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Preparation and *In Vitro* Characterization of Alginate Beads Containing the Aqueous Extract of *Artemisia dracunculus*

Artemisia dracunculus Su Ekstresi İçeren Aljinat Boncukların Hazırlanması ve *İn Vitro* Karakterizasyonu

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ABSTRACT

Objective: *Artemisia dracunculus* is a plant traditionally used in folk medicine, and its antioxidant, anti-inflammatory, and antihyperglycemic effects have been demonstrated in scientific studies. This study aims to prepare alginate beads containing the aqueous extract of *Artemisia dracunculus* and perform in vitro characterization studies.

Methods: Four different extraction methods were tested to prepare the water extract, and the total phenolic content of the extracts was determined using the Folin–Ciocalteu method. The extract with the highest phenolic content was selected, and alginate beads were prepared by ionotropic gelation. The beads were dried using oven-drying or lyophilization methods. The beads were characterized in vitro (particle size, morphological analysis, encapsulation efficiency, swelling behavior, and FT-IR analyses).

Results: The bead sizes were found to range from 0.73 ± 0.12 mm to 1.76 ± 0.13 mm, and it was determined that lyophilized beads were larger and more porous. The entrapment efficiency was found to range from 4.86% to 14.28%. Swelling studies have shown that lyophilized beads have a higher swelling capacity. FT-IR analysis revealed that the extracts were retained within the polymer matrix.

Conclusion: Alginate beads containing *Artemisia dracunculus* aqueous extract have been successfully prepared and characterized *in vitro*.

Keywords: Alginate, *Artemisia dracunculus*, beads, in vitro characterization.

ÖZ

Amaç: *Artemisia dracunculus*, geleneksel halk tıbbında kullanılan bir bitkidir ve antioksidan, antiinflamatuar ve antihiperglisemik etkileri bilimsel çalışmalarda gösterilmiştir. Bu çalışmanın amacı, *Artemisia dracunculus*'un su ekstresini içeren aljinat boncukları hazırlamak ve in vitro karakterizasyon çalışmaları yapmaktır.

Yöntemler: Su ekstresinin hazırlanmasında dört farklı ekstraksiyon yöntemi denenmiş ve ekstrelerin toplam fenolik içerikleri Folin–Ciocalteu yöntemi ile belirlenmiştir. En yüksek fenolik içeriğe sahip olan ekstre seçilerek iyonotropik jelasyon ile aljinat boncukları hazırlanmıştır. Boncuklar etüvde kurutma veya liyofilizasyon yöntemleriyle kurutulmuştur. Boncukların in vitro karakterizasyonu (partikül boyutu, morfolojik analiz, enkapsülasyon etkinliği, şişme davranışı ve FT-IR analizleri) yapılmıştır. Şişme çalışmaları sonucunda, liyofilize boncukların şişme kapasitelerinin daha yüksek olduğu görülmüştür.

Bulgular: Boncuk boyutları 0,73 ± 0,12 mm ile 1,76 ± 0,13 mm arasında bulunmuş ve liyofilize boncukların daha büyük ve daha gözenekli yapıda olduğu belirlenmiştir. Yükleme etkinliğinin %4,86 ile %14,28 arasında değiştiği bulunmuştur. FT-IR analizleri, ekstrelerin polimer matrisi içinde tutulduğunu ortaya koymuştur.

Sonuç: *Artemisia dracunculus* su ekstresi içeren aljinat boncukları başarıyla hazırlanmış ve in vitro karakterize edilmiştir.

Anahtar Kelimeler: Aljinat, *Artemisia dracunculus*, boncuk, in vitro karakterizasyon.

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Introduction

Artemisia dracunculus, commonly known as tarragon, is a member of the Asteraceae family and is naturally distributed in Eastern Anatolia in Turkey (Benli, 2007). *Artemisia dracunculus*, which originates from Siberia and Mongolia, can also grow naturally in Central Asia, Eastern Europe and Mediterranean countries and is also used as a spice. It has been used in traditional Asian medicine, especially in India, Iran, Azerbaijan and Pakistan, as an analgesic, hypnotic, antiepileptic, antipyretic and anti-inflammatory agent. It is also used in Europe to treat constipation, ulcers, intestinal cramps and cancer (Ekiert et al., 2021). Scientific studies have reported that *Artemisia dracunculus* extracts have antioxidant, anti-inflammatory, analgesic, immunomodulatory, and anti-tumor activities, as well as hepatoprotective and hypoglycemic effects (Abtahi Froushani et al., 2016; Ekiert et al.; 2021; Majdan et al.; 2020; Rajabian, 2017; Shahraki et al. 2017). Majdan et al. (2020) evaluated cytokine secretion by stimulating neutrophils isolated from venous peripheral blood samples from healthy human donors in their study on the anti-inflammatory activity of the aqueous extract of *Artemisia dracunculus*. It has been reported that treatment with an aqueous tarragon extract inhibits the production of free oxygen radicals and decreases the release of IL-8 and TNF-α. In another study, Abtahi Froushani et al. (2016). examined the immunomodulatory effects of the aqueous extract of *Artemisia dracunculus* in mice. In the study, mice were immunized intraperitoneally with sheep erythrocytes and then given *Artemisia dracunculus* aqueous extract orally. It has been reported that there is an increase in antibody levels against sheep erythrocytes and a decrease in cellular immunity. In addition, treatment has been shown to decrease the production of proinflammatory cytokines IL-17 and IFN-γ and to increase the phagocytic properties of macrophages. The study emphasized that the aqueous extract of *Artemisia dracunculus* may be a promising immunomodulatory agent. In another study, serum insulin levels, blood glucose and liver enzyme levels were evaluated in rats given drinking water containing fructose. It was shown that the aqueous extract of *Artemisia dracunculus* had anti-hyperglycemic, anti-lipidemic, and anti-hepatotoxic effects (Shahraki et al., 2017).

