A Systematic Review of The Characteristics of Herbal Formulations Using Various Ratios of Natural Coating Materials and Their Benefits For Meat

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Abstract.
Herbal plants contain various secondary metabolites that serve both as plant defense mechanisms and as therapeutic agents for the human body. Additionally, compounds such as alkaloids (e.g., caffeine or curcumin) exhibit stimulating or analgesic effects, while many of these components are utilized as astringents to treat wounds and digestive issues. Therefore, we conducted a systematic literature review of published studies regarding various herbal plants and coating material ratios applied to meat, examining aspects such as composition, application methods, and outcomes. Data extraction from the Scopus database yielded over 500 titles related to various herbal plants and natural encapsulants. A screening process subsequently identified 20 relevant journals for in-depth analysis in this systematic review. The mapping and analysis of these articles indicate that the use of coating materials—applied at varying concentrations to herbal plant extracts—can provide optimal protection for antibacterial and antioxidant components.
Keywords: *Coating; herbal plants; meat and systematic review.*

I. INTRODUCTION

Selecting the coating material is a crucial step in the microencapsulation process; the materials used are generally hydrophilic and/or hydrophobic, capable of forming films or network-like structures. Common coating materials used in the microencapsulation of omega-3 fatty acids include proteins, polysaccharides, lipids, gums, and cellulose [1]. Polysaccharides such as maltodextrin are cost-effective and capable of forming films, though they possess low emulsifying capacity, whereas dextrin has low viscosity, allowing for the formation of thin coatings [2]. On the other hand, gum arabic is highly soluble and widely used to encapsulate oils and spices. Combining polysaccharides with gum arabic is expected to yield high-quality microcapsule walls. Furthermore, research [3] indicates that coating aromatic herbs with gum arabic can enhance the quality of beef.

To better understand the combinations and ratios of coating materials, this systematic literature review aims to identify and describe the benefits of natural coating materials—considering their types, raw materials, and application methods on animal-based food products—based on publications indexed in Scopus. The study examines the utilization of coating materials via diverse application methods and the suitability of combining them based on the characteristics of natural ingredients [4]. Furthermore, this paper seeks to highlight research gaps regarding the variations in coating materials used and their benefits in enhancing the quality and shelf life of livestock products. While the effects of coating materials in the food sector have been studied, to the best of our knowledge, an analysis or review of this specific nature has not previously been conducted. The paper is structured as follows: Stage 1 outlines the background and motivation for this research regarding the use of various encapsulants, viewed through the lens of literature found in the Scopus database. Data extraction from Scopus is detailed in Stage 2. The extracted data are then analyzed, and the results are discussed in Stage 3. Based on the findings, recommendations for future research are presented in Stage 4, and the conclusions are provided in Stage 5.

II. METHODS

The systematic literature review in this study was conducted by accessing the Scopus database (https://scopus.com (accessed on July 17, 2026). Scopus serves as a high-quality data source for academic research in the field of quantitative analysis [4]. A search of the database using the keyword "HERBS" yielded over 500 titles. An initial screening using the keywords "MICROENCAPSULATION," "COATING MATERIAL," and "MEAT" reduced the number of results to 116 titles. A second screening involved excluding categories irrelevant to this study—specifically pharmaceuticals, fabrics, textiles, and cosmetics—reducing the count to 72 titles. Subsequently, a further screening stage eliminated 28 titles that did not meet the criteria for relevance to the topic under evaluation. Further abstract selection narrowed the list down to 20 key articles to be discussed in detail in this report. The PRISMA diagram illustrating the article selection process is shown in Figure 1.

III. RESULT AND DISCUSSION

Based on 20 key articles regarding the characteristics of herbal microcapsules at various coating material ratios and their benefits in meat, several classification categories were identified based on: (1) the herbal plants and their contained bioactive compounds; (2) the composition of the coating materials used; (3) the percentage of encapsulating material added to the herbal extract; and (4) the results obtained after applying the herbal microencapsulation to food products. The herbal plants included in this systematic review were turmeric, thyme (*Thymus pulegioides*), rosemary (*Rosmarinus officinalis*), garlic (*Allium sativum* L.), cinnamon (*Cinnamomum verum*), and other medicinal herbs. The majority of the reviewed herbs originate from plants native to tropical regions, such as Southeast Asia. Furthermore, the coating materials employed included maltodextrin, gum arabic, sodium alginate, carrageenan, whey protein concentrate (WPC), carboxymethyl cellulose (CMC), skim milk, and chitosan. Polysaccharides such as cyclodextrin and starch are cost-effective and capable of forming films, though they possess low emulsifying capacity; meanwhile, dextrin exhibits low viscosity, resulting in the formation of thin films [5], [6]. On the other hand, chitosan is highly soluble and has been widely utilized for the encapsulation of essential oils derived from herbal plants [7]. Polysaccharides used for encapsulating herbal materials can yield optimal microcapsule walls [8], [9].

