

Development and Characterization of Sodium Alginate/Gum Arabic Beads using Encapsulation Technique with Dimocarpus longan Extracts for Food Industry

Varunya Fuangchoom

Maejo University

Nukrob Narkprasom

Maejo University

Somkiat Jaturonglumlert

Maejo University

Jaturapatr Varith

Maejo University

Rajeswaran Ramaraj

Maejo University

Thitirat Rattanawongwiboon

Thailand Institute of Nuclear Technology (Public Organization)

Kanjana Narkprasom (✉ knarkprasom@gmail.com)

Maejo University

Research Article

Keywords: Longan bead, Sodium alginate, Encapsulation efficiency, Gamma irradiation

Posted Date: January 31st, 2024

DOI: <https://doi.org/10.21203/rs.3.rs-3907489/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Encapsulation can be accomplished by a variety of methods. Extrusion is used to obtain granules with encapsulated liquid active ingredients for food and pharmaceutical applications and has been used for volatile active compounds. This work aimed to study the microencapsulation of the total phenolic compound of longan extract through the extrusion method. According to the findings of the study of the encapsulation process of longan extract, the optimized condition of longan beads was 1.5% sodium alginate and 4% calcium chloride. Under these conditions, the total phenolic compound, antioxidant activity, and encapsulation efficiency of longan extract beads were 3.845 mgGAE/gbead, 55.06%, and 66.95%, respectively. A study of the combination of sodium alginate with natural polymers (gelatin, pectin, and gum arabic) found that alginate/gum Arabic longan beads had the highest encapsulation efficiency of $74.86 \pm 0.171\%$. The effect of pH on the stability of total phenolic compounds (pH 2, 5, and 8) found that longan beads exhibited good stability under acidic conditions were studied. Finally, to study the effect of gamma irradiation on sterilization and the physical of longan beads, A gamma irradiation dose of 7.5 kGy could effectively sterilize microorganisms and strengthen the longan beads. These results indicate that longan beads can produce beads rich in phenolic compounds that can be used as natural supplements and antioxidants in various food products.

1. Introduction

Consumers have recently become more interested in using food to improve their health as well as prevent ailments. As a result, it is critical to produce new food products that contain benefits. Longan is a tropical fruit that grows in abundance in the subtropics. It is one of many fruits that Thailand grows in sufficient quantities to meet the needs of the country. They can also be exported. One of Thailand's most important economic crops is longan. It has a distinct flavor and scent that makes comparisons to other fruits difficult. However, the longan has a short shelf life. Processing canned longan, longan in syrup, and dried longan are some of the popular ways in the processed longan industry to extend the shelf life. However, the activities involved in the processing of, longan result in seed as waste from the production process. Longan seeds are rich in phenolic compounds, composed of gallic acid, ellagic acid, and corilagin [1], which are natural sources of antioxidants. Polyphenols, on the other hand, have a disadvantage: they have a high rate of metabolism, poor water solubility, and sensitivity to heat and light in their free state, which causes them to leave the body rapidly. All of these characteristics contribute to low stability and bioavailability, significantly reducing their effectiveness [2].

Encapsulation is a technique for protecting delicate substances from the effects of the environment. Encapsulation can also help with regulated release and masking unpleasant sensory characteristics of some substances [3]. There are several encapsulation techniques, but the most widely used is the extrusion method because it is simple to prepare, can be made in a single step, and allows the user to regulate the particle size, which consists of mixing longan seed extract into hydrocolloid solution, followed by extrusion through the nozzle. After that, droplets, or sprayed into a bath of calcium chloride solution, and then stirred to distribute them [4]. While there are many kinds of hydrocolloids, sodium

alginate is the most widely utilized form for encapsulation since it is a non-toxic, biodegradable biomaterial with various uses in the food sector. The disadvantage of sodium alginate particles is their high porosity and susceptibility to acidic environments [5]. To overcome this, it can be resolved by combining alginate with other natural polymers. Alginate can dimerize to form bridges with other chains and produce hydrogel networks. Alginate and other polyelectronegative polymers will interact via intermolecular hydrogen bonds. The combination with polymers, such as gum arabic, pectin, and gelatin can increase their synergistic effect compared to the single polymer [6].

Gamma irradiation is an extremely effective disinfection method. It offers several advantages over other sterilizing methods: Gamma radiation has a high rate of penetration. There are no leftover effects from a modest chemical reaction. During irradiation, the temperature changes somewhat. It is a process that is completed in one step. Further, it is attractive when comparing price and performance. The biological sterilization of materials that will be utilized to make biomedical products is also done with gamma irradiation. Furthermore, ionizing radiation causes the breaking of glycosidic linkages in polysaccharides like alginate, resulting in their destruction. As a result, this technology is less complicated and less harmful to the environment than traditional approaches [7].

