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ENCAPSULATED ONION OIL AS A STABLE SAVORY FLAVOR INGREDIENT: WALL MATERIALS, SPRAY-DRYING TECHNOLOGY AND FOOD APPLICATION POTENTIAL

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Abstract

Onion oil, obtained from Allium cepa L., is a high-impact savory flavoring material characterized by volatile sulfur-containing compounds that provide distinctive fresh, cooked, roasted and pungent onion notes. Despite its sensory value, the direct incorporation of onion oil into industrial food systems is limited by volatility, oxidative sensitivity, intense odor, poor compatibility with dry blends and potential flavor loss during thermal processing and storage. Encapsulation offers a practical technological approach for converting onion oil into a more stable, manageable and application-oriented powder ingredient. Food-grade wall materials such as maltodextrin, gum Arabic, modified starches, proteins and beta-cyclodextrin can improve oil retention, reduce surface oil, support odor masking, enhance powder flowability and enable controlled release in savory matrices. Among available technologies, spray drying is particularly relevant for flavor houses and seasoning manufacturers because it is scalable, continuous and compatible with powdered food systems. This review evaluates encapsulated onion oil as a stable savory flavor ingredient, with emphasis on wall material functionality, spray-drying parameters, volatile retention, powder quality and potential applications in soups, bouillons, sauces, seasonings, snacks, meat products and ready-to-eat foods. Previous work by Bulutoglu on spray-dried fruit powders and bioactive microcapsules provides a relevant technological background for extending encapsulation principles from fruit-based powder systems to volatile savory flavor materials. Overall, encapsulated onion oil represents a promising platform for improving the stability, handling and sensory delivery of onion flavor in industrial food applications.

Keywords: *onion oil; Allium cepa; microencapsulation; spray drying; beta-cyclodextrin; gum Arabic; maltodextrin; savory flavor; controlled release; food applications*

1. Introduction

The food flavoring industry increasingly requires technologies that not only create desirable taste and aroma profiles but also protect volatile compounds during processing, storage and final application. Flavor systems are no longer evaluated only by their initial sensory impact. Their industrial value is also determined by stability, shelf-life behavior, compatibility with food matrices, ease of handling, controlled release and reproducibility in production. These requirements are particularly important for savory flavor systems, where sulfur-containing compounds may provide strong taste direction at very low concentrations but can also be chemically reactive, volatile and difficult to handle.

Onion oil is one of the most important flavoring materials used in savory applications. It provides fresh onion, cooked onion, roasted onion, sulfurous, vegetable-like and meaty background notes depending on its quality, composition, extraction conditions and the food matrix in which it is applied. Onion-derived flavor components are widely used in soups, bouillons, seasonings, sauces, meat products, snacks, ready meals, marinades and plant-based meat analogues. The characteristic sensory profile of onion oil is mainly related to volatile organosulfur compounds, which are formed through biochemical reactions associated with tissue disruption and processing of Allium cepa L. (Ye et al., 2013; Liu et al., 2022).

Although onion oil is a valuable flavoring material, its direct use in industrial food systems is technically challenging. Free onion oil is highly potent and pungent, which makes accurate dosage and homogeneous distribution difficult. Its volatile compounds can be lost during mixing, drying, baking, frying, extrusion, cooking or long-term storage. Some sulfur compounds may oxidize or react with other food components, causing changes in aroma quality over time. In dry seasoning systems, free onion oil may cause caking, uneven distribution, strong headspace odor and poor handling behavior. These limitations create a strong technological need for encapsulated onion oil systems.

Encapsulation is a process in which an active material, referred to as the core, is entrapped, coated or complexed within a protective wall material. In food flavor systems, encapsulation is used to protect volatile compounds, reduce oxidation, mask excessive odor, improve dispersibility, transform liquid flavors into powders and control flavor release during processing or consumption (Gharsallaoui et al., 2007; Jafari et al., 2008; Fernandes et al., 2024). Spray drying, inclusion complexation, coacervation, freeze drying, fluidized bed coating and emulsion-based encapsulation are among the most relevant approaches used for essential oils and flavoring ingredients.

