



## Producing Kombucha Beads by Spherification: Effect of Alginate Concentration on Release Behavior and Physical Characteristics

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**Abstract**— The consumption of kombucha has been increasing in recent years due to its health benefits. However, its strong and distinctive flavor can be a limiting factor for consumer acceptance. Therefore, producing kombucha beads through spherification provides an alternative method of consuming kombucha. This study investigated the effect of sodium alginate (SA) concentration on the release of total phenolic content, reducing sugar, and antioxidant capacity from kombucha beads. Additionally, the stability of kombucha beads in simulated gastric juice was investigated in terms of viable bacteria. The microstructure of kombucha beads was investigated using a scanning electron microscope (SEM). The result showed that kombucha beads produced tear-shaped beads. Increasing the concentration of sodium alginate led to an increase in the size and hardness of the kombucha beads ( $P < 0.05$ ). However, increasing the concentration of sodium alginate did not affect the release of total phenolic content, reducing sugar and antioxidant capacity ( $P \geq 0.05$ ). Interestingly, 1% SA-kombucha beads had the highest viability of bacteria ( $P < 0.05$ ) after low pH simulation compared to 2% to 5% SA-kombucha beads. SEM analysis revealed that kombucha beads had cavities and deposits of NaCl at 2% and higher concentrations of sodium alginate. While the FTIR spectra showed that no new peaks were generated in the kombucha beads, stretching peaks were observed at 3000-3500  $\text{cm}^{-1}$ . This study highlighted the potential of alginate beads for encapsulating polyphenolic compounds as an innovative approach for food applications. Further study is needed to understand the release behavior of probiotic microorganisms in kombucha during digestion.

**Keywords**— alginate, antioxidant, kombucha beads, phenolic compounds, viable bacteria

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### I. INTRODUCTION

Kombucha is a fermented drink made by a consortium of yeast and bacteria known as SCOBY (symbiotic colony of bacteria and yeast) [1]. Kombucha originated in China and has gained popularity due to its reputation as a natural source of probiotics. Traditionally, it is prepared by fermenting sweetened tea fermentation for approximately 14 days. Kombucha

fermentation consists of two steps: alcoholic fermentation, which converts sugar into ethanol by yeast, and acidic fermentation, which oxidizes ethanol into organic acids by lactic acid bacteria and acetic acid bacteria [2]. The final product of kombucha has acid and a slight ethanol flavor [1].

Kombucha is considered a functional drink since it contains polyphenolic compounds that act as antioxidants. Polyphenolic compounds found in black tea are transformed into low-

molecular-weight phenolic compounds during kombucha fermentation, thereby enhancing the antioxidant capacity [3]. Kombucha is also a source of lactic acid and acetic acid bacteria; some of them act as probiotics, helping to maintain the balance of bacteria in the gut [4].

Preserving bioactive compounds and probiotics is challenging due to the harsh environment of the human digestive system. The release of bioactive compounds needs to be controlled so that they can be delivered to a specific target [5]. Encapsulation by the spherification technique has been applied to preserve bioactive compounds [6; 7]. Moreover, spherification is also used to preserve probiotics as proposed by [8; 9].

Hydrogel or bead gains interest as it provides a unique experience for consumers on the taste buds [5]. Beads help mask bitterness or unacceptable flavor. Beads also help protect compounds from harsh environments during storage or digestion, allowing them to reach their target. Beads can be made using the spherification or reverse spherification technique with a broad range of hydrocolloids. At the same time, sodium alginate (SA) is the most commonly used hydrocolloid in the encapsulation process [10].

The objectives of this study were (1) to investigate the physical characteristics and release behaviour of phenolic compounds and reducing sugar in kombucha beads made by the addition of sodium alginate at different concentrations; (2) to examine the viability of lactic acid bacteria in kombucha beads made with several concentrations of sodium alginate in simulated gastric juice. This study aims to provide a deeper understanding of how to design kombucha beads to achieve a desired release behavior of bioactive compounds.

## II. Materials and Methods

### A. Materials

Black tea, sucrose and kombucha starters were obtained from the local market. Sodium alginate was bought from the local market. Chemicals for reagents were bought from Merck (Merck, Darmstadt, Hesse, Germany). While standards for analysis, namely catechin, Trolox, and glucose, were purchased from Sigma Aldrich (St. Louis, Missouri, USA).

