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# Spray drying for the encapsulation of oils-A review

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**Abstract**
In comparison to other drying procedures, the use of the spray drying method in the food industry for the manufacturing of a wide variety of components has become particularly attractive. In recent years, the spray drying method has been widely used to create functional meals, medications, and nutritional supplements. Because spray drying offers more financial benefits than other encapsulation techniques, it is highly favoured. Oils are encapsulated using the spray drying technology to improve the handling characteristics of the goods and to increase oxidation stability by shielding the bioactive ingredients. The type of wall materials, total solids, and inlet and outlet temperatures are only a few of the variables that affect the quality of the finished product when encapsulating oils. Hence, this evaluation emphasises the application and optimization of the spray drying process for the encapsulation of oils used as food ingredients.

**Keywords:** Spray drying, encapsulation, oils, wall material, food ingredients

## Introduction
There is a significant demand for foods that contain bioactive or functional ingredients (particularly natural ones) that improve the health of modern consumers, and this desire is fueled by consumers' growing awareness of the importance of nutrition. Dietary composition and overall health of food [1]. Due to their numerous uses, oils in particular are becoming more and more in demand in the food, drug, and cosmetic industries. Yet, due to their high level of unsaturation, marine and vegetable oils are susceptible to oxidative deterioration, which can also produce an unpleasant flavour. Moreover, due to their sensitivity to light and heat, oils are unstable during processing and storage, which restricts their use in the food business. Thus, it is vital to safeguard the oils to improve their stability throughout handling, processing, and storage [2, 3]. These variations have a negative impact on the resulting items' sensory qualities, shelf life, and general acceptance [4]. Encapsulation is a popular method for resolving the aforementioned issues because it shields the essential components from heat, light, and oxygen, which promotes stability, increases bioavailability, masks flavour, and allows for controlled release while preserving the functional qualities of the oils and improves their handling ease [5]. The process of encasing one substance— referred to as the core material or active agent within another—referred to as the coating, shell, or carrier/wall material—is known as encapsulation. In the food business, encapsulation utilising spray drying is a dependable method that has been employed to address these difficulties [6, 7]. Oils are increasingly being employed with microencapsulation technology worldwide. such as microencapsulated palm oil, microencapsulated fish oil, and microencapsulated coconut oil, which are used as food ingredients.
Encapsulation may improve consistency of dispersion, sufficiency of concentration, and convenience of handling [8]. Spray dryers feature high drying temperatures despite the core materials' brief drying contact time (a few seconds) in the drying chamber, usually with an input air temperature of $150^0$ to $250^0$ C, and $50^0$ to $80^0$ C for the exit air [9]. A few nanometers to a few hundred micrometres in size are the resultant particles [10]. The preparation technique and the wall materials used generally affect the structural type and intended size [11]. The use of encapsulation in food production necessitates that the wall materials be of food quality and have qualities that shield the core ingredients from outside influences. The carrier materials typically used for oil encapsulation include synthetic polymers and natural biomaterials (commonly carbohydrates and proteins) [12].
Therefore, this review focus on the principles, wall materials, and processing parameters of spray drying for oils encapsulation. In addition, this review illustrates recent research on oil encapsulation through spray drying and the application of these products in foods.

## Oil Encapsulation Benefits
Oil encapsulation enhances the lipids' resistance to oxidation and shields the main components, which include active ingredients, oils, flavourings, and vitamins, from outside influences. This makes the core substance very soluble, enables simple mixing, and controls the core material's release in order to achieve a suitable delay before the suitable stimulus. Moreover, it lessens the volatile chemical evaporation in the core material, masking or hiding any unfavourable tastes related to the core material. [13–16]. The reasons for applying encapsulation for oils can be summarized as follows:

a. Using the encapsulation technique to create powdered edible oil products improves the oxidative stability of lipids, extending shelf life by shielding oils from oxidation [14].
b. Protecting core ingredients from oxygen, light, or water. They are typically delicate chemicals like oils, flavours, and vitamins. Food oils generally have a high sensitivity to radiation, air, temperature, and light [17, 18].
c. In order to create powder with high solubility and suitable mixing qualities of the core materials, the oils are changed from a liquid to a dry state. A significant use of encapsulation in the food sector is the transformation of the fluid feed (flavours and edible

oils) into powders in solid form with appropriate handling properties [19].

