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BIOLOGICAL POTENTIAL, HEALTH CAPACITY, AND FUNCTIONAL ACTIVITY OF EMULSION SYSTEMS OBTAINED BY INCORPORATING PLANT EXTRACTS

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Abstract

The production of safe food with high quality is one of the most important topics nowadays. The researchers have been looking for innovative approaches to the preparation of a new generation of emulsified products that can serve as a matrix carrier for the incorporation of valuable components with high functional potential. New products may have the capacity to prevent cardiovascular and central nervous system diseases, oncological diseases, and atherosclerosis. Finding and identifying new properties and applications of medicinal plants containing biologically active ingredients is of great importance in the future. Medicinal plants and their secondary metabolites are subject of interest in the pharmaceutical and food industries. In the article, the three valuable species of herbs: hawthorn fruit (*Crataegus monogyna*), thistle (*Onopordum acanthium* L.), thyme (*Thymus callieri*) and their potential for incorporation in food emulsions are reviewed.

One hundred seventy-three literary sources were studied - studies of various scientific groups around the world. The research covers a significant range of results concerning plants as a source of biologically active substances, and the integration of plant extracts into food products. The antioxidant potential and chemical composition of plants as a bio-component for food matrices have been studied. A thorough characterization of the chemical composition, pharmacological activities, and biological potential of three plants distributed in the Republic of Bulgaria - hawthorn fruit (*Crataegus monogyna*), thistle (*Onopordum acanthium* L.), and thyme (*Thymus callieri*) was made. Their application in the food industry was studied. The potential possibilities for the preparation of food emulsion systems with the addition of plant sources have been examined. A broad overview of the innovative modern approaches for obtaining a new generation of emulsion products was made.

The present review evaluates the possibilities of enhancing the biological potential and health effects of edible emulsion dispersion systems by incorporating plant extracts of medicinal plants into them.

***Key words**: Biological potential, Secondary metabolites, Emulsions.*

1. Introduction

A great challenge for food producers nowadays is to provide healthy and nutritious food for all. Food products should be processed in an environmentally sustainable and safe way, in the presence of global problems such as malnutrition due to deficiency of protein, vitamins, and micro- and macronutrients in available food and at the same time an increase in the number of obese people in developed countries. In this context, the consumer interest in natural sources has grown and thus the demand for plant-based food products has increased.

The link between diet and physiology demonstrates the ability of food to maintain good health status and to improve the overall human condition. Scientists are looking for novel products with positive physiological potential. Nowadays, one of the fastest-developing research areas in food science and technology is the extraction and characterization of new natural ingredients with high biological potential that can be incorporated into functional foods [1]. The market for functional foods and beverages has significantly grown because of the demand for a higher-quality lifestyle. Functional foods are considered to have a positive impact on health status, which promotes well-being and results in longevity. Functionality is achieved by enriching the nutritional value of food, by incorporating biologically active substances at certain concentrations [2].

Many scientific groups are working on solutions to the problem of providing safe and qualitative food for the general population. Innovative approaches are sought to obtain a new generation of emulsified products to serve as a matrix carrier for the incorporation of valuable components with high functional potential into emulsion systems. Vegetable oils rich in polyunsaturated fatty acids are included in the composition of emulsion dispersion systems [3]. They could be further enriched by adding oil extracts containing various biologically active substances: glycosides, organic and phenolic acids, polyphenols, polysaccharides, terpenoids, flavonoids, alkaloids, etc. [4].

The main objective of the present review is to evaluate the possibilities of enhancing the biological potential and health effects of edible emulsion dispersion systems by incorporating plant extracts of medicinal aromatic plants into them. The review discusses the biological, pharmacological, and health activities of three plant species - hawthorn (*Crataegus monogyna*), donkey thistle (*Onopordum acanthium* L.), and thyme (*Thymus callieri*). Their potential for incorporation into food emulsions as a valuable raw material for the production of functional emulsified products was pointed out.

2. Plants as a source of biologically active substances

2.1 Plants

Since ancient times plants have been used for food purposes. After discovering their healing properties some plants are used as natural remedies. With the development of medical science, many plants play an important role in disease treatment and life health care [5]. Aromatic plants are a rich source of biologically active substances and essential oils [6]. They are also applied in the production of nutraceuticals - substances with specific beneficial effects on human health - carnitine, glucosamine, octacosanol, proanthocyanidins, lycopene, lutein, linolenic acid, melatonin, etc. In recent years, aromatic plants and their extracts have been tested by several scientific working groups, checking and assessing their degree of safety in terms of nutritional application [6].