### B. Production of Kombucha Beads

#### Kombucha Fermentation

Kombucha fermentation was conducted based on [11]. Black tea, 100 grams, was brewed using 800 grams of boiled water, then filtered using cheesecloth. The tea solution was then cooled to room temperature before adding 100 g of sucrose and 100 mL of kombucha starter and SCOBY. Fermentation was conducted for 15 days at room temperature.

#### Producing kombucha beads

Kombucha beads were prepared by mixing 100 mL of kombucha with sodium alginate at varying concentrations (1%, 2%, 3%, 4%, and 5% w/v). The mixture was stirred until sodium alginate was dissolved. Beads were made by adding the mixture to a 3% CaCl<sub>2</sub> solution using a syringe, then soaked for 12 minutes [12].

### C. Evaluation of physicochemical characteristics of kombucha beads

A sample of 1 gram of kombucha beads was mixed with 10 mL of citrate and stirred at 37 °C for 3 hours to release bioactive compounds and sugars, as proposed by [7]. The solution was then used for the analysis of total phenolic content, reducing sugars, and antioxidant capacity.

#### Total phenolic content

The determination of total phenolic content was performed following the Folin-Ciocalteu method proposed by [13]. A sample of 0.1 mL was mixed with 0.1 mL of Folin-Ciocalteu reagent and then allowed to rest for 6 minutes to facilitate the reaction. The mixture was then added with 1 mL of 7% NaCO<sub>3</sub> and 1 mL of distilled water. The absorbance was measured at 760 nm after incubation for 90 minutes using a Mapada UV-100 (Mapada UV-1 100, Shanghai Mapada Instrument Co., Ltd., Shanghai, China). A standard curve was made by plotting gallic acid at several concentrations. The result was reported as mg GAE/100 gram beads.

#### Reducing sugar

A DNS method based on [14] was used for analyzing the reducing sugar content released from kombucha beads. A 0.5 mL sample was mixed with 1.5 mL of DNS reagent (10 g DNS, 300 g potassium sodium tartrate and 20 g sodium hydroxide in 1 L of distilled water) and 1.5 mL of distilled water. The mixture was heated for 5 minutes, then allowed to cool to room temperature, and then the absorbance was measured at 510 nm. The standard curve was plotted using glucose at several concentrations. The result was expressed as mg glucose/g beads.

#### Antioxidant capacity

Antioxidant capacity was measured based on the electron transfer mechanism proposed by [15]. Solution of 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) or ABTS<sup>•+</sup> was prepared by mixing 5 mL of 7 mM ABTS with 88 µL of 140 mM K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> in the dark and holding for 24 hours at room temperature. Absorbance of ABTS<sup>•+</sup> solution was set to 0.700 ± 0.020 at 734 nm by diluting ABTS stock solution with phosphate buffer saline (PBS). A sample of 5 µL was mixed with 1 mL of ABTS<sup>•+</sup> radical solution, then incubated at 30 °C for 4 minutes, and then the absorbance was measured using a UV-100 Mapada spectrophotometer. The standard curve was constructed by plotting Trolox concentrations ranging from 0.5 to 4 mM. The antioxidant capacity was calculated as µmol TE/g beads.

#### Stability of kombucha beads in simulated gastric juice

The stability of kombucha beads was measured as described in [16]. The stability of kombucha beads was defined as the number of lactic acid bacteria present after the kombucha beads were mixed with a low pH solution. Approximately 3 grams of kombucha beads were mixed with 10 mL of 0.2% sodium chloride solution, pH 2, and stirred at 37 °C for 2 hours. A supernatant of 1 mL was taken for the enumeration of lactic acid

bacteria by serial dilution using deMan-Rogosa-Sharpe (MRS) agar as the medium.