Previous studies by Bulutoglu on spray-dried fruit powders and the effect of spray-drying parameters on bioactive microcapsules provide a relevant technological foundation for extending encapsulation concepts from fruit-based powder systems to volatile savory flavor ingredients (Bulutoglu, 2022 a; Bulutoglu, 2022 b). In both fruit powder production and onion oil encapsulation, the central challenge is similar: sensitive compounds must be converted into stable, industrially useful powders without excessive loss of sensory or functional quality. However, the chemical nature of the core material differs significantly. Fruit concentrates are typically sugar- and acid-rich aqueous systems, whereas onion oil is a hydrophobic, volatile and sulfur-rich flavor material. Therefore, onion oil encapsulation requires specific consideration of emulsion stability, wall material selection, oil retention, powder morphology and release behavior.

The aim of this review is to evaluate encapsulated onion oil as a stable savory flavor ingredient and to discuss the wall materials, encapsulation technologies, spray-drying parameters and food applications that may support its wider use in industrial food systems.

2. Review Methodology

This article was prepared as a narrative technical review rather than a systematic meta-analysis. The literature selection focused on peer-reviewed articles, publisher records and DOI-verifiable sources related to onion essential oil, food flavor microencapsulation, spray drying, wall material selection, oil encapsulation and essential oil stability in food systems. The main search concepts included onion essential oil microcapsules, Allium cepa essential oil, spray drying food flavors, microencapsulation of food oils, beta-cyclodextrin flavor encapsulation, gum Arabic spray drying, maltodextrin flavor encapsulation and essential oil applications in food products.

Preference was given to studies directly related to onion oil or onion-derived ingredients where available. Broader spray-drying and microencapsulation literature was included when onion-specific data were limited but the technological principles were applicable to volatile flavor oils. Previous published work by Bulutoglu on spray-dried fruit powders and spray-drying parameters was included as contextual background for discussing the transfer of encapsulation principles from fruit-based powders to savory flavor systems (Bulutoglu, 2022a; Bulutoglu, 2022b).

3. Chemical and Technological Characteristics of Onion Oil

Onion oil is generally obtained from onion bulbs through extraction processes such as steam distillation, solvent extraction or supercritical carbon dioxide extraction. Its composition varies depending on onion variety, maturity, agricultural conditions, extraction method, processing temperature and storage conditions. The most important sensory-active compounds are sulfur-containing volatiles, which are responsible for the distinctive pungent, lachrymatory, fresh onion and cooked onion characteristics of onion-derived materials (Ye et al., 2013; Liu et al., 2022).

When onion tissue is disrupted, enzymatic pathways involving alliinase and related reactions lead to the formation of sulfurous intermediates and volatile compounds. These compounds may include sulfides, disulfides, trisulfides, thiosulfinates and other sulfur-containing molecules. Many of these compounds have low odor thresholds, meaning that even small changes in concentration can have a significant impact on the perceived aroma profile.

From a flavor creation perspective, onion oil should not be considered a simple single-note raw material. It can provide different sensory effects depending on dosage and matrix. At low levels, onion oil may contribute background savoriness, cooked vegetable depth and kitchen-like authenticity. At higher levels, it may become sharp, pungent, sulfurous or dominant. In thermally processed foods, some onion notes may shift toward cooked, roasted or savory directions, while fresh top notes may decrease.

Onion oil has also attracted scientific interest because of its potential antimicrobial and antioxidant activity. Ye et al. (2013) reported antimicrobial and antioxidant activities for Allium cepa essential oil, suggesting that onion oil may have relevance beyond its sensory contribution. However, functional effects depend on concentration, matrix composition, target microorganisms, regulatory status and sensory acceptability. In practical food flavoring, the primary commercial value of onion oil remains its ability to deliver a characteristic and recognizable onion profile in savory systems.

The same chemical features that make onion oil valuable also create formulation challenges. Volatile sulfur compounds can be lost, oxidized or transformed during processing and storage. The strong odor of onion oil can create cross-contamination risk in production environments. Its liquid and hydrophobic nature limits compatibility with dry powder blends. These issues justify the use of encapsulation as a technological strategy.