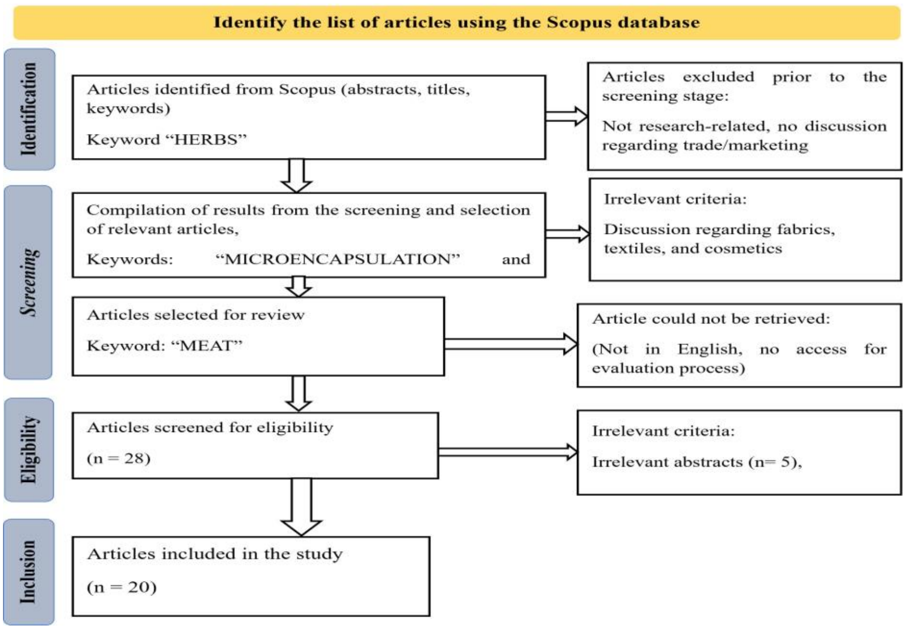

Fig. 1. PRISMA diagram for article screening.

Furthermore, cyclodextrin and whey protein concentrate (WPC) are carbohydrate and protein polymers suitable for use as a combined coating material for microencapsulation via freeze-drying. Cyclodextrin is characterized by high solubility, low viscosity, and the ability to form colorless solutions. However, cyclodextrin has poor emulsifying properties, necessitating its combination with whey protein concentrate to produce a stable emulsion. Whey protein is extracted from cheese-making by-products; it contains globular proteins—such as β-lactoglobulin—that act as emulsifiers and serve as protective agents for bioactive compounds. Research [10] reported that a WPC and cyclodextrin coating in a 60:40 ratio yielded microcapsules of rosemary and oregano essential oil phenolic extracts with the highest encapsulation efficiency. Meanwhile, study [11] reported that the use of cyclodextrin at a concentration of 0.1% was highly effective as a coating material for garlic (*Allium sativum* L.). Research [12] also indicated that the best microcapsules for mandarin (Citrus reticulata) and ajowan (*Carum copticum*) were obtained using a mixture of chitosan, pectin, and whey protein as encapsulating agents.

Based on the data in Table 1, the encapsulation of herbal plants has also been reported to exhibit antibacterial and antipyretic activities in numerous recent studies. Bioactive compounds such as saponins, flavonoids, and terpenoids demonstrate inhibitory effects on the growth of common pathogenic bacteria. This antibacterial efficacy reinforces the role of these plants in treating wounds and minor infections, aligning with their traditional use in rural communities. Study [13] further supports the finding that turmeric extract can alleviate fever through mechanisms likely involving the modulation of immune responses. This highlights a strong correlation between ethnobotany and modern pharmacological evidence. Regarding antidiabetic activity, scientific research demonstrates the significant role of plant bioactive compounds in modulating glucose metabolism. Flavonoids and phenolics are classes of compounds proven to inhibit enzymes associated with carbohydrate digestion, such as α-glucosidase and α-amylase. Other observed mechanisms include enhanced insulin sensitivity and the protection of pancreatic beta cells against oxidative damage. These findings support the use of plants like turmeric and guava as complementary therapies for diabetes mellitus. Study [14] indicates that flavonoids possess a high affinity for molecular targets associated with diabetes. The immunomodulatory activity of traditional medicinal plants is increasingly garnering attention due to its role in enhancing or balancing the immune system.