In recent years, the use of herbal extracts as therapeutic agents has attracted considerable attention and studies on this subject have increased. However, the short stability and low bioavailability of aqueous extracts limit their use. Therefore, it is recommended to load plant extracts into matrix systems to protect them from environmental factors, increase their stability and control their release (Arriola et al., 2019; Rijo et al., 2014; Stojanovic et al., 2010).

With conventional dosage forms, the plasma level of the active compound can be maintained within the therapeutic window through frequent, repeated administration. However, this situation both reduces patient compliance and causes fluctuations in the blood plasma level of the active compound. To overcome these problems and provide an effective treatment, new carrier systems are being developed that reduce the dose and frequency of administration of the active compound, thereby reducing side effects and increasing patient compliance (Gürsoy, 2002; Tuylek, 2017).

Modified release systems are being developed to control the release site or timing of the active compound. Modified-release systems are classified under two general headings, delayed- and extended-release systems, in the United States Pharmacopoeia (USP 43-NF 38). Delayed-release systems aim to protect the active compound against pH or to prevent irritation. The aim of extended release systems is to prolong the release of the active compound. Extended-release systems can be broadly categorized as matrix and reservoir-structured systems. In matrix systems, the active compound is dissolved and/or dispersed in hydrophilic/hydrophobic polymers. Hydrophilic matrix systems swell upon hydration and form a viscous layer on the system's surface that acts as a barrier to release. The swelling and gradual degradation of the polymer reduce the release rate of the active compound and help control it. Matrix systems can be prepared as tablets, microtablets, microspheres, nanoparticles, pellets and beads (Dortunç, 2002; Garapati et al., 2015; Tu et al., 2010).

In multiparticular drug delivery systems (beads, pellets, minitablets, etc.), the active compound is divided into small subunits with the same properties. These systems ensure release reproducibility and dosing safety. Unlike single-unit systems, which are located in a single part of the gastrointestinal tract, multi-unit systems are more likely to be distributed throughout the tract. In this way, both the effect of food on the absorption of active compounds and the irritant effect of the active compound in the gastrointestinal tract are reduced. At the same time, these systems exhibit more reproducible pharmacokinetic behavior and reduced intra-individual and inter-individual variability (Dey et al., 2008; Dortunç, 2002; Torrado et al., 2008).

Sodium alginate is a mucoadhesive, biodegradable and water-soluble polymer. Sodium alginate is the sodium salt of alginic acid, composed of (1-4)-β-D-mannuronic acid units (M blocks), α-L-glucuronic acid units (G blocks) and blocks of these units (M-G blocks). Sodium alginate, which is a hydrophilic polymer, swells in water to form a viscous gel. When divalent cation ions such as Ca+2 and Zn+2 are present in the medium, they form egg basket-shaped aggregates as a result of ion exchange with G blocks. This phenomenon, known as ionotropic gelation, is used to prepare drug carrier systems (such as nanoparticles, microparticles, and beads) (Garapati et al., 2015; Tu et al., 2010; Tonnesen and Karlsen, 2002).

Bead formulations are suitable dosage forms for increasing the stability of aqueous plant extracts, converting liquid active compounds into a solid form, making them suitable for use as therapeutic agents or food supplements, and providing extended release. The objective of this study is to prepare alginate beads containing the aqueous extract of *Artemisia dracunculus* and to conduct in vitro characterization studies.

Methods

Preparation of *Artemisia dracunculus* Aqueous Extracts

Four different methods were applied to obtain aqueous extract from dry powdered *Artemisia dracunculus* leaves:

Method i: 10 g of powder was weighed, 100 or 200 mL of ultrapure water was added, and it was stirred in a magnetic stirrer for 24 hours at room temperature.

Method ii: 10 g of powder was weighed, 100 or 200 mL of ultrapure water was added, and it was stirred for 24 hours in a water bath with a horizontal shaker at 50 °C.

Method iii: 10 g of powder was weighed, 100 or 200 mL of boiling ultrapure water was added and mixed in a magnetic stirrer until it reached room temperature.

Method iv: 10 g of powder was weighed, 100 or 200 mL of ultrapure water was added to it, and it was boiled for 10 minutes (on a magnetic stirrer with heating), and stirring was continued until it reached room temperature.

All extracts were first filtered through filter paper and then through 0.45 µm membrane filters.

Determination of Total Phenolic Content in Extracts

The total phenolic content was determined using the Folin-Ciocalteu method to assess the extract for use in preparing alginate beads. The basis of the method is that phenolic compounds react with the Folin-Ciocalteu reagent in an alkaline medium to form a blue-colored complex, which is analyzed spectrophotometrically at 765 nm. Gallic acid was used as a standard, and the results are given as gallic acid equivalents. Briefly, 100 µL of Folin-Ciocalteu reagent was added to 20 µL of the extract or standard solution, and the mixture was incubated for 5 min. Then, a 7.5% Na_2CO_3 solution was added and incubated at room temperature, and the absorbance was measured at 765 nm using a UV-spectrophotometer (Büyüktuncel, 2013).