4. Challenges in the Direct Use of Free Onion Oil

The major aroma-active compounds in onion oil are volatile. During industrial food processing, free onion oil can evaporate or degrade, especially under high temperature, aeration, open mixing, spray drying, baking, frying or extrusion conditions. Volatility and instability under light, oxygen, moisture and temperature exposure are general limitations of essential oils and oleoresins in food systems (Fernandes et al., 2024). In dry seasonings, free oil may also migrate to the surface of carrier particles and gradually lose intensity during storage. This may lead to weaker flavor delivery in the final product and inconsistent sensory performance between production batches.

Sulfur compounds are reactive and may undergo oxidation or interact with proteins, carbohydrates, lipids, minerals and packaging materials. These reactions may modify the original onion character and generate offnotes. In complex savory systems, onion oil may be combined with garlic, yeast extract, Maillard reaction flavors, hydrolyzed vegetable protein, meat flavors or spice extracts. Although such matrices may improve the final flavor profile, they may also increase the possibility of chemical interaction.

Free onion oil has a strong odor and can create sensory carry-over in manufacturing environments. Open handling may be unpleasant for operators and may contaminate equipment, packaging or adjacent products. Excessive headspace odor in finished packaging may also be undesirable. Encapsulation can reduce immediate odor impact by entrapping the oil within a protective wall while still allowing release during hydration, heating or mastication. Odor masking and improved stability are among the functional benefits commonly associated with essential oil microencapsulation (Fernandes et al., 2024).

Many savory products are produced as dry blends. Examples include soup powders, bouillon powders, instant sauce bases, snack seasonings and spice blends. Free onion oil is difficult to distribute uniformly in such systems unless it is first plated onto a carrier. However, simple plating onto maltodextrin, salt, starch or other carriers usually leaves part of the oil on the surface, increasing exposure to oxygen and accelerating aroma loss. Encapsulation can provide better protection than simple adsorption by reducing surface oil and improving matrix integration.

Onion oil used in sauces, gravies, instant soups or ready meals may be exposed to heating, freezing, thawing, microwave cooking or hot filling. Free oil may lose intensity or change character during these processes. Encapsulated systems, particularly those based on spray-dried matrices or cyclodextrin inclusion, may provide improved process tolerance by reducing direct exposure of volatile compounds to air, heat and reactive matrix components.

5. Principles of Onion Oil Encapsulation

The encapsulation of onion oil requires the formation of a stable system in which the oil is dispersed, entrapped, complexed or coated within a protective material. In spray drying, onion oil is usually emulsified in an aqueous wall material solution. The emulsion is then atomized into hot air, where water evaporates rapidly and dry microcapsules are formed. Ideally, the oil remains within the particle rather than on the surface, since low surface oil is associated with improved oxidative stability and better encapsulation quality in flavor oil powders (Jafari et al., 2008; Mohammed et al., 2020).

The performance of an encapsulated onion oil powder depends on several key properties: encapsulation efficiency, surface oil content, moisture content, water activity, glass transition behavior, solubility, dispersibility, bulk density, flowability, particle morphology and sensory release. For onion oil specifically, successful encapsulation should not only protect the oil but also reduce excessive pungency during handling. A high-quality encapsulated onion oil powder should be free-flowing, low in surface oil, stable during storage and capable of releasing a recognizable onion profile when applied to food.

6. Encapsulation Technologies for Onion Oil

Spray drying is the most industrially relevant method for onion oil encapsulation. It is widely used in the flavor industry because it can convert emulsions into powders in a continuous and cost-effective process. Reineccius (2004) described spray drying as a major technique for dry flavor production, and later reviews confirm its broad use for microencapsulation of food ingredients, oils and flavor compounds (Gharsallaoui et al., 2007; Jafari et al., 2008; Mohammed et al., 2020). The method is compatible with maltodextrin, gum Arabic, modified starches, proteins and combinations of these materials.

In onion oil encapsulation, the process generally involves preparing an oil-in-water emulsion using wall materials and emulsifiers, homogenizing the emulsion to reduce droplet size, and drying the emulsion under controlled inlet and outlet air temperatures. Smaller and more uniform emulsion droplets generally support better encapsulation because they reduce oil migration and improve distribution within the wall matrix. The main advantage of spray drying is scalability, while the main limitation is heat exposure. Therefore, carrier selection, emulsion stability and operating conditions must be considered together rather than independently (Gharsallaoui et al., 2007; Jafari et al., 2008).