The World Health Organization (WHO) predicts that 80% of the world's population relies on traditional medicine and uses plant extracts and their bioactive compounds. The compounds isolated from biological systems are divided into two distinct groups: primary metabolites - substances such as carbohydrates, amino acids, peptides, proteins, and lipids, which are essential for the maintenance, growth, and development of cells, and secondary metabolites - substances with low molecular weight such as phenolic acids, alkaloids or terpenes [7]. Certain plants possess the ability to produce secondary metabolites which are used in the pharmaceutical and food industries and traditional medicine. Several studies have shown that the production of plant secondary metabolites strongly depends on the local climate, the soil, and the growing conditions of the crops [8]. Studies related to the health-promoting properties of secondary metabolites on children's growth and their preventive effects against several diseases in adult organisms have been conducted [9]. Most of these properties are due to the presence of essential oils, which contain secondary metabolites that positively affect the beneficial production of digestive enzymes and can increase immunity status [9, 10]. Plant biologically active substances can be extracted from the different structural parts of the plant - roots, stems, bark, leaves, flowers, fruits, and seeds and consequently the extracts are to be identified.

2.2 Plant extracts

The methods for obtaining extracts from plant raw materials are mainly steam distillation, hydro-distillation, pressing, and extraction [11]. Liquid extracts are obtained by processing aromatic and medicinal plants with polar and non-polar volatile and non-volatile extracts. In the case of extraction, the choice of technological parameters depends on the type of raw material and the concentration of the biologically active substances in it. The choice of a specific extract (the type of decoction or infusion) must be carried out through a complex assessment of the organoleptic profile, physicochemical indicators, biological value of the extracts, and their compatibility with the other components of the foods or beverages in which they are added. Plant extracts can also be added to functional foods - foods that, in addition to being subject to daily nutrition, have a beneficial effect on one or more physiological functions [12]. The extraction process is expected to produce an extract with a certain concentration of one or more active ingredients (glycosides, acids, polyphenols, polysaccharides, terpenoids, flavonoids, alkaloids, etc.) without changing their structure. The extract is ready for use in the pharmaceutical, cosmetic, and food industries in liquid or dry state [13]. Although modern science has discovered many plants and plant extracts that affect the treatment of diseases, finding and identifying new plants containing functional ingredients will have a special role for humans in the future. Medicinal and aromatic plants can be applied to improve the flavor of food products, as well as they serve as organic preservatives [10]. The accumulated knowledge about medicinal and aromatic plants from antiquity to the present day has passed from generation to generation, improving people's health [10]. Plants are the main source of natural aromatic molecules. Scientific works present undeniable evidence that nutrition affects the health status of a person. This is mainly due to the biologically active substances abundant in plants [14]. Regular consumption of plant foods, including herbs, is associated with reduced oxidative stress and a lower risk of degenerative diseases [15]. The beneficial effect of herbs is due to the antioxidant capacity of their secondary metabolites such as polyphenols. Food science is focused on the development of innovative strategies to enrich and diversify food intake. The consumption of foods and beverages rich in biologically active substances derived from herbal extracts that have unique functional characteristics should be encouraged. In recent years, the interest in foods that provide health-promoting biologically active substances has increased.

2.3 Antioxidant potential of plants

Antioxidants of plant origin consumed in food can decrease the harmful effects of oxidative stress on human health [16]. The natural origin of plant extracts aligns with the desire of consumers for more natural food, providing them with beneficial health effects. This desire encourages emerging scientific interest in natural antioxidants from plants that can protect live cells from harmful degenerative changes.

Plants contain compounds that possess antioxidant. These compounds can be extracted in the aqueous, oily, or alcoholic phase. They can be prepared in the form of infusion or decoction [17]. The prepared extracts can be used as additives to meals. New foods and beverages can be created by applying novel processing technologies and optimizing conventional ones, supplying a high content of biologically active components and increasing their bioavailability. There are options for a new approach to the usage of familiar raw materials by creating new applications or new organoleptic profiles. Ni *et al.*, [18], investigated the use of natural antioxidants in food production. Over the past decade, they have achieved great popularity, due to their relatively high medical value and nutritional properties. Antioxidants with plant origin are valuable biologically active compounds with good potential for use in the food industry where they are used as natural preservatives that can extend the shelf-life of foods. Natural compounds such as essential oils (EO) are plant-based food ingredients of interest to food researchers engaged in the study and characterization of new compounds and their functionalities.

Vinceković *et al.*, [19], carry out extraction based on plant raw material, isolating biologically active compounds and essential oils (EO). Essential oils are natural volatile liquids consisting of secondary metabolites of aromatic plants. They are usually extracted by hydro-distillation and steam distillation, solvent extraction, or supercritical fluid extraction [20]. A series of aromatic components, including alkaloids, flavonoids, phenolic acids, monoterpenes, isoflavones, aldehydes, oxygen-containing, and non-oxidized terpene hydrocarbons are components of essential oils and extracts [21]. Essential oils can be extracted from a variety of plants and aromatic spices, which differ in flavor depending on the type and number of components present in the oil [22]. Thanks to their unique flavor and naturally occurring antimicrobic bioactive components, essential oils and extracts of herbs are included in foods to extend their shelf-life and ensure their safety.