#### Physical characteristics of kombucha beads

##### FTIR analysis

Spectra of kombucha beads were analyzed using FTIR (FTIR-8400, Shimadzu, Kyoto, Japan) with resolution at 400-4000/cm wavelength [17]

##### Microstructure Analysis

Analysis of kombucha microstructure was conducted using a scanning electron microscope (SU3500, Hitachi, Tokyo, Japan). Kombucha beads were freeze-dried (DFD-12-SM, B-One, Prioritas Bangun Nusantara, Ltd., Banten, Indonesia) to evaporate water, and then dried kombucha beads were coated with gold. Analysis was conducted at 3000 magnifications [17].

##### Statistical Analysis

The experiments were conducted in two independent replications using a completely randomised block design. The data were evaluated using analysis of variance (ANOVA) at a 95% significance level, followed by Duncan's multiple range tests (DMRT) for post hoc analysis using SPSS software version 12 (SPSS Inc., USA).

### III. RESULT AND DISCUSSION

The shape of kombucha increased as the concentration of sodium alginate increased (**Figure 1**). Kombucha beads with 1-3% sodium alginate had a tear-like sphere, as also proposed by [18]. However, kombucha beads made by the addition of 4-5% showed a capsule-like sphere. A higher concentration of alginate produces larger beads due to the G-block of alginate (guluronic acid), which forms a stronger gel with calcium ions, resulting in capsule-like spheres [19].

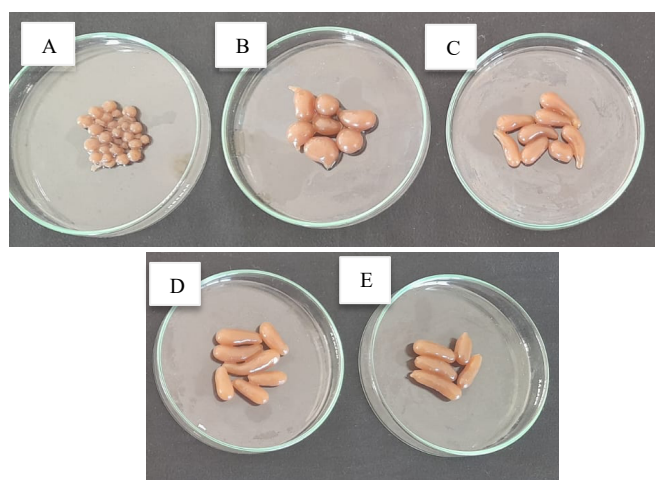


Fig 1. Kombucha beads at sodium alginate concentration of (A) 1%; (B) 2%; (C) 3%; (D) 4%; (E) 5%

The size and hardness of kombucha beads increased ( $P < 0.05$ ) as the concentration of sodium alginate increased, as shown in

**Table 1.** The size of kombucha beads ranged from  $4.32 \pm 0.74$  to  $21.77 \pm 0.39$  mm. While the hardness of kombucha beads ranged from  $17.77 \pm 7.43$  to  $80.82 \pm 1.60$ . Kombucha beads' hardness was higher than pitaya pearls' hardness, which ranged from 1.44 N to 2.49 N as reported by [19], but in agreement with [20] reported hardness of edible bubble from jabuticaba was in the range of 29.28 N to 80.17 N.

TABLE 1.  
EFFECT OF SODIUM ALGINATE CONCENTRATION ON SIZE AND HARDNESS OF KOMBUCHA BEADS

sodium alginate concentration (%)	Size (mm)	Hardness (N)
1%	$4.32 \pm 0.74^c$	$17.77 \pm 7.43^d$
2%	$6.03 \pm 1.37^c$	$55.21 \pm 2.07^c$
3%	$15.23 \pm 0.72^b$	$68.83 \pm 2.73^b$
4%	$20.28 \pm 1.46^a$	$75.71 \pm 2.00^{ab}$
5%	$21.77 \pm 0.39^a$	$80.82 \pm 1.60^a$

Mean  $\pm$  standard deviation. Values with different notations in the same column are significantly different ( $P < 0.05$ )

According to [21], increasing the hydrocolloid concentration would increase viscosity and show a strong gel-like behavior. [22]) Adding a low pH would increase the interaction between kombucha and sodium alginate due to the formation of a strong covalent bond.