Preparation of Alginate Bead Formulations

The ionotropic gelation method was used to prepare alginate beads (Stojanovic et al., 2012). First, 5% $CaCl_2$ solution with ultrapure water and a 2% sodium alginate solution in the extract [prepared using 100 mL or 200 mL of ultrapure water; E(100) and E(200), respectively] were prepared separately. The alginate solution was then dropped into the CaCl2 solution under magnetic stirring. The formed beads were allowed to harden by stirring for a further 15 min, then collected by filtration [Wet beads prepared with E(100): E(100)-W, wet beads prepared with E(200): E(200)-W].

Two different methods were used for drying the prepared beads:

i. Drying in an oven at 50 ºC for 24 h [Oven-dried beads prepared with E(100): E(100)-O, Oven-dried beads prepared with E(200): E(200)-O]

ii. Lyophilization after freezing at -20 ºC (-55 °C, 24 h) [Lyophilized bead prepared with E(100): E(100)-L, lyophilized bead prepared with E(200): E(200)-L]

For the preparation of blank beads (B) not prepared with extracts, the same procedures were applied, but the sodium alginate solution was prepared with ultrapure water [Wet beads not prepared with extracts (blank): B-W, oven-dried blank beads: B-O, lyophilized blank beads: B-L].

Characterization of Alginate Bead Formulations

Particle Size: The particle sizes of the prepared beads were evaluated in the wet and dry states. For each formulation and drying method, 50 beads were randomly selected from 3 batches, and their sizes were measured using Vernier calipers (Uğur et al., 2019).

Morphological Analysis: Digital photographs and scanning electron microscope (SEM) images were taken to examine the bead formulations in the wet and after-drying states. Digital photographs were taken in the wet state immediately after filtration. After drying (in an oven or by lyophilization), SEM images were taken after gold coating, and the surface properties were examined (Rijo et al., 2014; Uğur et al., 2019).

Entrapment Efficiency: In the determination of the entrapment efficiency, the total phenolic content in the beads was proportioned to the total phenolic content in the polymer-extract solution. For this purpose, 50 mg of oven-dried/lyophilized beads was weighed, and a 10% sodium citrate solution was added and stirred on a magnetic stirrer (600 rpm) for 3 hours. After centrifugation at 12500 rpm for 15 min, the supernatant was analyzed for total phenolic content (Stojanovic et al., 2012).

Swelling Properties: The swelling study for the bead formulations was carried out in two media with different pH levels. After weighing 50 mg of oven-dried/lyophilized beads into amber bottles, 15 mL of either pH 1.2 HCl buffer or pH 6.8 phosphate buffer was added, and the bottles were then immersed in a water bath at 37 °C ± 0.5. After removing the excess liquid from the bead surfaces taken from the medium at certain time intervals, the beads were weighed. The % swelling values of the beads were calculated using the following formula (Uğur et al., 2019)

%Swelling=((Wt-W0)/(W0)*100)

FT-IR Analysis: FT-IR analysis of the extract (lyophilized at -55 °C for 24 hours), formulation components, and formulations (oven-dried/lyophilized) was performed ("Shimadzu IRSpirit-T, Japan") (Stojanovic et al., 2012.; Uğur et al., 2019).

Statistical Analysis

SPSS Statistics 22.0 (IBM SPSS Corp., Armonk, NY, USA) was used to analyze the data. An independent samples t-test was applied, and differences were considered statistically significant when $p<.05$.

Results

Determination of Total Phenolic Content in Extracts

Gallic acid calibration curves were generated by plotting absorbance against gallic acid concentrations (20–200 µg/mL), followed by linear regression analysis (Figure 1). Total phenolic content was expressed as gallic acid equivalents (GAE) and reported as mean ± standard deviation (Table 1; n = 3).

Figure 1.
Calibration line and equation of gallic acid (n=3)

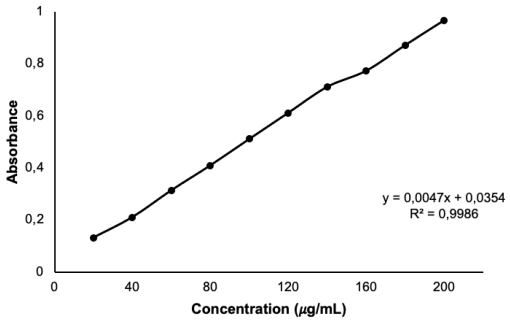


Table 1.
Total phenolic contents of extracts (Mean ± SD; n=3)

Method	Amount of Water	Total Phenolic Content (GAE µg/mL)
i	100 mL	1687.52 ± 32.50
	200 mL	1004.26 ± 15.81
ii	100 mL	1743.97 ± 21.71
	200 mL	1087.38 ± 8.52
iii	100 mL	1892.06 ± 37.64
	200 mL	1270.92 ± 61.20
iv	100 mL	1855.11 ± 12.90
	200 mL	1199.01 ± 41.40

Accordingly Table 1, Method III yielded the highest phenolic content. Therefore, the Method III extract [prepared using 100 or 200 mL of ultrapure water; E(100) and E(200)] was used in the subsequent stages of the study.