In 2020 Satyal and Setzer [23], reported food preservation based on essential oils derived from anise (*Pimpinella anisum*), cloves (*Syzygium aromaticum*), mint (*Mentha piperita*), oregano (*Origanum vulgare*), cinnamon (*Cinnamomum zeylanicum*), lemongrass (*Cymbopogoncit ratus*), rosemary (*Salvia rosmarinus*), thyme (*Thymus vulgaris*), ginger (*Zingiber officinale Roscoe*) and other plants. Previous studies by Ribeiro-Santos *et al.*, [24], indicate that the antioxidant activity of EO is different in extracts from different plant species and depends on the extraction methods and solvents used. The strong antioxidant capacity of EO and extracts is due to their phenolic compounds and some other secondary metabolites which are structurally similar to the known plant phenols with antioxidant potential. The researchers found antioxidant oxygen monoterpenoids such as aldehydes, ketones, and esters from plants, EO; monoterpenes and phenolic compounds, such as thymol or carvacrol, which are the main compounds with the strongest antioxidant activity. Timol and carvacrol are the main components of EO extracted from medicinal plants that possess the ability to scavenge free radicals [25]. On the other hand, some alcohols, ethers, ketones, and aldehydes are also responsible for the antioxidant properties of EO.

The selection of a suitable plant functional component is important to obtain a quality end product. Nowadays, a large assortment of functional components from various plant sources containing biologically active substances, which are a constituent of healthy foods, is available. To obtain maximally enriched with biologically active substance extracts, it is necessary to study and select suitable plant species and conditions for conducting the extraction process. Three Bulgarian plants were selected: *Crataegus monogyna* (fruit), *Onopordum acanthium L* (flowers), and *Thymus callieri* Borbás ex Velen (flowers with stems) [26].

2.4 Hawthorn (*Crataegus monogyna*)

2.4.1 Description and distribution

Hawthorn (*Crataegus* Linnaeus, 1753) belongs to the Angiosperm, Dicotyledonous class, order Rosales, family *Rosaceae*, genus *Crataegus* (hawthorn). Common hawthorn (*Crataegus monogyna*) is a prickly shrub or small tree, its height is between 4 to 8 m. The crust is smooth with a brown-grayish or dark-gray color. Hawthorn wood is very hard and strong. Some of its shortened branches are converted into spines. It is distributed along roads, on margins, in shrubs, and oak forests. Hawthorn grows on sandy and clay soils in the sun or semi-shadow [27]. Around 1,000 species of hawthorn exist in nature. It is found in Eastern Europe, West Asia, North Africa, and North America. It grows in temperate and continental climates of the northern hemisphere [28].

2.4.2 Chemical composition

The fruits of hawthorn are rich in sugars, pectin, organic acids, minerals, vitamins C and A, and enzymes. Fructose is the predominant sugar in the fruit. There is also glucose and a little sucrose. Malic acid predominates in concentration, followed by succinic acid and tartaric acid. Common hawthorn (*C. monogyna*) contains chlorogenic acid. Hawthorn fruits are rich in minerals - sodium, potassium, calcium, phosphorus, and aluminum. Stoyanova, [29], found high concentrations of chlorogenic, caffeic acid, ellagic acids, and quercetin. The antioxidant activity of the fruit was determined by two methods, the values being: ORAC 280.7 μmol TE/g (Trolox equivalents) and HORAC 107.5 μmol gallic acid equivalents (GAE/g), which the authors explain by the presence of phenolic acids and flavonols It has been pointed out that hawthorn fruits are rich in vitamin C, sugars, organic acids and pigments and also containing anthocyanins, flavonoids and phenols [29].

2.4.3 Pharmacological activities and biological potential

According to Tadic *et al.*, [30], extracts of dried hawthorn (*Crataegus monogyna* - Jacq., *Crataegus oxyacantha* L., and *Crataegus laevigata*), can be used as an anti-inflammatory, gastroprotective, and antimicrobial agent. Barros *et al.*, [31], studied the antimicrobial activity of hawthorn extract, which has shown moderate bactericidal activity, especially against Gram-positive bacteria such as *Micrococcus flavus, Bacillus subtilis,* and *Listeria monocytogenes*, with no effect against *Candida albicans*. Belkhir *et al.*, [32], studied both the chemical composition and antimicrobial activity of hawthorn extracts of the species *Crataegus monogyna* prepared from leaves and fruits. These extracts have shown high *in vitro* antioxidant and antiradical activity and weak antibacterial activity, especially against Gram-positive bacteria such as *Staphylococcus aureus* and *Streptococcus faecalis*. Hawthorn is presented by scientific teams as a means of treating the cardiovascular system [33]. Heathorn is used for the treatment of chronic heart disease, it ameliorates the risk of arrhythmia and it improves heart and brain blood circulation. It is used in the treatment of hypertonia, blood imbalances, anxiety, insomnia and chronic fatigue, atherosclerosis, hepatic cirrhosis, increased thyroid function, and enlarged prostate gland as well as to regulate cholesterol levels [34]. It calms down the central nervous system and is characterized by a preventive effect against cancers. The hawthorn is also used to treat malaria and other fevers. The hawthorn is considered to stimulate the arteries [35]. These effects are due to the available flavonoids, especially flavonols and flavones, which are abundant in hawthorn flower buds, while proanthocyanidins are found in greater abundance in fruits [36]. Hawthorn and its preparations are used for long-term treatment. It is good to be taken for weeks or more because the effect is slow. It can be combined with other drugs, the herb itself has no side effects and does not enhance the side effects of drugs. This is important for people with an initial form of heart failure and accompanying diseases requiring a variety of drug treatments. Another advantage of hawthorn is that the habituation effect does not develop with long-term use, i.e. it is not necessary to continuously increase the doses to achieve the initial effect of the herb. The roots (decoction), the leaves (infusion), the flowers (infusion), and the fruits (infusion) are used.