d. Managing the release of the core material in order to achieve a suitable delay for the proper stimulus; a vital benefit of the encapsulation of oils and flavours is control over the release time of the active ingredients until they have arrived at their target [20].
e. Preventing volatile substances in the core materials from evaporating. The encapsulation technique results in a dry powder with good oxidation stability and low volatility. Oils are encapsulated to produce a dry powder that has better oxidation and less volatility, which makes it easier to use in a variety of final goods including cakes and beverages [21].
f. Covering or masked the unsavoury flavours of the main ingredient. Due to the excellent nutritional content of these goods, some edible oils, such as marine or vegetable oils, are frequently used in food products [16]. The unappealing "fishy" flavour of fish oil and the susceptibility of polyunsaturated fatty acids to oxidation, both of which have a detrimental effect on food acceptability, are additional issues that can be resolved with encapsulation [16, 22]. Compared to oils without encapsulation, encapsulation improves the stability and resistivity of oils under storage circumstances [23].

**Encapsulation Using the Spray Drying Technique**

Encapsulation is a procedure that involves enclosing tiny particles or droplets of active chemicals that have multiple desirable properties under a covering to shield them from environmental elements like oxygen, light, moisture, and interactions with other substances.

Particles of food components or other materials with a diameter of 1–1000 m is commonly obtained through encapsulation. Moreover, this method permits the controlled release of the enclosed core under specific circumstances [24]. Since the late 1950s, encapsulation using a spray dryer has been employed often for food manufacturing on an industrial scale, mostly for fats, oils, and flavourings and colours [25]; see Table 1. Moreover, because it is affordable, versatile, and can be utilised in a variety of ways, encapsulation is frequently employed in the food sector to incorporate oil aromas in a spray-dried form. continuous operation and generates high-quality particles [5]. The operation can be carried out by constantly converting the liquid form of the slurry emulsion into a powder. This method's fundamental idea is to generate a liquid emulsion by dissolving the core/wall materials in water, and then feed that emulsion into a heated medium (between $100^0$ and $300^0$ C) to evaporate the water. Depending on the type of materials used in the feed, how the dryer is constructed, and the operating circumstances, the dried product can be collected as a powder or as agglomerated particles. The water evaporation from the droplets is facilitated by the drying chamber's high temperature [26]. Spray drying has been demonstrated to be more economical than freeze drying for the encapsulation of oils, with a 30 to 50 times lower cost [27], despite the energy needed in the process in terms of heat. Nonetheless, this method does necessitate hot temperatures and air availability. Although the spray dryer's temperature is high, the wet-bulb only needs to be exposed for a brief period of time (a few seconds), and water vaporisation occurs at temperatures between $30^0$and 50 $^0$C [28]. Figure 1 shows a schematic diagram of the spray drying method's encapsulation process. Encapsulation via spray-drying, according to Bakry *et al*. [18], involves four primary steps: I creating a stable emulsion; (ii) homogenising the dispersion; (iii) atomizing the emulsion; and (iv) dehydrating the atomized particles. To fully saturate the polymer molecules and avoid any variances brought on by temperature changes, the first stage is typically carried out by dissolving the wall components in distilled water and emulsifying, or dispersing, using a magnetic stirrer overnight at 25 C. Depending on the emulsifying properties of the wall materials, the core materials can be mixed with an aqueous solution of the wall materials before the second stage begins, and then the emulsifying agent can be added. the emulsion that was created and contained the core and wall materials and the core substances must be stable until the drying stage [29].

**Unit Operation of Spray Drying**

The process of spray drying is illustrated in Figure 1.