Characterization of Alginate Bead Formulations

Digital photographs of the beads in their wet state and after drying (either oven-drying or lyophilization) are presented in Figure 2. SEM micrographs of the dried beads (oven-dried or lyophilized) are provided in Figure 3.

Figure 2.
Digital photographs of beads

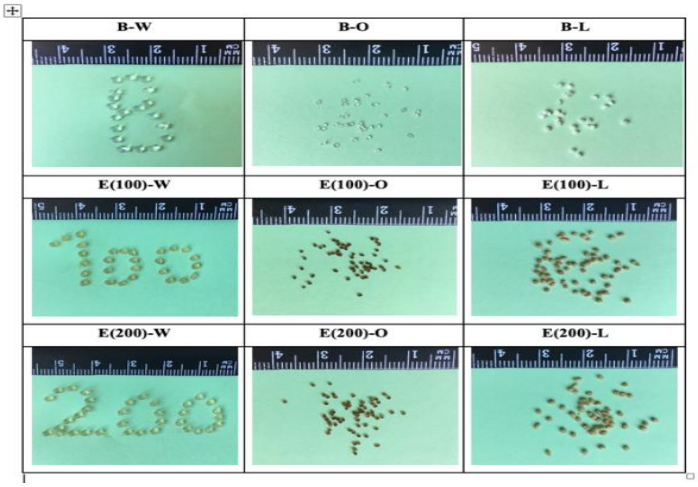
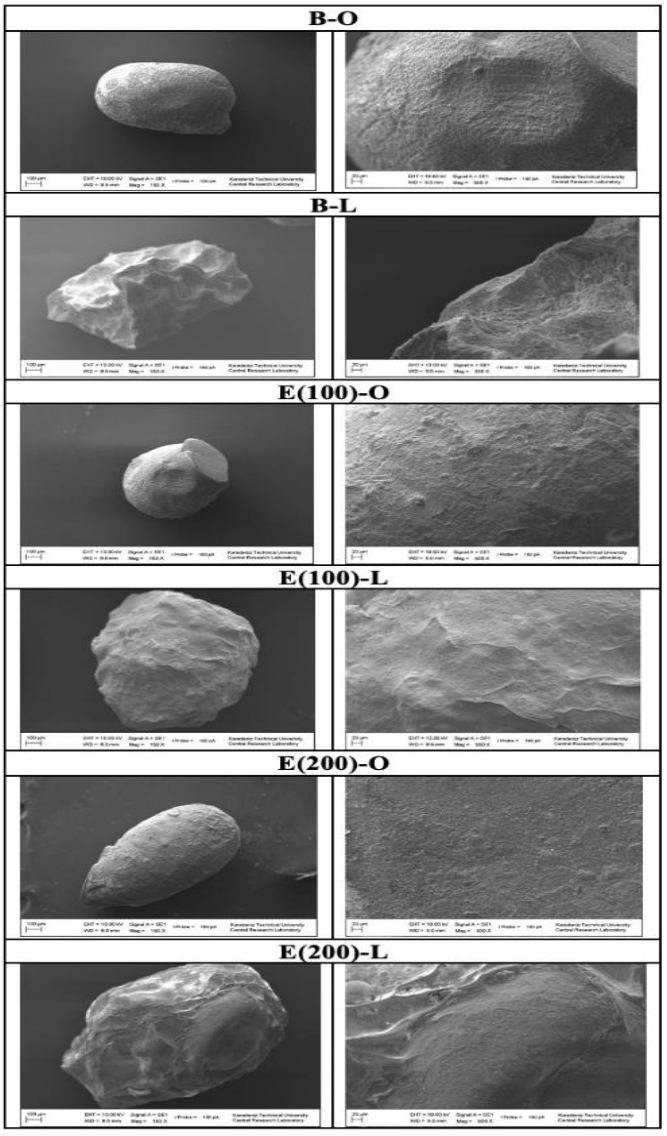


Figure 3.
SEM images of beads



The sizes of the beads were measured with calipers and the results are presented in Table 2.

Table 2.
The particle sizes of beads (Mean ± SD; n=150).

Formulation	Particle Size (mm)
B-W	1.76 ± 0.13
B-O	0.86 ± 0.15
B-L	1.16 ± 0.15
E(100)-W	1.59 ± 0.13
E(100)-O	0.73 ± 0.12
E(100)-L	1.19 ± 0.19
E(200)-W	1.73 ± 0.14
E(200)-O	0.80 ± 0.11
E(200)-L	1.23 ± 0.11

The entrapment efficiencies (EE%) of dry beads containing the extract are given in Table 3.

Table 3.