2.4.4 Application in the food industry

It was established that hawthorn is both a medicinal plant that is used in folk medicine and an edible plant that is widely used for the preparation of various food products [37]. In addition to being a phytotherapeutic agent, hawthorn is also used in the food industry. The hawthorn fruit juice has a light red color, pleasant taste, and flavor. The fruits can be used to make jellies, marmalades, juices, syrup, and herbal tea, also after fermentation, they can be used for making vinegar and wine with a slightly astringent taste [36]. The good gelling properties of pectin, contained in hawthorn, and the high sugar content allow it to be widely used for garnishing desserts, the jelly is used to decorate cakes. Hawthorn flour obtained from dried fruit sand is used for making bread and sweets.

2.5 Donkey thistle (*Onopordum acanthium* L.)

2.5.1 Description and distribution

Donkey thistle (*Onopordum acanthium* L.) is a biennial herbaceous spiny plant from the *Asteraceae* family. The *Asteraceae* family is one of the largest families of flowering plants with over 1,600 genera and 2,500 species worldwide. The plant is widespread in Europe, Asia, America, and Australia, including in Bulgaria, mainly in dry and stony places. *Onopordum acanthium* L. has a spindle-shaped and fleshy root, the stem is gray fibrous and erect with a height of about 100 - 200 cm, it is strongly branched with broad longitudinal spines up to 5 mm long. Its leaves are oblong. They are roughly and unevenly cut and prickly. The baskets of the plant are hemispherical, single, or 2 - 5 in bundles on the tips of the branches. The flowers are bisexual, with a tubular shape and a red-violet (rarely white) color. The fruit seed is ovoid, four-sided, it is transversely wrinkled, white-black spotted, with a kite of numerous hairs at the base, which are fused into a ring. The flowering time of the donkey thistle is from June to September. The aerial part with the baskets and the leaves without the lower stem part of the plant, harvested during flowering (June - September), is used. The shelf-life of the dried herb is 3 years [37].

2.5.2 Chemical composition

According to Landjev [37], *Onopordum acanthium* L contains flavone glycosides (quercitin, isorhamnetin, and apigenin), sesquiterpenes, alkaloids, saponins, vitamin C, pigments, inulin, tannins, and flavones. Zhelev *et al.*, [38], measured the total lipid content in the herbs *Onopordum acanthium* L. and *Silybum marianum* L., growing and identified in Northeastern Bulgaria. They found the content of the main fatty acids oleic, linolenic, and palmitic in the highest amount, as well as the correlation between unsaturated and saturated fatty acids. This ratio in the herb *Onopordum acanthium* L. is 88.5 : 11.5 and in the herb *Silybum marianum* L. (milk thistle) it is 80.3:19.7. They also determined the amount of sterols, tocopherols and phospholipids in oil extracts of milk thistle and donkey thistle. Despite their great diversity, most representatives of the family have a similar chemical composition: milk thistle leaves contain tannins, sesquiterpenes, saponins, and alkaloids.

2.5.3 Pharmacological activities and biological potential

Asteraceae plant species have been applied in medicine for centuries. Flower baskets contain the polysaccharide inulin. *Onopordum* species demonstrate strong antioxidant, anti-inflammatory, and antimicrobial activity, and as well as diuretic properties, they also aid in wound healing. Their pharmacological effects can be attributed to a range of phytochemical compounds, including polyphenols, phenolic acids, flavonoids, acetylenes, and triterpenes. It is used in medical practice as an anti-inflammatory, anti-tumor, and cardiotonic agent [38]. Khalilov *et al.*, [39], studied the application of the considered species in medical practice as a bactericidal and cardiotonic agent. Its therapeutic effect is due to the content of a large amount of active components, one of which is silymarin. It contributes to the proper functioning of the prostate and increases potency. Silymarin is believed to have ten times the antioxidant power of vitamin E, which is needed for structural and functional maintenance of skeletal, cardiac, and smooth muscles. *Onopordum* supports the formation of red blood cells and helps maintain stores of vitamins A and K, iron, and selenium. The effect on the heart and circulatory system is due to the flavonoids, due to their antioxidant properties. Flavonoids have a major impact on the cardiovascular system. Oxygen radicals can oxidize low-density lipoproteins (LDL cholesterol), which damages the endothelial wall and therefore favors atherosclerotic changes. Studies show that the intake of flavonoids protects against heart problems and diseases. Milk thistle also acts against the accumulation of cholesterol plaques. A biennial herb of *Asteraceae* shows faster action in extract form [39].