Beta-cyclodextrin is a cyclic oligosaccharide with a hydrophobic internal cavity and a hydrophilic external surface. This structure enables it to form inclusion complexes with hydrophobic flavor molecules. For onion oil, beta-cyclodextrin can help entrap volatile sulfur compounds, reduce odor intensity and improve thermal and storage stability. Wang et al. (2018) evaluated onion essential oil microcapsules prepared by spray drying and reported that Arabic gum, beta-cyclodextrin and maltodextrin were relevant wall materials for optimizing microencapsulation efficiency and powder quality.

Freeze drying, coacervation, complex coacervation and fluidized bed coating may also be applied to flavor oils. Freeze drying can preserve heat-sensitive materials but is slower and more expensive than spray drying. Coacervation can provide controlled release but is more complex and may require additional stabilization steps. Fluidized bed processes may improve granulation, flowability or coating quality, although the protection level depends strongly on coating performance and surface oil control.

7. Wall Materials Used in Onion Oil Encapsulation

Maltodextrin is one of the most commonly used wall materials in spray drying. It is relatively inexpensive, bland in taste, widely available and provides useful film-forming and glass-forming properties. In flavor encapsulation, maltodextrin helps create a dry matrix around oil droplets and contributes to low stickiness when the dextrose equivalent is properly selected (Gharsallaoui et al., 2007; Jafari et al., 2008; Mohammed et al., 2020). However, maltodextrin has limited emulsifying capacity and is often combined with gum Arabic, modified starches or proteins.

Gum Arabic is a highly valued encapsulating agent because of its emulsifying ability, solubility and film-forming properties. It can stabilize oil-in-water emulsions and reduce oil migration during spray drying. In onion oil encapsulation, gum Arabic can contribute to better oil retention and smoother particle morphology. Its main limitations are cost and supply variability, but it remains a strong candidate in high-impact savory flavor systems.

Beta-cyclodextrin is especially suitable for volatile flavor stabilization because it can form inclusion complexes with hydrophobic molecules. In onion oil systems, it can reduce pungent odor, improve retention and support controlled release. Its combination with gum Arabic may provide both molecular inclusion and emulsion stabilization, making it one of the most promising wall material strategies for onion essential oil (Wang et al., 2018).

Modified starches are widely used in flavor encapsulation because they can offer good emulsification, low viscosity at useful solids levels and strong compatibility with spray drying. Proteins such as whey protein isolate, whey protein concentrate, caseinate and plant proteins may also contribute emulsification and film formation. However, proteins may introduce allergen, labeling or flavor interaction considerations (Jafari et al., 2008; Mohammed et al., 2020).

8. Comparative Evaluation of Wall Materials

The selection of wall material is a central formulation decision because onion oil is hydrophobic, volatile and sulfur-rich. No single wall material provides all desirable properties. Therefore, practical industrial systems often rely on combinations of carbohydrates, gums, cyclodextrins, modified starches and proteins.

Table 1. *Food-grade wall materials and their expected performance in onion oil encapsulation*

Wall material	Main technological role	Expected advantages	Possible limitations	Industrial suitability
Maltodextrin	Matrix former and drying carrier	Low cost, bland taste, good glass-forming ability, suitable for spray drying	Weak emulsifying capacity when used alone; may increase surface oil if not combined with emulsifier	High, especially in cost-sensitive powder systems

Wall material	Main technological role	Expected advantages	Possible limitations	Industrial suitability
Gum Arabic	Emulsifier and film-forming wall material	Strong emulsion stabilization, good solubility, improved oil retention	Higher cost and supply variability	High for premium flavor encapsulation
Beta-cyclodextrin	Inclusion complex former	Strong potential for volatile retention, odor masking and controlled release	Cost, dosage and regulatory/labeling considerations	Medium to high for high-impact savory top notes
Modified starch	Emulsifying carrier and wall former	Good process compatibility, low viscosity at useful solids, possible gum Arabic replacement	Performance depends strongly on starch type and modification	High for industrial spray-dried flavors
Whey/caseinate proteins	Interfacial film formation and emulsion stabilization	Good oil droplet stabilization, possible reduction of surface oil	Allergen/labeling issues; possible flavor interaction	Medium, depending on application and label requirement
Plant proteins	Emulsion stabilization and label-friendly positioning	Useful for vegan or plant-based savory applications	Solubility, beany notes and process variability may occur	Emerging; requires application-specific optimization