The steps of the spray drying process involve: (a) atomization of fluid feed; (b) drying of the medium; (c) drying of the feed and spray contact; and (d) separation of the product from air. All of the processes, including their operational parameters, have a direct impact on the characteristics of the finished product. Spray drying is a relatively quick and repeatable process. Due to the enormous surface area produced by the atomization of the liquid input, drying methods [30] are used.

**1. Feed Atomization**

In order to achieve a balance between heat and mass transfer during the drying stage, as well as to increase the surface area and enable a fair distribution of the feed within the drier chamber, atomization entails breaking down the fluid feed (emulsion) into small, uniform-sized droplets. The increase in particle size (surface area) causes water to evaporate quickly, forming a crust that quickly dries the feed. To achieve feed liquid collapse, a variety of atomizers, including rotary atomizers, pressure nozzles, pneumatic nozzles, and sonic nozzles, are available [30]. based on the feed that needs to be dried into powder and the desired final product particle size when selecting the type of atomizer.

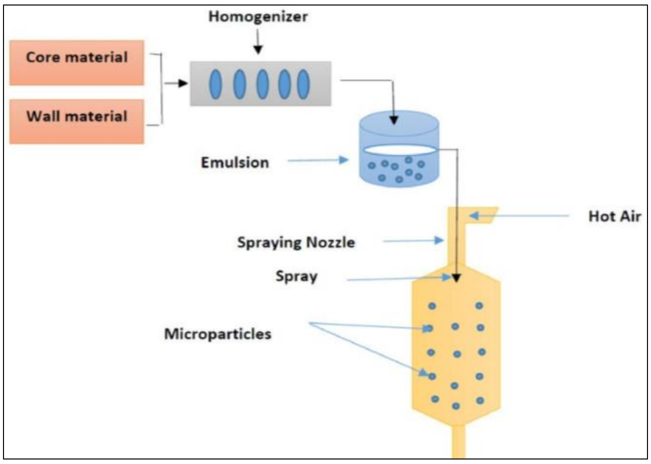


**Fig 1:** Schematic representation of the encapsulation process by spray-drying.

**2. Air Flow Contact**

Both the fluid spray and the air contact time have an impact on air flow contact because they both affect the drying rate and drying intensity. The air flow contact at this point begins with the drying step and continues through atomization. The air heating and filtration system's operational parameters regulate the atmosphere in the spray dryer's heating chamber. Typically, nitrogen or another gas selected based on the feed's sensitivity to or instability in the presence of oxygen is employed during the process [30]. There are typically two different feed-drying air flow conditions available

a. The co-current drying design: in this set-up, the atomizer and the entrance for the drying gas stream are both situated on top of the drying chamber. Heat-sensitive composites favour it because the feed is sprayed in the same direction as the hot air. Rapid vaporisation typically occurs at the inlet temperature of 150–220 °C; however, the output temperature of 50–80 °C prevents thermal deterioration. This design exposes heat-sensitive materials to the lower exit air temperature only.
b. The counter-current drying design, which is uncommon and only has a few uses for dry products. At opposing ends of the drier, the emulsion and drying air are introduced. As the dried powders are exposed to high temperatures, this configuration is more thermally efficient than the co-current drying system, but it has limited application for items that are heat-sensitive. The drying processes in these systems are unclear as a result of the convoluted flow [29, 31].

**3. Drying And Particle Formation**

The third step is drying and particle formation by convection. When the droplets' moisture content is evaporating, the heat from the drying medium is transmitted to them and transformed into latent heat. The diameter of the droplets and the relative velocities of the air and the droplets determine the temperature and mass transfer rate, respectively. As soon as the droplets come into touch with the drying air, the moisture quickly evaporates. At first, moisture from within the droplet is continuously transferred in bulk to the droplet surface. Eventually, a dried shell forms, and moisture evaporation then progresses more slowly until the finished product is produced [29, 30].