Onopordum acanthium L. is one of the most common herbs that is increasingly used in oncology research. In the past, it was used to treat liver and biliary disorders, for detoxification and purification. It is usually considered to be the most active component and therefore in medicine it is used to treat liver diseases [38]. The potential of plant products as antioxidants to protect against various diseases caused by free radicals has been investigated. In addition to free radical scavenging, antioxidants involve the inactivation of metal catalysts by reducing hydroperoxides to stable hydroxyl derivatives and synergistically interacting with other reducing compounds [40].

2.5.4 Application in the food industry

According to the study by Zhelev *et al.*, [38], the oil extracts of the herbs *Onopordum acanthium* L. and *Silybum marianum* L. are used not only in pharmaceutical products but also in food and nutritional products. The stems and buds of the plant are used in cooking as an analogous product to artichokes in European cuisine. The inflorescences contain a complex of proteolytic enzymes „onopordonsin", which can be used as a milk curd agent in the dairy industry. A scientific team from the Higher Institute of Food Technology in Argentina also analyzed an extract from the flowers of *Onopordum acanthium* L. (family *Asteraceae*) and used it as a plant coagulant in the pasteurization of beef milk to produce a semi-hard type of cheese. It has been proven by the scientific community that the quality of cheese produced with *Onopordum acanthium* L. extract is similar to that of established commercial cheese brands [41].

2.6 Thyme (*Thymus*)

2.6.1 Description and distribution

Thyme (*Thymus vulgaris* Linnaeus, 1753) is a perennial herbaceous plant or small shrub of the Angiosperms, class Dicotyledonous (Magnoliopsida), the *Lamiaceae* family, genus *Thymus*. The plant is widespread in Europe, North America, and Asia. The wild thyme (*Thymus serpyllum*) covers large areas of dry rocky soils in southern Europe [42]. Apart from cultivated thyme, in Bulgaria, wild thyme grows naturally on grassy and rocky sunny places. The shoots (flowering above-ground part of the plant) are harvested in the flowering phase - from June to August. The best healing qualities are obtained when the thyme herb is picked in the sun. The biomass should be dried in the shade or a dryer at a temperature of up to 35 ^{0}C. Dried mass storage is in closed containers or paper bags in a dry and ventilated place [43]. There are a large number of types of thyme that are difficult to distinguish. In another source, it contains about 400 species of perennial aromatic, evergreen, or semi-evergreen herbaceous plants with many subspecies, varieties, subvarieties, and forms [43]. About 16 species are distributed in Bulgaria, including *Thymus atticus* Čelak; *Thymus callieri* Borbás ex Velen; and *Thymus comptus* Friv.; Thymus herba-barona; *Thymus jankae* Čelak; *Thymus longedentatus* (Degen and Urum.) Ronniger; *Thymus perinicus*; *Thymus pseudolanuginosus*; *Thymus pulegioides* L.; *Thymus serpyllum*; *Thymus stojanovii* Degen; *Thymus striatus* Vahl.; *Thymus vandasii* Velen.; *Thymus vulgaris; Thymus x citriodorus*; and *Thymus zygioides*.

Thymus callieri Borbás ex Velen has been discovered by Aneva *et al.*, [44], in three natural habitats in Bulgaria. One habitat is at an altitude of 900 m. *Thymus callieri* Borbás ex Velen was also found in two localities near the town of Velen, Dospat with an altitude of about 1200 m.

2.6.2 Chemical composition

The chemical composition and antimicrobial properties of the essential oil of *Thymus vulgaris* cultivated in Romania are studied. The essential oil was isolated in a yield of 1.25% by steam distillation from the aerial part of the plant and subsequently analyzed by gas chromatography/mass spectrometry (GC/MS). The major components were p-cymene (8.41%), γ-terpinene (30.90%), and thymol (47.59%). Its antimicrobial activity was evaluated on 7 common food-related bacteria and fungi by using the disk diffusion method. The results demonstrate that the *Thymus vulgaris* essential oil tested possesses strong antimicrobial properties, and may in the future represent a new source of natural antiseptics with applications in the pharmaceutical and food industry [43]. Thyme contains flavonoids, terpinene, beta-carotene, and tannins - antioxidants that scavenge free radicals in the body's metabolites with antioxidant activity. It is a source of mineral salts- iron, manganese, calcium as well as dietary fiber [44]. Thyme owes its healing effect to terpenes and terpenoids in the thyme essential oil (limonene, α- and β-pinene, menthol, citral, citronellal, etc.). Thyme contains about 0.15 - 1.5% essential oil, which varies for different types and contains up to 5% tannins and resinous substances. Essential oils are volatile liquids with characteristic aromas extracted from plant materials, such as flowers, roots, bark, leaves, seeds, fruits, wood, and whole plants [45].