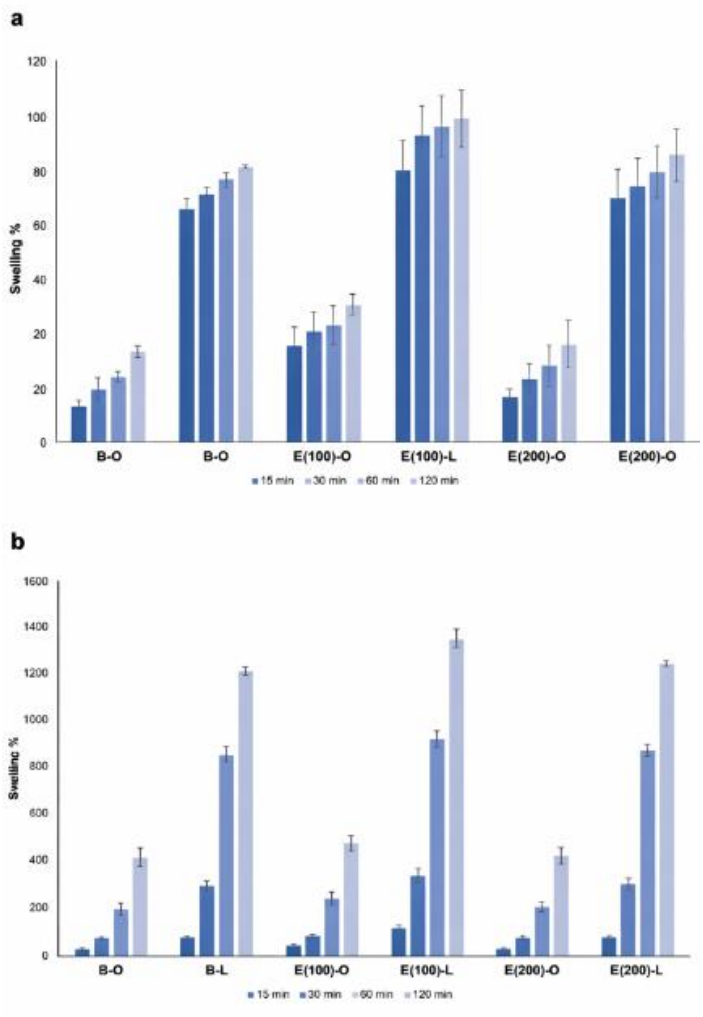
The entrapment efficiencies of formulations (EE%, Mean ± SD; n=3)

Formulation	EE%
E(100)-O	10.20 ± 1.48
E(100)-L	14.28 ± 0.54
E(200)-O	4.86 ± 0.15
E(200)-L	6.08 ± 0.71

Swelling behaviors of dry beads were investigated in pH 1.2 HCl and pH 6.8 phosphate buffer, and are shown in Figure 4.

Figure 4.

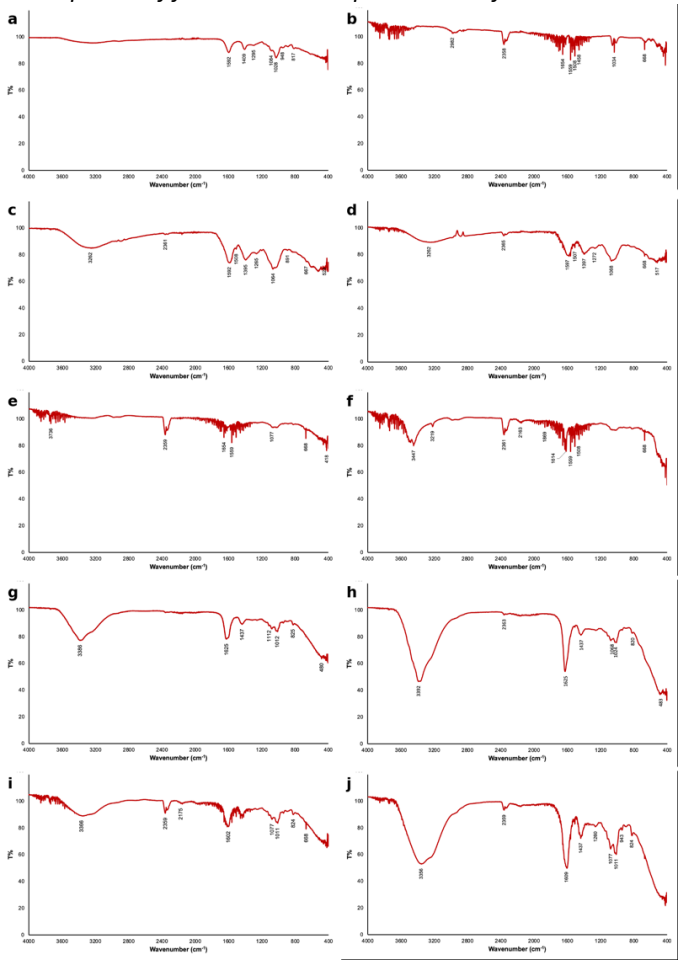
Swelling behaviors of beads: a) pH 1.2 HCl buffer, b) pH 6.8 phosphate buffer (Mean ± SD; n=3).



The FT-IR spectra of the extract, formulation components, and formulations are presented in Figure 5.

Figure 5.