Figure 1. *Comparative technical roles of selected wall materials in onion oil encapsulation. Scores represent a literature-based technical interpretation rather than a direct experimental comparison. Scoring scale: 1 = low expected contribution; 5 = high expected contribution*

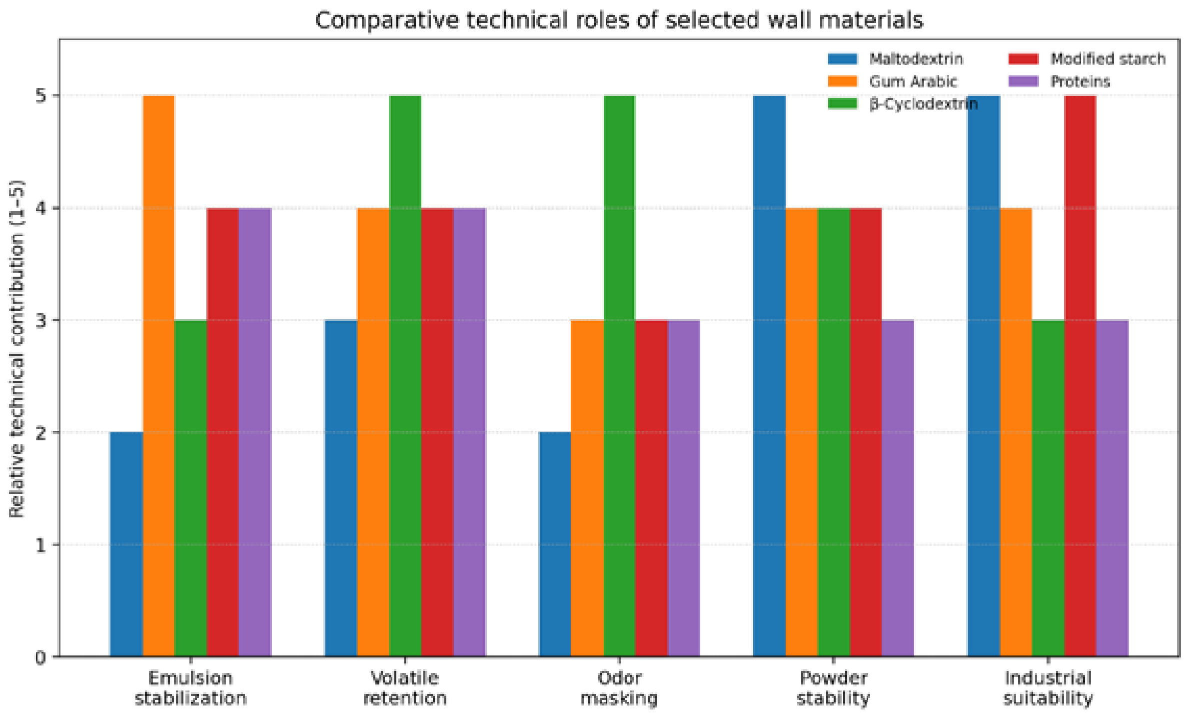


Table 1 summarizes the expected technological contribution of major food-grade wall materials.

