have an undesirable preference for the instance of sustenance appropriateness and financial practicality as per most wall materials don't have all the ideal properties; a typical practice includes blending at least two materials. Such materials can be chosen from a wide assortment of normal and engineered polymers, including the accompanying that we feature: sugars: starch, modified starches, dextrins, sucrose, cellulose and chitosan; gums: arabic gum, alginate and carrageenan; lipids: wax, paraffin, monoglycerides and diglycerides, hydrogenated oils and fats; inorganic materials: calcium sulfate and silicates; proteins: gluten, casein, gelatin and egg whites.[6]

Microencapsulation of phytochemicals:

Phytochemicals are chemical compounds that are found in plants and have biological activity. Studies on them show that they have a good effect on human health and serve as disease prevention. They have antibacterial, antioxidant, antiviral, anti-inflammatory and anti-cancer properties, as well as regulate blood pressure, cholesterol synthesis and stimulate the immune system. The incidence of age-related illnesses and chronic diseases such as stroke, cancer and heart disease decrease with higher consumption of fruits and vegetables rich in phytochemicals. Phytochemicals are found mainly in vegetables, fruits, whole grains and legumes.[7]

Microencapsulation of Vitamins:

Vitamins are essential for human health. They are essential nutrients and facilitate the treatment of skin problems and the regulation of oxidative stress in the body. Vitamins are easily oxidized, which makes them unstable. Improving their physicochemical stability, as well as increasing their physiological strength, is accomplished by nano- and microencapsulation. Vitamin A, which is derived from β-carotene and has antioxidant functions and serves as a colorant, is a fatsoluble vitamin and can be extracted from fish oil, dairy products or the liver. Its precursor is bcarotene, which promotes the body's natural immunity, cell growth, and promotes bone growth and visual health[8].

Encapsulation of Flavors:

The aroma of food is essential and is closely related to how a food is perceived by consumers. Aromatic compounds depend on the temperature of processing and storage and are therefore difficult to control because they are volatile. Encapsulation techniques are used to protect odors from evaporation during processing and storage. Depending on the wall materials used and the processing conditions, the volatile compounds can be encapsulated in various forms. Oleoresins are highly sensitive to light, oxidation and heat. Encapsulation techniques are used to prevent this sensitivity. Cardamom oleoresin, for example, is encapsulated using gum arabic, modified starch, or maltodextrin for encapsulating materials, and then spray drying is used.[9]

EncapsulationTechniques:

Depending on the nature of the core and intended use of the finished products several encapsulation techniques have been investigated. Various methods of micro/nanoencapsulation have been described in various literatures with their application in food, pharmaceuticals, agriculture, textiles, paper and other allied industries. These methods vary in their complexities. Coating of an active by a solution of shell material is the simplest method of encapsulation used in food industries. It involves pan, spray or fluidized bed coating followed by drying. Other methods involve the emulsification of a core material (e.g. oil or enzyme) with a solution of a wall material (usually a polysaccharide or a protein or their synergies) followed by drying process to obtain the encapsulated material in dry powdered form for convenient handling and storage. The proper designing and functioning of encapsulation systems require a physicochemical understanding of the encapsulation mechanisms, possible interaction of the actives with the shell matrices, active stability and release behaviour from the shell matrix. Incorporation of additional stabilizing agent can also play an important role in the success of the whole process of encapsulation.[10]

Spray Drying:

Spray drying is a highly effective and widely used encapsulation technique in food and pharmaceutical industries because of its comparative advantage over other methods of encapsulation. It is highly automated and cost-effective, and produces a good quality product. One of the most remarkable advantages of the spray drying is its capacity to process several kinds of materials to produce fairly dried product with pre-specified properties. In this method, the active ingredient is well mixed in the encapsulating material forming an emulsion or a solution or a suspension. In general, the lipophilic core and hydrophilic shell materials are used to form an emulsion. The shell material is commonly a polysaccharide (e.g. gum or starch) or a protein (e.g. gelatin, milk protein or soy protein) or their synergies. Usually coarse emulsion is prepared by mixing the core and shell materials in required quantities. It is usually followed by single stage or two-stage homogenisation that yields a fine emulsion. This fine emulsion is atomized in a drying chamber at a pre-defined flow rate. Schemat.