**4. Separation of Product from the Drying Air**

Separating the product from the drying air is the final stage. While fines entrained in the drying air are separated from the atmosphere and separated after the dried particles recovered in a cyclone filter that is located outside the dryer with collection bottle, the spray drying begins when the dried particles fall to the bottom of the drying chamber and are collected through gravitational effects [29]. The liquid emulsion, which consists of the wall and core ingredients, is transformed into powdered, dried particles during the spray drying process. The dried particles have a size range of 10 to 100 micrometres and are spherical in form [32].

**Optimizing the Encapsulation Process Conditions**

Even if the coating material is adequate, the spray drying settings should be tuned to achieve high encapsulation efficiency and the desired particle quality. The characteristics of the wall/core materials, the characteristics of the in-feed emulsion, and the characteristics of the spray drying process, including inlet/outlet air temperature, humidity, air flow rate, and the type of atomization, all have a direct impact on the efficiency of encapsulation [33].

**1. Inlet and Outlet Temperatures**

The inlet and outlet air temperatures should be optimised, and the feed emulsion should be steady throughout the processing time, in order to produce a final product with a high yield and level of encapsulation [34]. Evaporation happens instantly and the inlet air temperature is typically between 150 and 220 °C. Low evaporation rates due to the cool air inlet temperature produce microcapsules with high-density membranes, high moisture contents, low fluidity, and easy agglomeration. As a result, the yield will be minimal since the particles will readily adhere to the internal wall of the drying chamber. Yet a very high intake temperature causes severe vaporisation, which may lead to membrane fractures, early release, and degradation or loss of the encapsulated cores [29]. According to Carmona [35], spray drying was used to best encapsulate palm fibre oil, and the inlet air temperature range was (130-202 °C). It was determined that 166 °C was the ideal inlet temperature. The impact of inlet air temperature (120–220 °C) on the characteristics of sour cherry oil that was spray dried recently was investigated by Başyiit, B., *et al*. [36]. The ideal temperature was 195 °C, and the study found that increased inlet air temperature had a beneficial impact on flowability. The impacts, according to the author, were caused by the wide range of reported intake and exit temperatures, which is thought to be a significant factor in the spray drying process to produce particles with stable properties.

**2. Total Solids of the Emulsion**

The ratios of the emulsion's (wall material + oil) components calculated and visualised on a dry basis are referred to as the total solid’s concentration. In their assessment of numerous earlier experiments that enhanced total solids in the emulsion for encapsulation, Jafari *et al*. [15] examined the results. The assessment suggested using the maximum feed solid content. Some research, however, recommended utilising the highest feed solid content possible for food flavours and oils due to two reasons: first, using a high wall material content outweighs solubility. Hence, the encapsulation process will not be improved by undissolved wall components, and the dried particles will retain less flavour as a result. The second purpose is to obtain the ideal emulsion, which is connected to the initial emulsion's viscosity. The emulsion content of the total solids was influenced by the nature of the core material. The efficiency of encapsulation as well as the core elements that are most prone to loss, including volatile compounds, are both significantly impacted by the total solid content. The optimal total solids were 30%, according to a recent study by Frascareli *et al*. [37] of the encapsulation process conditions for coffee oil encapsulated by spray drying. The ideal solid percentage was 35% when Carmona [35] looked at the effects of total solid content (20–40%) on the properties of spray-dried palm fibre oil.

Moreover, Ng *et al*. [38] showed that the best formulation for the encapsulation efficiency

(MEE) and the oxidative stability of encapsulated kenaf seed oil was 40% total solid content

(wall/oil). Furthermore, when optimisation was done using the range of total solid (16.5933.41%), it was discovered that the 20% optimum total solid stated by [36] was for the sour cherry oil encapsulated by spray drying. In order to generate encapsulated oils with the necessary characteristics, total solid concentration is therefore a crucial component that must be taken into consideration. The optimisation of encapsulation conditions for various oil sources is summarised in Table 1. It was discovered that the ideal spray-drying conditions for various components within various wall materials varied. The range of total solids was 20– 40%. Moreover, the range of the inlet air temperatures was 135–202 °C.