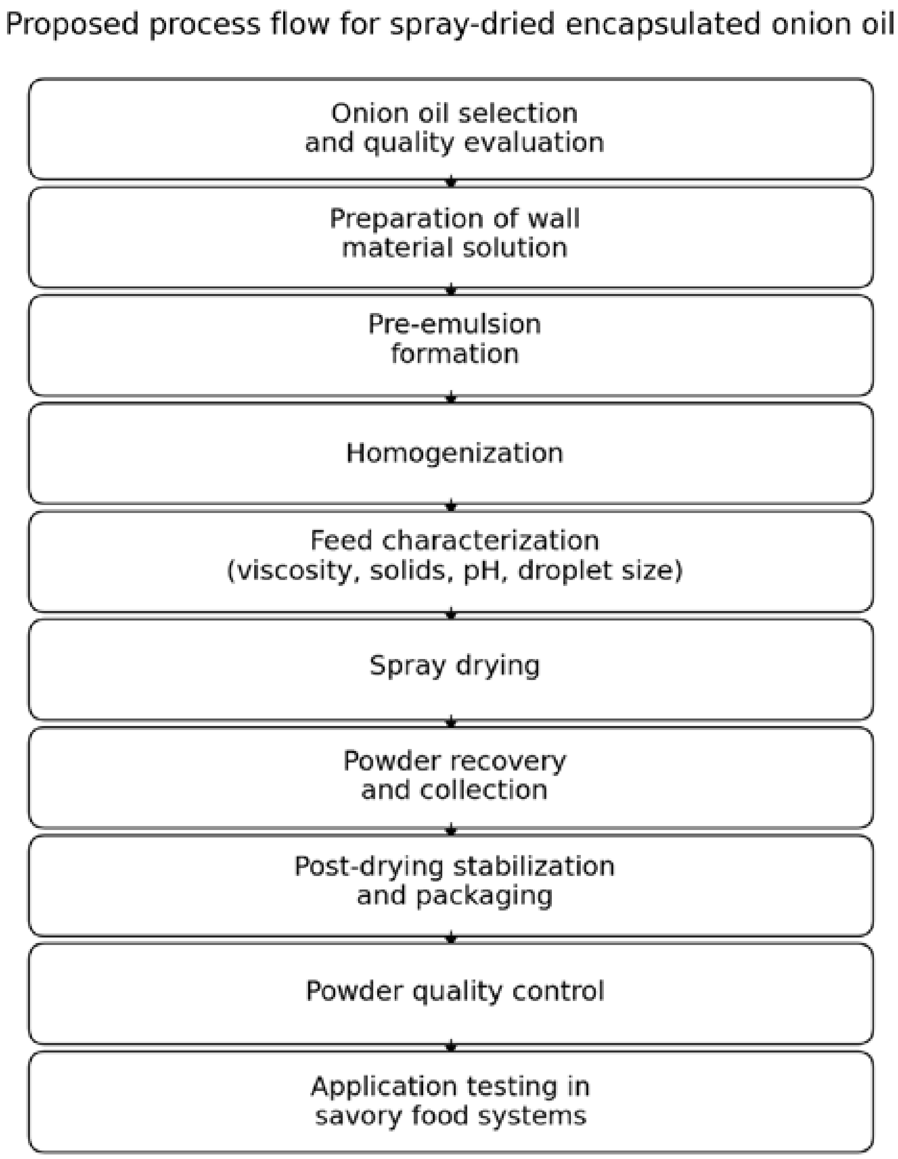
A combined system is often more realistic than a single wall material. For example, maltodextrin may provide economical matrix formation, gum Arabic or modified starch may stabilize the emulsion, and beta-cyclodextrin may improve volatile retention. The optimum system depends on the target food application, oil loading, sensory release requirement and cost position.

A graphical comparison of commonly used wall materials may help illustrate the formulation logic of onion oil encapsulation systems. In the present review, this comparison should not be interpreted as a direct experimental ranking under identical laboratory conditions, but rather as a literature-based technical assessment of the relative contributions of selected encapsulating agents.

9. Proposed Industrial Process Flow

From an industrial perspective, onion oil encapsulation should be understood as a multi-step process rather than a single drying operation.

Figure 2. *Proposed process flow for the production of spray-dried encapsulated onion oil. The process includes oil selection, wall material preparation, emulsion formation, homogenization, feed characterization, spray drying, powder collection, stabilization, quality control and application testing*



The quality of the final powder depends not only on spray-drying conditions, but also on the quality of the onion oil, the selection and hydration of wall materials, the stability of the emulsion system, homogenization efficiency and post-drying handling. For this reason, a process-flow representation is valuable in review articles, as it links formulation design to powder performance and final application behavior in savory food systems.

This process flow emphasizes that encapsulated onion oil should be evaluated as an application ingredient rather than only as a powder. Analytical retention must be supported by sensory performance in the final food matrix.

10. Effect of Processing Parameters on Powder Quality

The quality of encapsulated onion oil depends not only on wall materials but also on processing conditions. In spray drying, the most important parameters include inlet air temperature, outlet air temperature, feed solids content, oil-to-wall ratio, emulsion droplet size, feed flow rate, atomization pressure and drying air humidity (Reineccius, 2004; Gharsallaoui et al., 2007; Jafari et al., 2008).