Coating:

Coating of the granules, pellets or tablets with a solution of wall material by tumbling in a pan or similar equipment is the simple physicomechanical methods of encapsulation which is widely used in pharmaceutical and food industries Reference reported the scale-up process for pan coating in pharmaceutical industries; however, application of this coating in food sector is not well advanced. Other methods used for coating food ingredients are spray and fluidized bed coating Fluidized bed coating, developed by D.E. Wurster in the 1950s is also named as Wurster process. Reference reported three different types of fluidized bed coating techniques—top-spray, bottom-spray and hot-melt fluidised bed; top-spray coating is considered as the most feasible process, on technical and economic grounds, for industrial application. It is still a prefered method of encapsulation in various food industries owing to the lower cost of production and requirement of less sophisticated set up. In bottom spray coating, the liquid pulverizes concurrently with the air and the particles move towards the bottom of the coating chamber.[11]

Fluidized Bed Coating/Air Suspension:

The process involves the preparation of coating solution, fluidization of core particles/tablets/granules followed by coating of core particles with coating solutions. The types of materials for fluidized bed coating are water-insoluble and water-soluble polymers, lipids and waxes. The particles/granules are sprayed with coating solution at a specific temperature. Application of high temperature is not required; hence, this method is efficient in saving energy and time. However, this method is commonly used for secondary coating of the primarily encapsulated products to enhance the stability. For example, corn starch coating was used as secondary coating on caseinate encapsulated fish oil.

Spray Chilling and Spray Cooling:

Spray chilling is the process of solidifying an atomized liquid spray into particles. In these methods, mixture of core and wall is atomized into the cooled or chilled air, which causes the wall to solidify around the core. Unlike spray-drying, spray-chilling or spray-cooling does not involve mass transfer (evaporation of water). Therefore, it is more energy efficient process. In spray-cooling, the coating material is typically some kinds of vegetable oils or its derivatives including fat and stearin with melting points of 45˚C - 72˚C, as well as hard mono- and diacylglycerols with melting points of 45˚C - 65˚C. In spray-chilling, the coating material is typically a fractionated or hydrogenatevegetable oil with a melting point in the range of 32˚C - 42˚C. In these processes, a melted lipid, above its melting point, is sprayed onto the core material and allowed to cool; instant solidification of the lipid takes place yielding almost perfect spherical and free-flowing microcapsule powders. Microcapsules prepared by spray-chilling and spray cooling are insoluble in water due to the lipid coating. Consequently, these techniques are utilized for encapsulating water-soluble core materials such as chemical fertilisers, pharmaceutical ingredients, water-soluble vitamins, enzymes, acidulants, and some flavors.[12]

Extrusion Coating:

Extrusion based encapsulation is a convenient method that can be applied to produce highly dense encapsulated products. It is a liquid co-extrusion process in which bioactive core and coating agent are pumped separately through a concentric orifice located on the outer circumference of a rotating cylinder (i.e. head). Core material flows through the centre of the tube; coating material flows through the other tube. Since the equipment is attached to a rotating shaft both the core and shell matrix are coextruded through the concentric orifices as the head rotates. During this process, centrifugal force impels the rod outward, causing it to break into tiny particles. Due to the surface activity of the coating material, it quickly moves at the surface of the core until it completely surrounds the core material. A number of innovative foods approved this coating system to encapsulate products such as flavourings, seasonings, vitamins, and many others. The most common extrusion techniques include resonance and jet-cutting technique as well as electrostatic droplet generation. In this method, lowmolecular weight carbohydrates including reducing sugars and sugar alcohols are used as encapsulants. One of the advantages of extrusion based encapsulation is that resultant product is of larger particle sizes (0.1 - 5.0 mm) than that obtained from other methods of encapsulation. Bead diameter of up to 2.6 mm was reported in microencapsulation of B. longum in alginate. Wall materials used in extrusion process of encapsulation include gelatin, sodium alginate, carrageenan, starches, cellulose derivatives, gum acacia, fats & fatty acids, waxes, and polyethylene glycol.[13]