**Table 1:** Optimization of spray drying process conditions for various types of oils

| Core Material | Wall Material | Total Solids | Inlet/Outlet Temperature |
|---|---|---|---|
| Palm fibre oil | Gum Arabic | 20–40% | 130–202 °C/NM |
| Sour cherry oil | Maltodextrin +gum Arabic | 16.59–33.41% | 120–220 °C/NM |
| Walnut oil | SMP + Tween 80 | 30% | 180 °C/NM |
| Almond oil | Isolated starch | 30–40% | 145 °C/NM |
| Fish oil | Whey protein | 30% | 160 °C/NM |
| Corn oil | Brea gum | 30%–40% | 150 °C/60 °C |
| Virgin coconut oil | Soy protein isolate + maltodextrin | 20 to 30% | 160 and 180 °C |
| Palm Fibre Oil | Gum Arabic | 35% | 166 °C |
| PUFA-rich vegetable oil | Maltodextrin + modified starch | 2:1 (wall: oil) | 150 and 180 °C |
| Fish oil | Soybean protein | 1:1, 2:1, 3:1, 4:1 | 180 °C/96 °C |
| Rapeseed oil | Soy protein isolate + Maltodextrin | 30% | 140–220 °C/NM |
| Squash seed oil | Maltodextrin +gum Arabic | 25%,30%,35% | 140, 160, 180 °C/ 90 °C |
| Echium oil | Gum Arabic | 30% | 150 °C/NM |
| *Nigella sativa* oil | Maltodextrin + Sodium Caseinate | 20–60% | 150–190 °C/85 °C |
| Nigella sativa oil | Maltodextrin + sodium octenyl | 25% | 140 °C/95 °C |
| Lavender oil | Maltodextrin + gum Arabic | 25%,30%,35% | 140 °C/95 °C |
| Pomegranate Seed Oil | Xanthan gum + gum Arabic | 30%,35%45% | 170 °C/85 °C |
| Gac peel oil | Whey protein + gum Arabic | 24.5% | 160 °C/NM |
| Fish oil | Chitosan + maltodextrin | 26.5% | 160, 170, 180 °C/NM |
| Fish oil | Soy protein isolate + maltodextrin | 45% | 160 °C/85 °C |
| Rice bran oil | Jackfruit seed starch + Whey protein isolate | 30% | 140, 150 and 160 °C |
| Citronella oil | Gum Arabic | 20–60% | 136–203 °C |
| Ginger oil | Inulin + whey protein isolate | 20%,25%,30% | 140 °C,155 °C and 170 °C |

## 3. Wall Materials

In order to prevent premature interactions between the core material and other ingredients, reduce the core material's reactivity towards the external environment, reduce volatile losses, and enable controlled or sustained release under desired conditions, the wall materials serve as a barrier between the core materials and any external factors that may contribute to their degradation [29].

Table 2 lists the various wall materials that can be used to spray-dry oils. The choices of the wall material and encapsulation method are interconnected. The stability of the oil encapsulation and the effectiveness of the core compound's protection depend greatly on the wall material. The wall material affects the stability of the emulsion and the properties of the formed microcapsules [39, 40]. A wall material should have film-forming abilities, be highly water soluble, and have a low viscosity. Prior to spray drying, wall materials must also have enough emulsifying power to create stable emulsions [29]. However, a wide range of encapsulating substances, such as low molecular weight polysaccharides (starches, maltodextrins (MD), gum Arabic (GA), and corn syrups), lipids (mono and diglycerides), proteins (casein, milk serum, and gelatin), as well as newly emerging biopolymers, such as Millard reaction products [41], have been used for the encapsulation of flavours and oils. Combining two or more agents can provide favourable effects including improving the stability and droplet size distribution of emulsions and optimising the encapsulation efficiency of spraydried powders [39].