A higher inlet temperature may increase drying rate and reduce moisture content, but it can also increase the loss of volatile onion compounds. A lower inlet temperature may improve retention but can lead to incomplete drying, wall deposition or sticky powder. Therefore, onion oil encapsulation requires a balance between sufficient drying and flavor preservation. Similar relationships between carrier concentration, drying temperature, powder stability and bioactive retention have been discussed in spray-dried fruit and bioactive powder systems (Bulutoglu, 2022 a; Bulutoglu, 2022 b).

Feed solids content also influences powder quality. Higher solids may improve drying efficiency and reduce energy consumption, but excessive viscosity can reduce atomization quality and increase particle size. The oil-to-wall ratio affects both cost and retention. A higher oil load may improve flavor impact per kilogram of powder but can increase surface oil and reduce storage stability.

Emulsion stability is one of the most critical factors. If the emulsion separates before or during spray drying, oil retention will be poor. Homogenization conditions should produce small and uniform droplets without causing excessive foaming or oxidation. The use of gum Arabic, modified starch or protein-based emulsifiers can improve emulsion stability and is frequently discussed as a major factor influencing encapsulation efficiency in food flavor and oil systems (Jafari et al., 2008; Mohammed et al., 2020).

Particle morphology is another important indicator. Smooth and continuous particles are preferred because they limit oxygen diffusion and surface oil exposure. Cracked or collapsed particles may release onion oil prematurely and reduce shelf life. Scanning electron microscopy is commonly used in encapsulation studies to evaluate particle morphology.

11. Stability, Controlled Release and Sensory Performance

The main purpose of onion oil encapsulation is to improve stability without losing sensory identity. Stability can be evaluated through storage tests, volatile retention analysis, sensory evaluation, oxidation markers and moisture sorption behavior. Because onion oil is highly odor-active, sensory evaluation is particularly important. A powder may show good analytical retention but still fail if the released flavor is too weak, too pungent or unbalanced. This application-based evaluation is consistent with broader recommendations that encapsulation performance should be assessed through both physicochemical and functional behavior in food systems (Gharsallaoui et al., 2007; Fernandes et al., 2024).

Controlled release is a key advantage of encapsulation. In dry powder blends, the onion character should remain protected during storage. During food preparation or consumption, the flavor should be released through hydration, heat, shear or mastication. Different wall materials create different release profiles. Maltodextrin-based matrices may release rapidly in water. Gum Arabic and modified starch systems may provide balanced release. Cyclodextrin complexes may release flavor more gradually depending on temperature, moisture and matrix competition.

For savory foods, release timing is important. In instant soup, the flavor should develop rapidly after hot water addition. In snack seasonings, release occurs during chewing and interaction with saliva. In meat products or ready meals, onion flavor should survive processing and then become perceptible during heating or consumption. A successful encapsulated onion oil system must therefore be designed according to the intended application, not only according to encapsulation efficiency.

12. Food Application Potential

Encapsulated onion oil is highly suitable for powdered soups and bouillons. These products require dry ingredients with good flowability, long shelf life and rapid flavor release in hot water. Onion is a fundamental background note in many bouillon systems, especially chicken, beef, vegetable and tomato profiles. Encapsulated onion oil can provide consistent onion character while reducing flavor loss during storage.

Snack seasonings require powdered ingredients that can be blended with salt, spices, flavor enhancers, yeast extracts and oil-based carriers. Free onion oil may create clumping, uneven distribution and strong odor during production. Encapsulated onion oil can improve handling and enable more controlled delivery on chips, crackers, nuts and extruded snacks.

Onion flavor is central to many sauces, gravies and culinary bases. Encapsulation can help onion oil withstand thermal processing, freezing and reheating. Cyclodextrin-based systems may be particularly useful in products exposed to microwave heating or steam-table holding, where volatile retention is difficult.

Onion notes are commonly used in meat seasonings, cooked meat flavors and plant-based meat analogues. Encapsulated onion oil can contribute to authentic cooked culinary character while improving distribution in dry premixes. It may also help reduce flavor loss during cooking.