Table 1. Selected key articles reporting various types of herbal material encapsulation and their benefits in improving meat quality, as indexed in the Scopus database.

No.	Reference	Type of herbal plant + coating materials	Type of meat	Result
1	Okpala et al. 2023	Garlic (*Allium sativum* L.), ginger (*Zingiber officinale*), pineapple (*Ananas comosus*), and rosemary (*Rosmarinus officinalis* L.), maltodextrin	Beef and lamb	The marination process can support the heating process, or vice versa; conversely, in other cases, the thermal process can actually have a detrimental effect on marination.
2	Asres et al 2022	*Thymus schimperi* essential oil, and gum Arabic	Minced beef	Spray drying encapsulated Thymus schimperi demonstrated greater efficacy against *Escherichia coli* and *Salmonella typhimurium* (MIC: 4 mg/mL)
3	Visan et al., 2021	Ginger (*Zingiber officinale*)	Black angus beef meat	Sensory analysis showed that meat samples marinated in olive oil and rosemary for 120 hours achieved the highest hedonic scores among the samples tested.
4	Marc et al., 2022	Rosemary (*Rosmarinus officinalis* L.), Sage (*Salvia officinalis* L.), essential oils	Beef burger, turkey sausages	Improved bacterial stability during cold storage at 4°C for 12 days
5	Turp and Capan, 2019	Ginger (*Zingiber officinale*), Garlic (*Allium sativum*), essential oils	Beef, chicken filets, chicken	Various forms of herbs and spices—such as essential oils, organic acids, as well as powders and extracts—are used in the meat marination process, and

			skin, chicken breast and wing	their levels of effectiveness are known to vary.
6	Sheerzad et al., 2022	Cinnamon (*Cinnamomum verum*), whey protein isolate	Chicken breast fillets	Encapsulated herbs extended the shelf life of chicken breast fillets by more than 5 days compared to the uncoated group (control).
7	de Lima et al., 2024	Rosemary (*Rosmarinus officinalis* L.), chitosan	Beef *(Longissimus dorsi)*	Coatings containing 4% or 8% rosemary extract effectively inhibited the growth of mesophilic and psychrotrophic bacteria and *Staphylococcus spp.* on beef.
8	Jaworska et al., 2021	Oregano (*Origanum vulgare*), thyme (*Thymus vulgaris*) and black pepper (*Piper nigrum*)	Poultry breast meat	The shelf life, quality, and microbiological safety of meat products stored at a low temperature of 4°C can be enhanced by the addition of oregano and black pepper in dried or extract form.
9	Tkaczewska et al., 2022	Thyme (*Thymus pulegioides*), rosemary (*Rosmarinus officinalis*), furcellaran, and gelatin	Carp Fillets	Rosemary-enriched coatings proved effective in inhibiting biogenic amine formation and slowing microbial spoilage in carp fillets (reductions of 0.53 and 0.29 log CFU/g).
10	Vital et al., 2016	Rosemary (*Rosmarinus officinalis*) and oregano (*Origanum vulgare*) essential oils	Beef meat	The coating containing oregano was the most effective (resulting in a 46.81% reduction in lipid oxidation) and also exhibited the highest antioxidant activity.
11	Dokou et al., 2023	Garlic (*Allium sativum* L.), sea fennel (*Crithmum maritimum*), oregano (*Origanum vulgare*), and cyclodextrin	Chicken breast fillets	The herbal extract in cyclodextrin delayed meat lipid oxidation.
12	Ojeda-Piedra et al., 2022	Mandarin (*Citrus reticulata*), ajowan (*Carum copticum*), chitosan, pectin, and whey protein	Beef patties, chicken meat	Nano-systems can be applied directly during meat processing
13	Febrianta et al., 2022	Turmeric (*Curcuma longa* L.), and maltodextrin	Chicken breast	Improved the WHC, tenderness, and reduced the abdominal fat of chicken meat
14	Hashemi et al., 2023	*Thymus vulgaris* and *Thymbra spicata* essential oils, sodium alginate, and pectin	Beef meat, chicken meat	Reduction in microbial counts (1.73 log CFU/g)
15	Boskovic et al., 2019	Oregano (*Origanum vulgare*) essential oils, chitosan, xanthan, starch, and cellulose	Rainbow trout, beef burgers	The antimicrobial activity of thyme and oregano is attributed to their main phenolic components, thymol and carvacrol
16	Tomé et al., 2022	Oregano (*Origanum vulgare*), rosemary (*Rosmarinus officinalis*), and sodium alginate	Fish meat, pork sausage	Improved the stability of fish and pork meat products by preventing oxidative rancidity
17	Elgadir et al.,	Rosemary (*Rosmarinus*	Chicken breast,	Strong antioxidant, reduced (TBARS), improves