Liposomes Entrapment:

Liposome entrapment is well-known method of microencapsulation since 1970s; however, it has gained popularity after 1990s. It is highly popular in drug delivery and nutraceutical industry in recent years. Liposomes consist of an aqueous phase that is completely surrounded by a phospholipid-based membrane. These are formed in situ when phospholipids, such as lecithin, are dispersed in an aqueous phase. During spontaneous formation liposomes surround the core material which can be either aqueous or lipid-soluble. They have been used for delivery of vaccines, hormones, enzymes, vitamins and other sensitive neutraceuticals. Usually, liposome based encapsulated products consist of one or more layers of lipids that surround unstable core. The resultant product is highly stable and of superior quality. Permeability, stability, surface activity, and affinity of the core and resultant product can be varied through variations in the size and lipid composition. They can range from 25 nm to several microns in diameter. Among various types of liposome that are used in encapsulation of food ingredients, large unilamellar vesicles are considered as the most appropriate liposomes due to their high encapsulation efficiency, simple production methods, and enhanced storage stability.[14]

Coacervation:

polymer-rich phase (coacervate) and the poor polymer phase (equilibrium phase). The term originated from the Latin “acervus” meaning “heap”. This was the first reported encapsulation process used for the industrial production of microencapsulated products. Coacervation is mainly divided into two categories: simple coacervation and complex coacervation. The mechanism of microcapsule formation for both processes is identical, except for the way in which the phase separation is carried out. In simple coacervation a desolvation agent is added for phase separation, whereas the complex coacervation Coacervation is a partial desolvation of a homogeneous polymer solution into a involves interaction between two oppositely charged polymers. Basic steps in complex coacervation are: 1) preparation of solution of two polymers;2) mixing of lipophilic core with a polymer solution to form emulsion; 3) mixing of another polymer solution; 4) change of pH or temperature to induce formation of two immiscible phases; 5) deposition of the coacervates around the core; and 6) rigidization of the coating by nashwan cross-linking or application of heat. This method is capable of producing particles with smaller sizes that ranges from 1 to 100 μm. It also gives unusually higher payload (upto 90% for single core and 60% for multicore encapsulation. In complex coacervation, a protein and a carbohydrate (gum) are usually chosen as the shell materials. Protein is a positively charged polymer, whereas gum is negatively charged. Various biopolymers have been investigated for complex coacervation based encapsulation process. Gelatin and gum arabic are the most widely used polymer pairs; however, in recent years, gelatin has been replaced with other proteins such as whey protein isolate, lactoferrin and bovine serum albumin.

Major disadvantage of complex coacervation based microencapsulation technology is that the coacervates are stable within a very narrow range of pH and ionic strength . This limits the range of polymers that can be used as shell material in complex coacervation process. Another disadvantage is concentration of solute that can be used to form complex coacervates in solution form. The above discussion concludes that the complex coacervation method has huge application in food and pharmaceutical industry if associated bottlenecks are removed.[15]

Encapsulation Yield:

Encapsulation yield (EY) is another factor to be considered during an encapsulation process. EY also measures the effectiveness of encapsulation. Equation is used to calculate EY. EY=WtWi×100EY=WtWi×100 where, EY is encapsulation yield, Wt is mass of the total encapsulated active ingredient and Wi is the mass of the active introduced.[16]

Applications in the food industry:

The food industry uses practical fixings to enhance flavor, shading, and surface properties and to broaden the timeframe of realistic usability of items. Additionally, fixings that have practical medical advantages, for example, cancer prevention agents and probiotics, are of incredible intrigue Be that as it may, the vast majority of these fixings have low-security and are effectively decayed by ecological elements. In this way, the arrangement of highstability bioactive mixes is critical. Microencapsulation is one approach to address these issues. As of late, there has been a lot of research on the creation of high productivity microcapsules and their applications in the sustenance business[17]

Beverages:

Beverages assessed the steadiness of anthocyanin, which was embodied inside various bearer operators in an isotonic soft drink system. Anthocyanins are water-solvent shades got from plants. These shades are commonly utilized as colorants in nourishments and beverages, since they have high colorant control, low poisonous quality, and high water solvency. Besides, numerous examinations have demonstrated that anthocyanins have critical cancer prevention agent and anticarcinogenic properties All things considered, anthocyanins are flimsy shades and can be disintegrated to dry mixes by numerous components including pH, temperature, light, oxygen, and the nourishment lattice. In this manner, microencapsulation ~ 36 ~ Journal of Pharmacognosy and Phytochemistry has been utilized to build the dependability of these mixes. In their investigation, the splash drying system was utilized to typify anthocyanins started from Cabernet Sauvignon grapes. They found that the got microcapsules introduced uniform molecule sizes and a circular surface. Additionally, a blend of maltodextrin (MD) and gum Arabic (GA) brought about expanded security of the anthocyanin shades.[18]

Baked goods:

Baked Goods embodied vegetable shortening to increment oxidative strength and convert fat into a steady powder for use in short batter bread creation. At present, most fixings utilized in business bread generation are in dry frame. Be that as it may, the fat fixing must be included the type of fluid (oil) or block (fat), which requires an extra manual advance. The goal of this exploration was to create microcapsules of high-fat powders and assess their impact on bread quality contrasted with the nature of a control roll delivered with hydrogenated vegetable fat. It was discovered that microencapsulated vegetable fat delivered at a low homogenization weight, with whey protein focus (WPC) containing 5% protein as the epitomizing specialist, could be utilized for creating bread rolls with worthy qualities. Subsequently, microencapsulated high-fat powders could be utilized as a substitution for fat/oil in business scone generation.[19]

Future trends in food industry:

Future Trends in Food industries The extension in useful foods is by all accounts a long haul incline with essential market potential. In this manner, new developments have been presented in the food industry Microencapsulation is one of the advancements that are right now of intrigue. Also, numerous analysts keep on creating novel parts for use as useful fixings, additives, colorants, and seasons in sustenance items utilizing microencapsulation systems. Conclusion Microencapsulation has beenconnected in a wide assortment of items from various zones, and studies have appeared gigantic potential to furnish the center with beneficial highlights, bringing about unrivaled quality items, incorporating into the food industry. In any case, much exertion through innovative work is as yet expected to distinguish and grow new wall materials and to enhance and advance the current strategies for the better utilization of microencapsulation and its potential applications.[20]

Reference:

1. Ref: Methavee Peanparkdeea, Satoshi Iwamotoa,b, Ryo Yamauchia,b, MICROENCAPSULATION: A Review Of Applications In The Food And Pharmaceutical Industries. Peanparkdee et al. Reviews in Agricultural Science.2016;, 4: 56 – 65.
2. Ref: Mariel Calderón-Oliver, Edith Ponce-Alquicira.THE ROLE OF Microencapsulation in food application.molecules.2022;27(5):1499.
3. Ref: Dorina Petkova1, , Dasha Mihaylova 1, and Ivelina Desseva2. Microencapsulation in food industry – an overview. BIO Web of Conferences.2022; 45: 02005
4. Ref: Anjum Ayoub, Monika Sood, Jagmohan Singh, Julie D Bandral, Neeraj Gupta and Anju Bhat. Microencapsulation and its applications in food industry. Journal of Pharmacognosy and Phytochemistry.2019; 8(3): 32-37.
5. Ref: Kashappa Goud H. Desai and Hyun Jin Park*.Recent Developments in Microencapsulation of Food Ingredients. Drying Technology.2005; , 23: 1361–1394. .
6. Ref: Desai, K.G.H. and Park, H.J. (2005) Recent Developments in Microencapsulation of Food Ingredients. Drying Technology, 23, 1361-1394.
7. Ref: Silva C et al. Administracao oral de peptideos e proteinas: II. apllicaçtion de metodos de microencapsulacao. Revista Brasileira de Ciencias Farmaceuticas. 2003; 39:1-20.
8. Ref: 0. Roberts DD, Taylor AJ. Flavor release. Washington: American Chemical Society, 2000, 496.
9. Ref: D.S. Ferreira, A.F. Faria, C.R.F Grosso, A.Z. Mercadante, J. Braz. Chem. Soc. 20, 1908- 1915 (2009).
10. Ref: V.B Junyaprasert, A. Mitrevej, N. Sinchaipanid, P. Broome, D.E. Wurster, Drug Dev. Ind. Pharm. 27(6), 561-566 (2001).
11. Ref: S. Krishnan, A.C. Kshirsagar, R.S. Singhal, Carbohydr. Polym. 62, 309-315 (2005).
12. Ref: Madene, A., Jacquot, M., Scher, J. and Desobry, S. (2006) Flavour Encapsulation and Controlled Release A Review. International Journal of Food Science & Technology, 41, 1-21.
13. Ref: Petrovic, T., Nedovic, Dimitrijevic-Brankovic, S., Bugarski, B. and Lacroix, C. (2007) Protection of Probiotic Microorganisms by Microencapsulation. Chemical Industry and Chemical Engineering Quarterly, 13, 169-174.
14. Ref: Desai, K.G.H. and Park, H.J. (2005) Recent Developments in Microencapsulation of Food Ingredients. Drying Technology, 23, 1361-1394.
15. Ref: Schlameus, W. (1995) Centrifugal Extrusion Encapsulation. In: Risch, S.J. and Reineccius,G.A.,Eds., Encapsulation and Controlled Release of Food Ingredients. ACS SymposiumSeries,Vol.590,ACS Publications, Washington DC, 96-103.
16. Ref: Kirby, C.J.,Whittle, C.J., Rigby, N., Coxon, D.T. and Law, B.A. (1991) Stabilization of Ascorbic Acid by Microencapsulation. International Journal of Food Science and Technology, 26, 437-449.
17. Ref: Eratte, D., Wang, B., Dowling, K., Barrow, C.J. and Adhikari, B.P. (2014) Complex Coacervation with Whey Protein Isolate and Gum Arabic for the Microencapsulation of Omega3 Rich Tuna Oil. Food & Function, 5, 2743-2750.
18. Ref: Vongsvivut, J., Heraud, P., Zhang, W., Kralovec, J.A., McNaughton, D. and Barrow, C.J. (2012) Quantitative Determination of Fatty Acid Compositions in Micro-Encapsulated FishOil Supplements Using Fourier Transform Infrared (FTIR) Spectroscopy. Food Chemistry, 135, 603-609.
19. Ref: Borgogna M, Bellich B, Zorzin L, Lapasin R, Cesàro A. Food microencapsulation of bioactive compounds: Rheological and thermal characterisation of nonconventional gelling system. Food Chemistry. 2010; 122:416-423.
20. Ref: Wang D, Xu Y. Degradation kinetics of anthocyanins in blackberry juice and concentrate. Journal of Food Engineering. 2007; 82:271-275.
21. Ref: Comunian A, Thomazini M, Gambagorte F, Trindade A. Effect of Incorporating Free or Encapsulated Ascorbic Acid in Chicken Frankfurters on Physicochemical and Sensory Stability. Journal of Food Science Engineering. 2014; 11:167-175.

*****