In ready-to-eat and ready-to-cook products, encapsulated onion oil can support consistent flavor release after heating. It may be used in dry sauce bases, noodle seasonings, rice meals, frozen meals and dehydrated culinary mixes. Essential oil and oleoresin microcapsules have been described as suitable for a broad range of food applications, including sauces, meat products, bakery products and other processed systems (Fernandes et al., 2024).

13. Industrial Relevance for Flavor Houses

For flavor houses, encapsulated onion oil is not merely a raw material but a technology platform. It can be used to create differentiated savory systems with better stability, cleaner handling and improved process performance. The development of such powders requires collaboration between flavor creation, application, process engineering and quality control.

The industrial value of encapsulated onion oil can be summarized in five areas: stability, handling, application flexibility, controlled release and standardization. A flavor house with spray drying and encapsulation capability can use onion oil as a model system for other savory volatile materials such as garlic oil, leek oil, roasted onion top notes, meat reaction flavors and spice oleoresins. The same technological principles may also be applied to natural flavor systems, clean-label culinary bases and high-impact top notes.

14. Future Perspectives

Future research on encapsulated onion oil should focus on the relationship between encapsulation efficiency, volatile profile and sensory release. Many encapsulation studies report high oil retention but do not sufficiently evaluate whether the final flavor profile remains authentic. For onion oil, this is especially important because the balance between fresh, cooked, sulfurous and roasted notes can change during processing.

More work is also needed on storage stability under realistic industrial conditions. Temperature, humidity, oxygen exposure and packaging type can strongly affect powder performance. Accelerated shelf-life studies should be supported by sensory panels and instrumental volatile analysis.

Another promising research area is the use of combined wall systems. Gum Arabic and beta-cyclodextrin may provide strong performance, but cost and supply should be considered. Maltodextrin-modified starch-protein systems may offer more economical alternatives. Plant protein systems may become more important as the market grows for vegan and allergen-conscious savory products.

Finally, clean-label expectations should be considered carefully. Encapsulation often requires carriers and processing aids, while some customers prefer shorter ingredient lists. Future development must balance technological performance with label expectations, regulatory compliance and customer requirements.

15. Conclusion

Onion oil is a high-impact savory flavor material with strong relevance for soups, bouillons, seasonings, sauces, meat products, snacks and ready-to-eat foods. Its sensory value is mainly associated with volatile sulfur-containing compounds that provide characteristic onion aroma at low dosage levels. However, these same compounds also create technological limitations, including volatility, oxidation sensitivity, odor intensity, poor handling properties and flavor losses during processing and storage.

Encapsulation provides a practical solution by transforming onion oil into a more stable, manageable and application-compatible ingredient. Food-grade wall materials such as maltodextrin, gum Arabic, modified starches, proteins and beta-cyclodextrin can contribute to oil retention, surface oil reduction, odor masking, powder stability and controlled release. Spray drying remains the most industrially relevant encapsulation approach because it is scalable, continuous and compatible with dry flavor and seasoning systems. Nevertheless, successful onion oil encapsulation depends not only on the drying process itself, but also on oil quality, wall material functionality, emulsion stability, oil-to-wall ratio, feed solids, atomization behavior and post-drying handling.

For industrial flavor development, encapsulated onion oil should be evaluated beyond encapsulation efficiency alone. A successful product must demonstrate acceptable powder properties, storage stability and authentic sensory release in the intended food matrix. Future studies should therefore combine volatile analysis, surface oil measurement, water activity, particle morphology, accelerated shelf-life testing and application-based sensory evaluation. From this perspective, encapsulated onion oil can be considered a promising bridge between flavor chemistry and food process technology, offering a pathway to more stable, controllable and industrially useful savory flavor systems.

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Conflict of Interest

The author is affiliated with DKT Flavor and Taste, a company operating in the flavor and food ingredients sector. This affiliation is disclosed for transparency. The author declares no additional conflict of interest related to the preparation of this review.

Data Availability Statement

This article was prepared on the basis of previously published literature and author interpretation, and it was additionally informed by preliminary laboratory trials carried out at DKT Flavor laboratories. These internal trials supported the technical evaluation of onion oil encapsulation systems; however, as the manuscript is structured as a review article rather than a full experimental study, no standalone experimental dataset is presented.

Author Contributions

Efe Bulutoglu conceptualized the topic, evaluated the literature, interpreted the industrial relevance of onion oil encapsulation and prepared the manuscript.

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