	2025	*officinalis*) essential oils, oregano (*Origanum vulgare*), thyme (*Thymus vulgaris*) and clove (*Syzygium aromaticum*)	ground beef, minced pork	color stability, pH, and drip loss
18	Abandansarie et al., 2019	Rosemary (*Rosmarinus officinalis*) extract, soybean protein isolate	Beef meat	Nanoencapsulation of rosemary extract at a concentration of 1,600 ppm extended the shelf life of the fillets up to day 21.
19	Domínguez et al., 2021	*Laurus nobilis* leaf extract, *Umbelliferae*, *Zingiberaceae*, zein, gliadin, soy protein, and carrageenan	Minced beef, cooked ham	Herbal microcapsules exhibit an inhibitory effect on the growth of microorganisms.
20	Hussain et al., 2025	Thyme (*Thymus vulgaris*), oregano (*Origanum vulgare*), and chitosan	Raw hind leg of lamb	Oregano essential oil nanoparticles demonstrated lower values for microbiological parameters

Certain compounds—such as flavonoids, polyphenols, and vitamins C and E—are known to modulate immune activity by enhancing lymphocyte proliferation, cytokine production, or phagocytic capacity. Literature reviews on herbal plants report that these compounds can extend the shelf life of meat by protecting against oxidative and microbiological deterioration [15]. The nutritional components of these herbal plants are highly relevant given the growing need to preserve meat quality and shelf life, particularly in humid environments that facilitate contamination by pathogenic microorganisms. A study [16] indicates that herbal plants can significantly improve the fatty acid profile of beef.

Articles regarding the application of chitosan indicate that it is an effective coating material for herbal plants. Chitosan helps preserve bioactive compounds—such as the essential oils and antioxidants abundant in these plants—by sealing in volatile compounds, thereby preventing the loss of medicinal properties and characteristic aromas during storage. Furthermore, chitosan helps maintain color and aesthetic appeal by inhibiting the activity of polyphenol oxidase (PPO), the enzyme primarily responsible for browning in fresh herbal leaves. Environmentally friendly and safe for consumption, chitosan is biodegradable and non-toxic, making it safe to use on herbs intended for processing into traditional herbal remedies, teas, or supplements [7].

The final method for applying natural encapsulating agents involves using carrageenan as a coating material for various types of plant-based products. Utilizing carrageenan as a coating for herbal materials represents a highly effective biopolymer-based innovation for maintaining the stability of active substances and extending product shelf life. As a natural polysaccharide extracted from red algae (Rhodophyceae), carrageenan possesses exceptional gelling and film-forming capabilities, creating coatings that are both flexible and robust. Its effectiveness stems from a molecular structure rich in sulfate groups, which facilitates the formation of a dense polymer network that protects thermolabile compounds and sensitive antioxidants within the herbal material from degradation caused by exposure to oxygen, atmospheric moisture, and ultraviolet light. Carrageenan's hydrophilic nature also facilitates the controlled release of active substances upon consumption or application, as the coating dissolves readily in bodily fluids or water without leaving toxic residues [18]. Beyond its protective function, carrageenan's effectiveness can be further optimized by selecting the appropriate type of carrageenan or by combining it with natural plasticizers, such as glycerol, to enhance coating elasticity. Carrageenan-based coatings are biodegradable, biocompatible, and hold GRAS (Generally Recognized as Safe) status, making them a superior alternative to less environmentally friendly synthetic coating materials [19]. In the herbal plants, this coating technology not only preserves organoleptic qualities—such as the plant's original color, aroma, and taste—but also enhances the aesthetic appeal and commercial value of herbal products, whether in the form of tablets, capsules, or dried herbal materials [20].

This systematic review has certain limitations regarding the inclusion of articles. We could only interpret the obtained data qualitatively to ensure research validity, as we did not perform a quantitative analysis. Instead, we synthesized findings from previous studies to determine the potential of coating materials to protect bioactive components in various herbal plants, thereby enhancing meat quality.

IV. CONCLUSION

The use of various coating materials to preserve the bioactive content of herbal plants has a positive and beneficial impact on improving meat quality, limiting pathogenic bacterial populations in the meat, and extending shelf life. These coating materials are applied at varying concentrations to herbal plant extracts, utilizing diverse drying techniques to homogenize the extracts and ensure optimal protection of their antibacterial and antioxidant components.

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