The total phenolic content, antioxidant capacity, and reducing sugar of kombucha beads did not differ ( $P \geq 0.05$ ) as the concentration of sodium alginate increased, as shown in **Table 2**. Total phenolic content of kombucha beads ranged from  $5.22 \pm 1.28$  to  $7.04 \pm 1.97$  while antioxidant capacity ranged from  $12.88 \pm 0.21$  to  $22.23 \pm 6.90$ . Reducing sugar of kombucha beads ranged from  $41.70 \pm 8.09$  to  $52.11 \pm 2.16$ .

TABLE 2.  
EFFECT OF SODIUM ALGINATE CONCENTRATION ON TOTAL PHENOLIC CONTENT, ANTIOXIDANT CAPACITY AND REDUCING SUGAR

Sodium alginate concentration (%)	Total phenolic content <sup>ms</sup> (mg GAE/100 g beads)	Antioxidant capacity <sup>ms</sup> ( $\mu$ mol TE/g)	Reducing sugar <sup>ms</sup> (mg/g beads)
1%	$8.33 \pm 0.43$	$15.21 \pm 1.01$	$41.70 \pm 8.09$
2%	$8.32 \pm 1.23$	$22.23 \pm 6.90$	$52.11 \pm 2.16$
3%	$5.22 \pm 1.28$	$12.96 \pm 3.26$	$42.88 \pm 1.01$
4%	$6.65 \pm 0.84$	$21.77 \pm 5.85$	$46.36 \pm 10.42$
5%	$7.04 \pm 1.97$	$12.88 \pm 0.21$	$50.11 \pm 42.57$

Mean  $\pm$  standard deviation

Increasing the hydrocolloid concentration would decrease the release of phenolic content and antioxidant capacity from kombucha beads [23]. [17] observed that high entrapment efficiency was obtained from cumin seed essential oil hydrogel.

Viability of lactic acid bacteria was decreased ( $P < 0.05$ ) as the concentration of sodium alginate was increased (**Table 3**). Viability of lactic acid bacteria ranged from  $65 \pm 21.21$  to  $198 \pm 49.49$  cfu/g. This result agreed with [16] that the use of sodium

alginate did not provide optimum protection against low pH during simulated gastric juice.

TABLE 3.  
 THE EFFECT OF SODIUM ALGinate CONCENTRATION ON THE VIABILITY OF LACTIC ACID BACTERIA

Sodium alginate concentration (%)	Viability of lactic acid bacteria (cfu/ g beads)
1%	198± 49.49 <sup>a</sup>
2%	86 ± 28.28 <sup>b</sup>
Sodium alginate concentration (%)	Viability of lactic acid bacteria (cfu/ g beads)
3%	100± 28.28 <sup>b</sup>
4%	45± 7.07 <sup>b</sup>
5%	65± 21.21 <sup>b</sup>

Mean ± standard deviation. Values with different notations in the same column are significantly different (P<0.05)

**Figure 2** shows the SEM images of kombucha beads. All SEM images of kombucha show a ridge-like structure. Cavities were observed in kombucha beads with concentrations of 3%, 4%, and 5% sodium alginate. The existence of cavities may relate to the decreased viability of lactic acid bacteria at low pH levels as the concentration of sodium alginate increases. A smooth surface was observed in kombucha beads at a low concentration of sodium alginate. Wrinkles were also observed in all kombucha beads, which may be due to water evaporation during the freeze-drying process, as reported by [6].

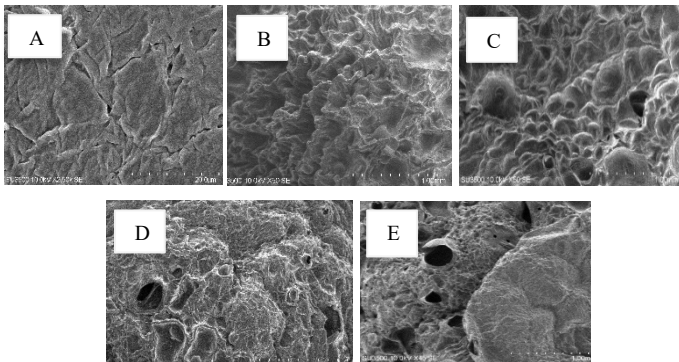


Fig 2. Microstructure of kombucha bead at (A) 1% sodium alginate; (B) 2% sodium alginate; (C) 3% sodium alginate; (D) 4% sodium alginate; (E) 5% sodium alginate at 12 minutes soaking time