The secondary plant metabolites that play an important role in plant protection possess antimicrobial and antioxidant properties. Thyme essential oil contains thymol, p-cymene, carvacrol, γ-terpineol, L-borneol, L- and D-pinene, γ-terpene, caryophyllene, linalool, etc., organic acids, flavonoids, tannals, minerals, vitamin C, and pigments. The essential oil of wild thyme (*Thymus serpyllum*) is rich in thymol (25 - 40%) and carvol [46]. It also contains borneol, linalool, p-cymene, isomeric hydrocarbon terpenes, organic pigments, minerals, tannins, natural ursolic acid, monounsaturated oleic acid, and others. The thyme essential oil (*Thymus vulgaris*) is about 1 - 2.5%, and it contains up to 10% tannins and resinous substances. Thymol (up to 50%), p-cymene, and gamma-terpinene have been found in it [42]. Rezzoug *et al.*, [47], identified a total of 29 compounds in the essential oil of *Thymus algeriensis*, of which α-terpinyl acetate (47.4%), neryl acetate (9.6%) and α-pinene (6.8%) were mainly present. Thyme also contains a variety of flavonoids, including apigenin, naringenin, luteolin, and timonin, which increase the antioxidant properties of the herb, and in combination with the high content of manganese, place thyme at the top of the list of antioxidant foods [48].

Some plants contain phytochemical components with antimicrobial activity. These include phenols and polyphenols. Biologically active components can be used against pathogens and bacteria causing food spoilage. Thyme essential oil belongs to plant products with strong antimicrobial activity [49].

Herbs and spices have been used in food preservation from microbial contamination for thousands of years [50]. The components in thyme essential oil have antimicrobial activity against many different bacteria and fungi - *Staphylococcus aureus, Bacillus subtilis, E. coli,* and others [43, 51].

2.6.3 Pharmacological activities and biological potential

The treatment of various infections continues to be a serious problem, due to several side effects of some drugs and the increasing resistance to antimicrobial agents. Therefore, the search for newer, safer, and helpful antimicrobial agents is imperative. Herbal medicines have gained popularity as a source of new antibacterial agents because they are considered time-tested and relatively safe for human use and the environment [52].
Several authors investigated the antimicrobial properties of the herb and its replacement with chemical preservatives and artificial antimicrobials. It has been proven that it inactivates the growth and development of pathogenic microorganisms [53].

Mihailova and Georgieva, [17], studied water extracts of 9 different Bulgarian plants, purchased in dried form from the commercial network of the city of Plovdiv. The infusions of tetra (*Cotinus coggygria Scop.*), oregano (*Origanum vulgare* L.), thyme (*Thymus vulgaris* L.), and mursalski tea (*Sideritis scardica* L.) showed the highest antioxidant activity. A significant correlation was also found between the presence of phenolic substances in the samples and the demonstrated antioxidant activity, which suggests their role. The obtained results reveal the possibility of using the investigated herbs as natural sources of antioxidants in food and culinary products.

The medicinal properties of thyme (*Thymus vulgaris* L.) have been established by scientific groups [54, 55]. It has been studied that its dried flowers are used for medicinal purposes, which have a pain-relieving effect. It also helps a lot with problems with the respiratory tract [56]. It is one of the many Bulgarian valuable herbs used for problems with bronchial asthma, lung inflammation, and bronchopneumonia. Soothes a dry cough and helps to release secretions. It also acts as a nervine and antispasmodic for ulcers, gastritis, and colitis [56]. Folk medicine is recommended it for intestinal disorders, insomnia, anemia, skin, and nervous diseases. Thyme oil has a disinfectant effect and is used for massage in arthritic diseases [56]. Apart from preparing tea, thyme is also used for compresses, gargles, decoctions, and even baths.

2.6.4 Application in the food industry

Thyme is an herb that is commonly used for flavoring food and as a preservative. It's been used since ancient times for different health and medicinal benefits. Thyme is a herb with known antimicrobial and antioxidant activity. It is used to impart flavor and to ensure safety by preventing the growth of pathogenic microorganisms in food [57]. Other authors as Bajpai *et al.*, [58], studied foods with added thyme extracts. The extracts have proven antimicrobial activity and are therefore used as a natural preservative. Thyme is widely used not only as a spice but also as a medicinal product - the main ingredient of some sorts of tea [59].