FT-IR spectra of formulation components and formulations



a: Sodium alginate, b: $CaCl_2$, c: E(100), d: E(200), e: B-O, f: B-L, g: E(100)-O, h: E(100)-L, i: E(200)-O, j: E(200)-L

Discussion

Artemisia dracunculus, also known as tarragon, is a plant that has been used in traditional medicine for many years and whose antioxidant, anti-inflammatory, immunomodulatory, and hypoglycemic effects have been scientifically demonstrated. Its high concentration of phenolic compounds increases its pharmacological value (Abtahi Froushani et al., 2016; Ekiert et al.; 2021; Majdan et al., 2020; Rajabian, 2017; Shahraki et al., 2017). However, since aqueous herbal extracts are complex systems containing numerous compounds, some limitations in terms of dosage and repeatability may be presented when they are used directly (Brendler et al., 2022). Therefore, formulating herbal extracts within polymeric carrier systems makes it possible to transform liquid extracts into solid, doseable systems with modified release potential (Arriola et al., 2019; Bhandurge et al. 2025; Rijo et al., 2014; Stojanovic et al., 2010). Sodium alginate is a suitable polymer for delivering and controlling the release of herbal extracts. Alginate is widely used due to its biocompatible, biodegradable, and mucoadhesive properties. Alginate can form a three-dimensional network structure via ionotropic gelation in the presence of divalent cations, such as Ca^{2+}. This allows it to

rapidly gel in an aqueous environment, trapping active compounds within the matrix (Frent et al., 2022; Jain & Bar-Shalom, 2014). In this study, sodium alginate beads were prepared with *Artemisia dracunculus* aqueous extract and characterized *in vitro*.

A variety of temperatures, durations, and mixing conditions can be applied in the preparation of aqueous extracts, and these parameters affect the resulting phenolic content (Bui-Phuc et al., 2022). In our study, four different extraction methods and two different water volumes were used, and the total phenolic content in the obtained extracts was determined to identify the most suitable method. The highest total phenolic content was obtained for Method III (direct addition of boiling water to dry plant material) and was used in subsequent studies. This can be explained by the fact that the cell structure is rapidly disrupted with the short-term application of high temperature, and phenolic compounds pass into the solvent more effectively (Antony & Farid, 2022; Liu et al. 2019).

Digital photographs and SEM images of the beads prepared in our study are given in Figure 1 and Figure 2, respectively. It was observed that when wet, empty beads appeared translucent, while beads containing extract were brownish in color, which indicates successful loading of extract into bead formulation. Ozturk (2022) prepared l-cycsteine HCl loaded alginate beads and reported that while blank beads was transparent, l-cysteine HCl loaded beads were semi-opaque similar to our study.

When the SEM images and digital photographs of the beads in our study, whose size decreased after drying, were examined, it was seen that the surfaces of the lyophilized beads were rougher than the surfaces of the beads dried in the oven (Figure 2 and Figure 3). Additionally, it was observed that the beads obtained by both drying methods were close to spherical. In the study conducted by Traffano-Schiffo et al. (2017), alginate beads were dried with two different methods in order to evaluate the effect of the drying method on the beads. It was reported that freeze-dried beads had spongier and more voluminous surface, while the vacuum dried beads were more compact and showed less exposed surface area. The results we obtained were found to be compatible with the literature.

In our study, the particle sizes of the prepared beads varied between 0.73 ± 0.00 mm and 1.76 ± 0.13 mm, depending on the presence of extract and the drying method (Table 2). When the particle sizes are examined, it is seen that the wet beads are larger than the dry beads. There was a significant decrease in the particle sizes of all the beads due to the shrinkage after drying (p<.05). When compared according to the drying method, drying the beads in the oven resulted in the formation of smaller particles (p<.05). During oven drying, the removal of water causes the polymer chains to come closer together, resulting in a collapsed matrix. This results in the beads shrinking and becoming smaller particles. However, lyophilization, which involves the removal of water through sublimation, largely preserves the porous, three-dimensional structure of the beads and limits volume loss (Nussinovitch, 2010). In the study by Santagapita et al. (2011), alginate beads prepared by the ionotropic gelation method were dried by three different methods (freeze drying, vacuum drying or oven-drying) and the effects of drying on the beads were evaluated. In the study, it was determined that the change in bead particle size after freeze-drying was minimal.

EE% of extract-loaded alginate beads ranged from 4.86% to 14.28%, depending on extract concentration and drying method. The EE% of the beads produced from E (100) is considerably higher than E (200) (p<.05). Compared by drying method, the phenolic content of beads dried by lyophilization is higher (p<.05). The low EE% values may be due to the extract's high solubility and leakage into the aqueous medium (Uğur et al., 2019).

The swelling behavior of the beads is affected by the medium pH. Exposure of alginate to pH (acidic medium, pH<4) below its pKa (3.2 and 4 for guluronic acid and mannuronic acid, respectively) leads to protonation of the alginate carboxylic groups (-COOH), which reduces the electrostatic repulsive forces between these groups and limits the relaxation of the polymer chains by the presence of intermolecular hydrogen bonds. In this way, a more compact network structure is formed, and the release of the active substance is reduced. Conversely, in neutral and alkaline media, carboxyl groups become ionized (COO-). As a result of the electrostatic repulsion between negative charges, the polymer network structure relaxes, yielding higher diffusion coefficients (Chuang et al., 2017; Uğur Kaplan et al., 2019). In our study, greater bead swelling was observed at pH 6.8 PB (p<.05), consistent with the literature (Figure 4). The greater swelling of lyophilized beads is due to the more porous structure created by this drying method. This structure allows water to penetrate the bead more easily. In contrast, beads dried in an oven have a denser and partially collapsed structure, resulting in limited swelling (Simoni et al., 2017).