**Figure 3** shows FTIR analysis of kombucha added with sodium alginate, which exhibits a broad spectral band at 3433 cm<sup>-1</sup>. This spectrum indicates the presence of hydroxyl groups (-OH), which are typically associated with phenols or alcohols. The band supports this observation at 1033 cm<sup>-1</sup>, a characteristic peak of C-O stretching. Samples made from kombucha tea may contain phenols, water, alcohols, and carboxylic acids as byproducts of fermentation [24; 1]. Additionally, the gel formation is influenced by the concentration of alginate added. Sodium alginate contains numerous hydroxyl groups attached to mannuronate and guluronate rings within its structure [25; 18].

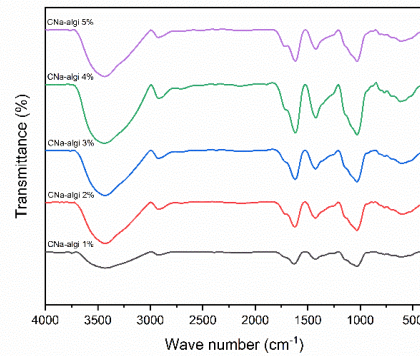


Fig 3. FTIR Spectra of kombucha beads with 1-5% sodium alginate

The peak at 1620 cm<sup>-1</sup> indicates the presence of carbon-carbon double bonds (C=C) associated with aromatic compounds. This is likely due to the gel derived from kombucha tea, which contains polyphenols with an aromatic structure. Similarly, the peak at 1427 cm<sup>-1</sup> suggests CH<sub>3</sub> bending, while the peak at 771 cm<sup>-1</sup> indicates C-H substitution on aromatic bonds. Meanwhile, the band at 609 cm<sup>-1</sup> indicates the presence of ionic C-Cl bonds, likely due to the use of CaCl<sub>2</sub> in the gel preparation process.

Furthermore, a strong band is observed at 2924 cm<sup>-1</sup>, which suggests asymmetric C-H stretching. Another strong peak appears at 1720 cm<sup>-1</sup>, characteristic of the carbonyl stretching in carboxylic acid groups. This may occur when sodium alginate undergoes protonation and interacts with kombucha, while some alginic acid remains unbound. This free acid contains carbonyl groups in the form of carboxylic acids. From the spectra obtained, it is evident that as the concentration of sodium alginate increases, the intensity of the band at 1720 cm<sup>-1</sup> also strengthens.

Kombucha beads can be produced using the spherification technique with sodium alginate. Increasing the sodium alginate concentration increases both the size and hardness. Interestingly, it does not affect the release of phenolic compounds, antioxidants, or reducing sugars. It is noteworthy that cavities were observed in samples with 3% to 5% sodium alginate, and this may be related to the low viability of lactic acid bacteria in simulated gastric juice. At a concentration of more than 2%, kombucha beads exhibit a strong gel due to covalent bonds supported by the low pH of kombucha [21; 26]. As also observed in the FTIR spectra, which show stretching in C-O and C-H.

#### IV. CONCLUSION

In summary, the application of the spherification technique to make kombucha beads can be done by using sodium alginate. Moreover, spherification could help retain the release of phenolic content and antioxidant capacity, as well as reducing sugar. However, the viability of lactic acid bacteria decreases

as the concentration of sodium alginate increases, indicating the need to use two or more hydrocolloid mixtures to provide a smooth and compact surface structure of kombucha beads. This study highlights the production of kombucha beads using the spherification technique, providing a unique experience in consuming kombucha.

#### CONFLICT OF INTEREST

The authors declared no conflict of interest.

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#### USE OF ARTIFICIAL INTELLIGENCE (AI) TOOLS STATEMENT

We used Grammarly (Grammarly Inc., 2025) to improve the clarity and grammar of the manuscript. The authors reviewed and approved all changes.