Panizzi *et al.*, [60], reported that thyme is used as a flavoring agent for various food products, used in the preparation of sauces, meat, and meat products in preservation of foods with a combination of meat and different sauces. Emiroglu *et al.*, [61], tested the antibacterial activity of thyme essential oil on ground beef. The scientific team has proven that it prolongs the shelf-life of meat under refrigerated conditions and thus improves safety. The team focused their research on the application of antimicrobial edible films made of thyme extracts on processed meat products, preferably on fermented sausages possessing an acidic pH and a high protein content. Radha-Krishnan *et al.*, [62], studied the effect of herb extract on raw chicken meat that was treated with extracts containing various combinations of herbs, one of which was thyme. Thyme-containing extracts exert interesting natural properties: they have very high effectiveness against microbial growth, and lipid oxidation and have antioxidant potential in the processing of raw chicken meat for the food industry. Heat-treated turkey meat products with added thyme aqueous extract have been studied, which showed increased antimicrobial activity against *Listeria monocytogenes* [63]. Fasseas *et al.*, [64], treated meat with oregano and thyme and found that the added herbs significantly reduced the oxidation of the meat, which also affected heat treatment and shelf-life. The high-fat content in some fish, as well as in meat products, reduces the antibacterial effect against various microorganisms. Aqueous extracts of oregano and thyme showed a better preservative effect against *Photobacterium phosphoreum* on tuna than on salmon with a higher fat content. Oregano and thyme essential oils were applied to the surface of whole fish or used as a coating on shrimp and possess inhibitory effects on *Salmonella enteritidis, Listeria monocytogenes,* and natural harmful flora [65]. A water extract of wild thyme (*Thymus serpyllum*) showed a preservative effect on fish. Yano *et al.*, [66], treated seafood with thyme oil in combination with rosemary, oregano, and horseradish, proving the effect of spices in reducing the risk of *Vibrio parahaemolyticus* contamination.

The thyme and rosemary essential oils are used in butter, milk, and dairy products, and both act as natural antioxidant and flavoring agents [67]. Essential oils of thyme, savory, and cloves added to tomato paste were tested and all of them inhibited the growth of *Aspergillus flavus* [68]. The team of Buhalova *et al*, [69], investigated Bulgarian herbs (oregano, thyme, and blueberries) by adding them to sunflower oil. They found that in oil samples with oregano and thyme, a double increase in β-carotene content was achieved, respectively from 2.76 ppm for the control to 4.92 - 5.77 ppm. They prove to have a prooxidative effect and the resulting oil extracts are not suitable for heat treatment. Thanks to the higher ratio of oleic/linoleic acid, oil extracts of oregano and thyme can be used as additives to salads, sauces, and dishes. Oregano and thyme oil extracts had unchanged brightness and increased chlorophyll and β-carotene content, while pine extract had reduced brightness and increased color difference with the control [69].

2.7 Food emulsion systems with plant additives

2.7.1 Food emulsion systems

Products with an emulsion structure have a significant relative share in a wide range of products in the food industry. Food emulsions are the basis of many culinary products, and a significant part of them are mayonnaises, sweet or salty emulsion sauces dressings, also emulsion meat products. Food emulsions in the form of sauces are often included in the composition of cold appetizers for some main meals and desserts. The concept of a mayonnaise-type emulsion culinary sauce can be defined as a stable oil-water emulsion consisting of vegetable oil, water, emulsifier, and additives [70]. It is quite relevant to expand the range of sauces by adding natural stabilizers and taste enhancers [71, 72]. Vitamins and minerals are additives that increase the nutritional and biological value of food. Their relevance is growing in parallel with the consumer's interest in the matter of rational nutrition. A very strong emphasis is put on the taste, safety, and health aspects of emulsion-type food products. Growing consumer demand for natural products is increasingly turning attention to edible plants as sources of safer and more effective natural antioxidants that stabilize and enrich food emulsion systems [73]. Various authors have analyzed the antioxidant activity of spices and herbs added to pure oils, but few spices lead to improved oxidative stability of W/W emulsions [74]. Oil extracts of herbs and spices can be used to improve microbiological safety. On the other hand, if they are not microbially clean, some herbs and spices can contaminate the final product [75]. Mihov *et al.*, [75], investigated food emulsions (salad dressing and mayonnaise) with an oil phase - olive oil (25 and 50%) and incorporated natural spices, herbs, and extracts, where microbiological and oxidative stability and sensory perception of food emulsions were studied. The team of Mihov *et al.*, [75], proved that the addition of spice and herb extracts significantly improved the antimicrobial stability of the two types of food emulsions studied. Oxidation processes are evaluated by measuring the formation of primary oxidation products. In comparison, samples with extracts are more resistant to oxidation than control samples. Salad dressing with basil is characterized by the best antioxidant stability.

2.7.2 Innovative approaches to obtaining a new generation of emulsified products

Synthetic antioxidants have recently been hypothesized to cause potential adverse effects on human health. There is a tendency to use natural antioxidants as substitutes for synthetic ones [76]. Some food manufacturers already use multi-purpose ingredients, such as rosemary and oregano, approved for use as spices and natural flavoring agents that can limit oxidation. But other plant sources haven't been used until now such as hawthorn (*Crataegus*) fruit; donkey thistle - *Onopordum acanthium* L.; *Thymus callieri* Borbás ex Velen - Callier's thyme, etc. Spices and natural flavoring agents can often be included in products that have certain benefits that extend the shelf life and quality of the products. Spices and natural flavors may have higher minimum effective concentrations than their synthetic counterparts, but they may offer better consumer acceptability, reduce potential health risks, and achieve the same degree of oxidation prevention. Therefore, essential oils (EO) and oil extracts are considered a good alternative because the majority of them are considered safe (GRAS). The antioxidant potential of organic substances mainly depends on their chemical composition. Phenolics and some other secondary metabolite compounds are linked by double bonds, which are responsible for the intrinsic antioxidant activity of EO [77]. Essential oils extracted from traditional plants are rich sources of oxygenated monoterpenes. In addition, monoterpene hydrocarbons and phenolic terpenoids, such as carvacrol or thymol, are the main chemical compounds that lead to stronger antioxidant activities in EO obtained from certain plants, such as the oil extracted from plants such as thyme, oregano, basil, clove, nutmeg.