**Table 2:** Wall materials commonly used in the spray drying process.

| Wall Material | Interest |
|---|---|
| Maltodextrin (DE < 20) | Film forming |
| Corn syrup solid (DE > 20) | Film forming, reducibility |
| Modified starch | Very good emulsifier |
| Gum Arabic | Emulsifier, film forming |
| Modified cellulose | Film forming |
| Gelatin | Emulsifier, film forming |
| Cyclodextrin | Encapsulant, emulsifier |
| Lecithin | Emulsifier |
| Whey protein | Good emulsifier |
| Hydrogenated fat | Barrier to oxygen and water |
| Chitosan | Carrier of drug delivery |

### 3.1 Carbohydrate

In general, it has been discovered that oxidised or lipophilicated starches exhibit good solubility, good emulsifying, and oil retention qualities with low viscosities at high solid concentrations. The interfacial qualities required for high encapsulation efficiency prevent these materials from being employed alone, thus they are combined with additional encapsulating substances such proteins or gums [40]. Chemically altering carbohydrates can improve the encapsulation qualities of wall materials. For instance, some modified starches are utilised often in the process of encapsulation by spray-drying and have surface active characteristics. Products made from hydrolyzed starch are hydrophilic substances, thus they have low affinity for flavours and oils that are hydrophobic [42, 43].

Maltodextrins are starch hydrolysates made when starch is partially hydrolyzed by either enzymatic or acidic mechanisms. Maltodextrin is widely used in food processing because it is affordable, nutritive, flavourless (not sweet), highly soluble in cold water, and effectively protects flavour from oxidation. Maltodextrin is the best substitute for Arabic gum because it has been shown to increase the oxidative stability of encapsulated oils [29]. Maltodextrin offers a potent barrier against external influences and safeguards against oxidation of the core components [44]. The rheological behaviour of the finished product is also greatly influenced by the characteristics of the maltodextrin phase [45]. The carrier offers benefits and drawbacks in terms of its price, characteristics, and encapsulation effectiveness. Based on their dextrose equivalent (DE) value, which indicates the degree of hydrolysis of the starch molecule and is directly related to the synthesis of reducing sugars, different maltodextrins are categorised into grades. The physical characteristics of maltodextrin with dextrose equivalent values of 10, 20, and 30 are favourable, and the particles have a smooth, spherical surface [46]. Excellent thermal defenders, maltodextrins are essential for maintaining the integrity of anthocyanins during their encapsulation. Maltodextrin and sodium caseinate were used with proteins and other carbohydrates as wall materials to effectively encapsulate certain oils [32].

### 3.2 Gums

Due to their capacity to stabilise the emulsions, gums are frequently used during the encapsulation step of the film-forming process. Acacia gum, often known as gum Arabic (GA), is one of the most popular gums and has several useful qualities, including the ability to emulsify. In addition to over 2% protein, GA is a polymer made up of d-glucuronic acid, Lrhamnose, d-galactose, and L-arabinose [47, 48]. As an emulsifier, flavouring agent, humectant, thickening, surface-finishing agent, and for delaying sugar crystallisation, GA has useful qualities [48]. The most common gum in encapsulating technology is GA, but it has limited availability, is expensive, and cannot stop oxidation [40]. Many studies have reported the use of gum Arabic for the encapsulation of oils, including kenaf seed oil and fish oil [49].kenaf seed oil [50], and palm fibre oil [35].