Figure 5 shows the FT-IR spectra of the formulation components and beads. Observation of functional peaks in the extracts in the bead formulations containing the extract, along with slight shifts, indicates that the extract is trapped within the alginate matrix and may interact with the alginate chains (Orozco-Villafuerte et al., 2019).

Conclusion

In this study, alginate beads containing *Artemisia dracunculus* aqueous extract were successfully prepared and characterized in vitro. It was determined that beads dried by lyophilization exhibited higher swelling capacity and higher encapsulation efficiency. The fact that the beads showed greater swelling at pH 6.8 compared to pH 1.2 indicates that the system has a pH-sensitive structure. FT-IR analyses confirm that the extract is successfully retained within the polymer matrix. The developed alginate beads can be considered a suitable carrier system for the delivery of *Artemisia dracunculus* aqueous extract.

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References

Abtahi Froushani, S. M., Zarei, L., Esmaeili Gouvarchin Ghaleh, H., & Mansori Motlagh, B. (2016). Estragole and methyl-eugenol-free extract of *Artemisia dracunculus* possesses immunomodulatory effects. *Avicenna Journal of Phytomedicine*, *6*(5), 526–534. https://doi.org/10.22038/AJP.2016.6479

Antony, A., & Farid, M. (2022). Effect of Temperatures on Polyphenols during Extraction. *Applied Sciences*, *12*(4), 2107. https://doi.org/10.3390/app12042107

Arriola, N. D. A., Chater, P. I., Wilcox, M., Lucini, L., Rocchetti, G., Dalmina, M., Pearson, J. P., & de Mello Castanho Amboni, R. D. (2019). Encapsulation of stevia rebaudiana Bertoni aqueous crude extracts by ionic gelation - effects of alginate blends and gelling solutions on the polyphenolic profile. *Food Chemistry*, 275, 123–134. https://doi.org/10.1016/j.foodchem.2018.09.086

Benli, M., Kaya, I., & Yigit, N. (2007). Screening antimicrobial activity of various extracts of *Artemisia dracunculus* L. *Cell Biochemistry and Function*, *25*(6), 681–686. https://doi.org/10.1002/cbf.1373

Bhandurge, O. N., Metangale, S. K., Navale, R. G., Bali, S. R., Mhaske, S. D., & Anwane, H. (2025). Novel Drug Delivery System in Medicine. *Asian Journal of Research in Pharmaceutical Science*, 299–308. https://doi.org/10.52711/2231-5659.2025.00044

Brendler, T., Brinckmann, J., Daoust, M., He, H., Masé, G., Steffan, K., & Williams, M. (2022). Suitability of botanical extracts as components of complex mixtures used in herbal tea infusions—challenges and opportunities. *Frontiers in Pharmacology*, *13*, 1-10. https://doi.org/10.3389/fphar.2022.1013340

Bui-Phuc, T., Nguyen, T. K., Ngo, N. X., & Trieu, Q. A. (2022). The effect of extraction parameters on the total polyphenol content and the antioxidant activity of aqueous Moringa oleifera leaf extract. *Nucleation and Atmospheric Aerosols*, *2610*(1), 060005. https://doi.org/10.1063/5.0100818

Büyüktuncel, E. (2013). Toplam fenolik içerik ve antioksidan kapasite tayininde kullanılan başlıca spektrofotometrik yöntemler. *Marmara Pharmaceutical Journal, 17*, 93-103.

Chuang, J. J., Huang, Y. Y., Lo, S. H., Hsu, T. F., Huang, W. Y., Huang, S. L., & Lin, Y. S. (2017). Effects of pH on the shape of alginate particles and its release behavior. *International Journal of Polymer Science*, *2017*, 1–9. https://doi.org/10.1155/2017/3902704

Dey, N. S., Majumdar, S., & Rao, M. E. B. (2008). Multiparticulate drug delivery systems for controlled release. *Tropical Journal of Pharmaceutical Research*, *7*(3), 1067–1075. https://doi.org/10.4314/TJPR.V7I3.14692

Dortunç, B. (2002). Oral Sistemler. In: A. Gürsoy (ed), Kontrollü Salım Sistemleri (pp. 151-176). Kontrollü Salım Derneği.

Ekiert, H., Świątkowska, J., Knut, E., Klin, P., Rzepiela, A., Tomczyk, M., & Szopa, A. (2021). *Artemisia dracunculus* (Tarragon): a review of its traditional uses, phytochemistry and pharmacology. *Frontiers in Pharmacology*, *12*, 653993. https://doi.org/10.3389/fphar.2021.653993

Frent, O. D., Vicas, L., Duteanu, N., Morgovan, C., Jurca, T., Pallag, A., Muresan, M., Filip, S., Lucaciu, R., & Marian, E. (2022). Sodium alginate—natural microencapsulation material of polymeric microparticles. *International Journal of Molecular Sciences, 23*(20), 12108. https://doi.org/10.3390/ijms232012108

Garapati, C., Gupta, H., Renekuntla, J., & Boddu, S. (2015). The Release of Drugs Using Excipient. In: A. Narang & S. Boddu (eds). Excipient Applications in Formulation Design and Drug Delivery, (pp 201–236). Springer.