Phenolic compounds are one of the main food additives in the food and pharmaceutical industry [78]. Health-promoting ingredients such as phenolic compounds, vitamins, and minerals are being introduced into foods and beverages to produce foods specifically designed to improve human health [79]. However, it is a challenge to incorporate these food additives into foods, as they are hardly soluble and chemically unstable. This problem can be overcome by encapsulating the bioactive components in nanoparticle-based delivery systems. The bioavailability of the encapsulated bioactive agents increases when the size of the particles containing them decreases, due to their faster digestion, their ability to penetrate the mucus layer, or their direct uptake by cells. Nanoparticles can be shaped to pass unhindered through different parts of the gastrointestinal tract and then release the beneficial substances they contain, thereby maximizing potential health benefits. Nanoparticles loaded with food additives can be produced by lipid formulations, natural nanocarriers, and bio-polymer nanoparticles by various techniques [78, 79]. Nutrient bioavailability is the main factor to be considered in the design of functional foods. Bioavailability is the amount of a bioactive compound that can reach the bloodstream. When people consume dietary supplements through food, these compounds pass through the mouth, stomach, and intestines until they reach the bloodstream [79]. The authors cited above have reviewed and discussed nano-emulsions. The bioavailability of nanoencapsulated phenolic products and their ability to produce functional foods are also considered [79].

Phenolics can contribute to the taste and color of food and drink. For example, anthocyanins are responsible for the orange, red, blue, and purple colors of many fruits and vegetables such as pomegranates, berries, beets, and onions [80]. Fine micro- and nano-encapsulation systems of phenolic compounds can be obtained by food nano-emulsions. An emulsion is a system consisting of two immiscible liquids, usually oil and water, one of which is dispersed as droplets in the other. A stable and heterogeneous dispersion of the two liquids results from using emulsifiers. Emulsifiers are classified into two main groups: macromolecule emulsifiers (e.g. whey protein concentrate) and low molecular weight surfactants [81].

Biopolymers are used as essential emulsifiers for producing stable oil-in-water (O/W) emulsions. Proteins (e.g. whey protein and casein) and polysaccharides (e.g. gums and pectin) are basic biopolymers that can be used alone or in combination with emulsions [82]. Emulsions (oil in water or water in oil) are also stabilized by using low molecular weight surfactants. Surfactants contain both hydrophilic and lipophilic groups. The ratio of these groups is represented by measuring the hydrophilic-lipophilic balance (HLB). The higher the HLB (8 - 12), the more hydrophilic the molecule; the lower the HLB (1 - 6), the more hydrophobic the molecule [83]. According to Dhankhar *et al.*, [84], a nanoemulsion is a thermodynamically unstable colloidal dispersion, consisting of two liquids, one of which is in the form of dispersed particles (with a size of about 100 nm) in the form of small spherical droplets that have two main critical properties, i.e. increased stability and biological activity. The antimicrobial and antioxidant activities of natural food preservatives could be enhanced by the small droplet size. There are several methods for obtaining a nanoemulsion including low-energy and high-energy technologies.

The antimicrobial and antioxidant action of the natural preservatives is enhanced due to the small size of the droplets. Several nanotechnologies have been used to create a nanoemulsion, including low-energy and high-energy methods. For example, ultrasonic emulsification is a high-energy method that is more and more applied and can efficiently create nanoemulsions with droplets of small diameters and even size distribution [85]. The technology for obtaining emulsion systems has been used for decades in the food industry to create a diverse range of products (homogenized milk, creams, dressings, sauces, desserts, and toppings). In recent years, there have been important advances in the science of emulsions, leading to new approaches to improving the quality and functionality of food [86].

3. Conclusions

- In the review was provided information regarding aromatic plants and their extracts. Their safety in terms of their food application was assessed. The use of plants and plant extracts rich in biologically active components in the pharmaceutical and food industry was also discussed.
- The scientific team conducted a study on the selected Bulgarian Endemic plants *Crataegus monogyna* (fruits), *Onopordum acanthium* L (flowers), and *Thymus callieri* Borbás ex Velen. (flowers with stems), regarding their biological potential and their potential for use in food. Their potential for inclusion in food emulsions as a valuable raw material for the production of emulsion products was also studied.
- Information on innovative approaches to obtaining emulsified products that can serve as a matrix is provided. The idea of incorporation of valuable components with high functional potential into emulsion systems is supported. The composition of the emulsion dispersion systems can include vegetable oils, further enriched by adding oil extracts (of herbs) containing various biologically active substances rich in polyunsaturated fatty acids.

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