### 3.3 Proteins

Because of their useful characteristics, proteins are good wall materials for encapsulation utilising spray drying. Furthermore, proteins have a great capacity for binding flavour and oil components [29]. Proteins have been investigated as oil encapsulates due to their amphiphilic properties, which are caused by a hydrophilic group and a hydrophobic (or lipophilic) group, as well as their high diffusivity, which promotes better distribution around the enclosed oil surface. Whey protein and sodium caseinate in particular have been studied in this regard. Soy, whey, casein, and lecithin are just a few of the proteins or protein-containing isolates that have been used for oil encapsulation. Blends of proteins, gums, and carbohydrates, where the protein fraction functions as an emulsifier and the carbohydrates serve as the matrix-forming component, are a common combination for oil encapsulation by spray drying. Due to the wide diversity of maltodextrins DE, soy or whey protein with maltodextrins is widely used. Because of its high solubility in water, ability to emulsify with oil, quick development of interfacial films, and superior surface activity, sodium caseinate is favoured over other dairy proteins. According to reports, the best emulsion stabiliser for fats is sodium caseinate. A range of volatile and non-volatile oils have been encapsulated using sodium caseinate, either alone or in combinations with various wall materials. Sodium caseinate exhibits good encapsulating qualities, particularly when combined with carbohydrates, according to research on its use as a wall material. High encapsulation efficiency—99% in powder form—was obtained by combining sodium caseinate with sunflower oil. In order to create a non-dairy creamer, used sodium caseinate, which produced a stable emulsion with a white colour and considerably altered the protein level, imparting a taste of milk (milk-sense). The concentrated combination produced a white colour and stable emulsion when added to drinks or coffee.

Some encapsulated oils, such as linseed oil and kenaf seed oil, have been produced with success using lecithin as an emulsifying agent to assure the stability of the feeding emulsions prior to spray drying. When soy lecithin and carboxymethyl cellulose (CMC) are included, encapsulation effectiveness and oxidative stability are improved due to maltodextrin's lack of emulsifying capabilities, oil retention, and emulsion stability.

## Applications of Encapsulated Oils in Food

Scientific proof that these foods boost human health is driving up consumer demand for them. The demand for a nutritious diet is also rising as a result of public health concerns with the goal of lowering mortality and raising quality of life. In general, oils' propensity for oxidation is linked to the difficulties in creating healthy oils for food applications. Oil-containing food products quickly oxidise due to a number of elements, such as light, heat, and oxygen. Fatty acid-induced food degradation restricts the use of some oils in food items, such as fish oil, which impacts the product's texture, flavour, aroma, colour, and shelf life. These issues can be fixed by encapsulating the oils to create a stable powder with very advantageous qualities. In order to create useful food items with stable features for the finished product, a variety of seed and marine oils have been used in the food manufacturing process. Dairy and non-dairy goods, meat products, pastries, soups, and other foods are examples of modern food products made with encapsulated oils. The same restriction, that fish oil and vegetable oils used in food preparation are particularly vulnerable to oxidation, has been found in a number of earlier research. Moreover, some oils, particularly marine oils, have a disagreeable flavour that makes adding them to food difficult. This unpleasant flavour could be concealed by using the microencapsulation process. Also, both producers and customers are interested in swapping out unhealthy sources of encapsulated oils for the fats in various products. Encapsulated oils have been effectively incorporated by researchers into a variety of food products, and these goods have higher oxidative stability and excellent sensory appeal.

## Conclusions

Vegetable oils have biological and functional lipids that promote good health. Due to the high concentration of unsaturated fatty acids in these oils, they are vulnerable to oxidation, instability, and deterioration. The oils can be used in several ways after being powdered, improving their oxidative stability. The characteristics of the oil (core) compounds, the level of stability of the encapsulated oil under storage and processing conditions, the characteristics of the food components, the cost of production, and the maximum encapsulation efficiency in the powder all play a role in the choice of an appropriate encapsulation technique. A crucial processing method used in a variety of pharmaceutical, nutraceutical, and functional food items is spray drying. Nonetheless, it is strongly advised that the conditions be optimised for the creation of stable and high-quality encapsulated oils. Also, there has been a notable increase in the market acceptance of functional foods that are fortified with bioactive substances, such as encapsulated functional oils from plants and marine life. The development of novel materials and methods should therefore be pursued in order to make novel products in the near future that are enhanced with constituents from encapsulated functional oils.

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