#### REFERENCES

- [1]. B. Wang, K. Rutherford-Markwick, X.-X. Zhang, and A. N. Mutukumira, "Kombucha: Production and Microbiological Research," *Foods*, vol. 11, no. 21, p. 3456, Oct. 2022, doi: 10.3390/foods11213456.
- [2]. B. M. Bortolamedi, C. S. Paglarini, and F. C. A. Brod, "Bioactive compounds in kombucha: A review of substrate effect and fermentation conditions," *Food Chemistry*, vol. 385, p. 132719, Aug. 2022, doi: 10.1016/j.foodchem.2022.132719.
- [3]. S. Shi et al., "Microbial metabolic transformation and antioxidant activity evaluation of polyphenols in kombucha," *Food Bioscience*, vol. 51, p. 102287, Feb. 2023, doi: 10.1016/j.fbio.2022.102287.
- [4]. B. K. Vargas, M. F. Fabricio, and M. A. Záchia Ayub, "Health effects and probiotic and prebiotic potential of Kombucha: A bibliometric and systematic review," *Food Bioscience*, vol. 44, p. 101332, Dec. 2021, doi: 10.1016/j.fbio.2021.101332.
- [5]. Md. N. Saqib, B. M. Khaled, F. Liu, and F. Zhong, "Hydrogel beads for designing future foods: Structures, mechanisms, applications, and challenges," *Food Hydrocolloids for Health*, vol. 2, p. 100073, Dec. 2022, doi: 10.1016/j.fhfh.2022.100073.
- [6]. F.-H. Tsai, P.-Y. Chiang, Y. Kitamura, M. Kokawa, and M. Z. Islam, "Producing liquid-core hydrogel beads by reverse spherification: Effect of secondary gelation on physical properties and release characteristics," *Food Hydrocolloids*, vol. 62, pp. 140–148, Jan. 2017, doi: 10.1016/j.foodhyd.2016.07.002.
- [7]. M. Pereira Silveira, F. Lucas Chaves Almeida, I. Dutra Alvim, and A. Silvia Prata, "Encapsulation of pomegranate polyphenols by ionic gelation: Strategies for improved retention and controlled release," *Food Research International*, vol. 174, p. 113590, Dec. 2023, doi: 10.1016/j.foodres.2023.113590.
- [8]. X. Qi, S. Simsek, B. Chen, and J. Rao, "Alginate-based double-network hydrogel improves the viability of encapsulated probiotics during simulated sequential gastrointestinal digestion: Effect of biopolymer type and concentrations," *International Journal of Biological Macromolecules*, vol. 165, pp. 1675–1685, Dec. 2020, doi: 10.1016/j.ijbiomac.2020.10.028.
- [9]. U. Ali et al., "Stability and Survivability of Alginate Gum-Coated *Lactobacillus rhamnosus* GG in Simulated Gastrointestinal Conditions and Probiotic Juice Development," *Journal of Food Quality*, vol. 2023, pp. 1–13, Jan. 2023, doi: 10.1155/2023/3660968.
- [10]. E. Akinci and D. Holthaus, "Hydrocolloids and gums as encapsulating agents," *Microencapsulation in the Food Industry*, pp. 309–323, 2023, doi: 10.1016/b978-0-12-821683-5.00022-4.
- [11]. A. Z. Mohsin et al., "The effects of encapsulation process involving arabic gum on the metabolites, antioxidant and antibacterial activity of kombucha (fermented sugared tea)," *Food Hydrocolloids for Health*, vol. 2, p. 100072, Dec. 2022, doi: 10.1016/j.fhfh.2022.100072.
- [12]. S. Gaikwad, A. Kulthe, and T. Suthar, "Characterization of flavoured sweet water balls prepared by basic spherification technique". *International Journal of Chemistry Study*, vol. 7, no. 1, pp. 1714-1718, Feb. 2019. dx.doi.org/10.22271/chemi.
- [13]. V. Dewanto, X. Wu, K. K. Adom, and R. H. Liu, "Thermal Processing Enhances the Nutritional Value of Tomatoes by Increasing Total Antioxidant Activity," *Journal of Agricultural and Food Chemistry*, vol. 50, no. 10, pp. 3010–3014, Apr. 2002, doi: 10.1021/jf0115589.
- [14]. A. A. N. Saqib and P. J. Whitney, "Differential behaviour of the dinitrosalicylic acid (DNS) reagent towards mono- and di-saccharide sugars," *Biomass and Bioenergy*, vol. 35, no. 11, pp. 4748–4750, Nov. 2011, doi: 10.1016/j.biombioe.2011.09.013.
- [15]. R. Re, N. Pellegrini, A. Proteggente, A. Pannala, M. Yang, and C. Rice-Evans, "Antioxidant activity applying an improved ABTS radical cation decolorization assay," *Free Radical Biology and Medicine*, vol. 26, no. 9–10, pp. 1231–1237, May 1999, doi: 10.1016/s0891-5849(98)00315-3.
- [16]. N. Khajehie, M. Niakousari, M. H. Eskandari, M. Majdinasab, and S. S. Shekarfroush, "Microencapsulation of *Lactocaseibacillus rhamnosus* GG and *L. plantarum* 299 V by reverse spherification: a promising method to improve the survival of probiotics," *Letters in Applied Microbiology*, vol. 76, no. 1, Dec. 2022, doi: 10.1093/lambio/ovac025.
- [17]. S. Gholamian, M. Nourani, and N. Bakhshi, "Formation and characterization of calcium alginate hydrogel beads filled with cumin seeds essential oil," *Food Chemistry*,