Gürsoy, A. (2002). Giriş. In: A. Gürsoy (ed). Kontrollü Salım Sistemleri (pp. 3-6). Kontrollü Salım Derneği

Jain, D., & Bar-Shalom, D. (2014). Alginate drug delivery systems: application in context of pharmaceutical and biomedical research. *Drug Development and Industrial Pharmacy, 40*(12), 1576–1584. https://doi.org/10.3109/03639045.2014.917657

Liu, D., Lopez-Sanchez, P., & Gidley, M. J. (2019). Cellular barriers in apple tissue regulate polyphenol release under different food processing and in vitro digestion conditions. *Food & Function, 10*(5), 3008–3017. https://doi.org/10.1039/C8FO02528B

Majdan, M., Kiss, A. K., Hałasa, R., Granica, S., Osińska, E., & Czerwińska, M. E. (2020). Inhibition of neutrophil functions and antibacterial effects of tarragon (*Artemisia dracunculus* l.) infusion-phytochemical characterization. *Frontiers in Pharmacology*, *11*, 947. https://doi.org/10.3389/fphar.2020.00947

Nussinovitch, A. (2010). Methods and mathematical models for the drying of polymeric beads (pp. 53–74). Springer. https://doi.org/10.1007/978-1-4419-6618-6_3

Orozco-Villafuerte, J., Escobar-Rojas, A., Buendía-González, L., Garcia-Morales, C., Hernández-Jaimes, C., & Alvarez-Ramirez, J. (2019). Evaluation of the protection and release rate of bougainvillea (Bougainvillea spectabilis) extracts encapsulated in alginate beads. *Journal of Dispersion Science and Technology*, *40*(7), 1065–1074. https://doi.org/10.1080/01932691.2018.1496834

Öztürk, K. (2022) Development and in-vitro characterization of l-cysteine loaded alginate beads for oral delivery. *Journal of Research in Pharmacy, 26*(1), 210-218.

Rijo, P., Matias, D., Fernandes, A. S., Simões, M. F., Nicolai, M., & Reis, C. P. (2014). Antimicrobial Plant Extracts Encapsulated into Polymeric Beads for Potential Application on the Skin. *Polymers, 6*(2), 479-490. https://doi.org/10.3390/polym6020479

Santagapita, P. R., Mazzobre, M. F., Buera, M. P. (2011). Formulation and drying of alginate beads for controlled release and stabilization of invertase. *Biomacromolecules, 12*(9), 3147-3155. https://doi.org/10.1021/bm2009075

Shahraki, M. R., Mirshekari, H., Samadi, Z., Shahraki, A. R., Shahraki, E. (2017). Effects of *Artemisia dracunculus* aqueous extract on blood sugar, serum insulin, triglyceride and liver enzymes in fructose drinking water male rats. *Zahedan Journal of Research in Medical Sciences*, *19*(2), e4402. https://doi.org/10.5812/zjrms.4402.

Simoni, R. C., Lemes, G. F., Fialho, S., Gonçalves, O. H., Gozzo, A. M., Chiaradia, V., Sayer, C., Shirai, M. A., & Leimann, F. V. (2017). Effect of drying method on mechanical, thermal and water absorption properties of enzymatically crosslinked gelatin hydrogels. *Anais Da Academia Brasileira De Ciencias, 89*(1), 745–755. https://doi.org/10.1590/0001-3765201720160241

Stojanovic, R., Belscak-Cvitanovic, A., Manojlovic, V., Komes, D., Nedovic, V., & Bugarski, B. (2012). Encapsulation of thyme (Thymus serpyllum L.) aqueous extract in calcium alginate beads. *Journal of the Science of Food and Agriculture, 92*(3), 685–696. https://doi.org/10.1002/jsfa.4632

The United States Convention (2020, October 4). United States Pharmacopeia (USP 43-NF 38). https://www.uspnf.com/notices /usp-nf-final-print-edition

Traffano-Schiffo, M.V., Aguirre Calvo, T.R., Castro-Giraldez, M., Fito, P.J., & Santagapita, P.R. (2017). Alginate beads containing lactase: stability and Microstructure. *Biomacromolecules, 18*(6), 1785-1792. https://doi.org/1010.1021/acs.biomac.7b00202.

Tønnesen, H. H., & Karlsen, J. (2002). Alginate in drug delivery systems. *Drug Development and Industrial Pharmacy, 28*(6), 621–630. https://doi.org/10.1081/ddc-120003853

Torrado, J., & Augsburger, L. (2008). Tableting of Multiparticulate Modified Release Systems. In: L. Augsburger, & S. Hoag (eds). Pharmaceuticals Dosage Forms: Tablets, Volume 2: Rational Design (pp. 509-532). Informa Healthcare.

Tu, J., Shan, Y., Mahalingam, R., Jasti, B., & Xiaoling, L. 2010. ‘‘Polymers in Oral Modified Release Systems’’ In: H. Wen & K. Park (eds). Oral Controlled Release Formulation Design and Drug Delivery. (pp 71–88). Wiley.

Tuylek, Z. (2017). Drug delivery systems and nanotechnological interaction. *Bozok Tıp Dergisi*, *7*, 89–98.

Uğur, A.B., Kandilli, B., Çetin, M., & Demirkaya Miloğlu, F. (2019). Preparation and in vitro characterization of AL-beads containing carbamazepine and/or levetiracetam. *Journal of Research in Pharmacy, 23*(4), 642-651.