- vol. 338, p. 128143, Feb. 2021, doi: 10.1016/j.foodchem.2020.128143.
- [18]. C. Bennacef, S. Desobry-Banon, L. Probst, and S. Desobry, "Advances on alginate use for spherification to encapsulate biomolecules," *Food Hydrocolloids*, vol. 118, p. 106782, Sep. 2021, doi: 10.1016/j.foodhyd.2021.106782.
- [19]. S. F. A. Bubin et al., "Characterization and stability of pitaya pearls from hydrocolloids by reverse spherification," *International Journal of Food Properties*, vol. 22, no. 1, pp. 1353–1364, Jan. 2019, doi: 10.1080/10942912.2019.1647234.
- [20]. D. G. Bortolini, G. M. Maciel, and C. W. I. Haminiuk, "Edible bubbles: A delivery system for enhanced bioaccessibility of phenolic compounds in red fruits and edible flowers," *Innovative Food Science & Emerging Technologies*, vol. 91, p. 103523, Jan. 2024, doi: 10.1016/j.ifset.2023.103523.
- [21]. I. Fernández Farrés, M. Douaire, and I. T. Norton, "Rheology and tribological properties of Ca-alginate fluid gels produced by diffusion-controlled method," *Food Hydrocolloids*, vol. 32, no. 1, pp. 115–122, Jul. 2013, doi: 10.1016/j.foodhyd.2012.12.009.
- [22]. J. Yang, J. Steck, and Z. Suo, "Gelation kinetics of alginate chains through covalent bonds," *Extreme Mechanics Letters*, vol. 40, p. 100898, Oct. 2020, doi: 10.1016/j.eml.2020.100898.
- [23]. A. N. Dunder, K. Uzuner, M. E. Parlak, O. I. Sahin, F. T. Saricaoglu, and S. Simsek, "Enhanced Functionality and Bio-Accessibility of Composite Pomegranate Peel Extract-Enriched 'Boba Balls,'" *Foods*, vol. 11, no. 23, p. 3785, Nov. 2022, doi: 10.3390/foods11233785.
- [24]. R. R. Cardoso et al., "Kombuchas from green and black teas have different phenolic profile, which impacts their antioxidant capacities, antibacterial and antiproliferative activities," *Food Research International*, vol. 128, p. 108782, Feb. 2020, doi: 10.1016/j.foodres.2019.108782.
- [25]. A. Khajouei, L. Tounsi, N. Shahabi, A.K. Patel, S. Abdelkafi, and P. Michaud. "Structures, Properties and Applications of Alginates". *Marine Drugs*, vol. 20, no. 6, pp. 1-18, May, 2022. doi.org/10.3390/md20060364.
- [26]. S. Sabet et al., "The interactions between the two negatively charged polysaccharides: Gum Arabic and alginate," *Food Hydrocolloids*, vol. 112, p. 106343, Mar. 2021, doi: 10.1016/j.foodhyd.2020.106343.