Based on the, this research aimed to study the variables that impact phenolic compound encapsulation in longan extracts, study the stability to pH of longan beads, and develop the use of gamma radiation for the sterilization of longan extract beads.

2. Materials and methods

2.1 Materials

Dried longans were obtained from a pilot plant located at Maejo University (Chiang Mai, Thailand). A blender was used to ground the longan flesh and seeds into powder, which was then dried at 45 °C for 20 hours before being milled to 40 mesh powder (Fig. 1). Samples were then put in aluminum trays and exposed to 254 nm UV light in a cabinet (ESCO Laminar Flow Cabinet) with type-II laminar flow for 60 minutes to sterilize them. The powder was then put in bags made of aluminum foil and preserved in desiccators.

2.2 Extraction procedure by Microwave-Assisted Extraction

In this research, the microwave-assisted extraction technique approach was used to extract the total phenolic compound and antioxidant activity from longan. Prepared 1 g of longan powder into a round bottom flask and 30 ml of distilled water, then extract using a microwave oven (Samsung, MS23F300EEK) that has been modified by a Soxhlet condenser coil extractor set was connected to a vapor condenser (Coolab, WBCI-15) that is set to 10°C (Fig. 2). The extraction time is 15 min, and the microwave power is 700 watts. Take the round-bottom bottle out of the microwave to allow it to cool when extraction is finished. The extract was then separated from the sediment using a centrifuge

(Dynamica, Velocity 18R) running at 3500 rpm for 15 minutes. Following the completion of the filtration, the clear extract was measured to determine the final volume and kept at room temperature in a tea-colored bottle until the following phase of analysis [8]. According to preliminary testing, longan extract has an antioxidant activity of 40.89% and a total phenolic compound of 20.14 mg_{GAE}/g_{sample}. The total soluble solids and total phenolic compounds in the longan extract increased thrice from the initial when concentrated using a vacuum evaporator quantity to 15 °Brix and 62.42 mg GAE/sample, respectively.

Preferable position for Fig. 2

2.3 Encapsulation procedure

The process for encapsulation of longan beads using the extrusion method has been slightly modified [9]. The instrumental parameters were improved during preliminary testing by Encapsulator B390 (BUCHI Labortechnik AG 9230 Flawil, B-390) (Fig. 3), and it was found that 3 ml/min of flow rate, 1440 Hz of frequency, and 440 V of electrode voltage could produce stable beads.

A three-level full factorial design was used to optimize the remaining encapsulation parameters while considering two encapsulation parameters. The concentration of the sodium alginate (Tokuyama Corporation, Japan) in the longan extract (1, 1.5, and 2 g/ml) and the concentration of the calcium chloride (3, 4, and 5 g/ml) were varied at three levels. Encapsulation efficiency of the total phenolic compounds, total phenolic compound, and antioxidant activity were among the response variables. After identifying the appropriate conditions, the alginate was combined with other natural polymers and studied to assess which one had the most encapsulation efficiency.

Preferable position for Fig. 2

2.4 Sizes and shapes

The particle size of the beads was analyzed 20 longan beads were randomly selected from each experiment. Then measure the diameter (D) with a digital vernier caliper to determine (500-196-30, Mitutoyo). Data is recorded as mean $\pm$ standard deviation (SD).

2.5 Mechanical properties

Texture profile analysis of longan beads was carried out using a Texture Analyzer (model TA. XT-PLUS, Stable Micro Systems, UK). 10 longan beads were randomly selected for testing using a cylinder p/50 probe at room temperature, compressed by 75% strain using pre-test speed of 1.0 mm/s, test speed of 5.0 mm/s, post-test speed of 5.0 mm/s, and trigger force of 5.0 g.

2.6 Surface morphology analysis

Longan beads were dried by freeze-drying before surface morphology analysis. Scanner electron microscopy (SEM) (JEOL, JMS 5410 LV) was used to examine the surface morphology of the dried beads for each formulation. To increase the conductivity, double-sided carbon tape is used to mount the beads to the aluminum stub. The beads are then gold-plated with a sputtering coater (JEOL, JFC1200). The

thickness of the gold layer applied to the sample should be approximately 10–20 nm, after which their morphology was examined in high vacuum mode, and samples underwent observation at an accelerating voltage of 15 kV.

2.7 Encapsulation efficiency (EE%)

Encapsulation efficiency was assessed with the quantity of encapsulated total phenolic compounds in beads (TPCb) and total phenolic compounds of the solution used for bead preparation (TPC).

Quantification of the encapsulated total phenolic compounds in beads was carried out after the beads were dissolved in a 5% (w/v) Na-citrate solution and then centrifuged at 7,500 rpm to dissolve them at 25 °C for 30 min, analyzed for phenolic compounds to calculate the encapsulation efficiency (%) as shown in Eq. (1):

$$\text{Encapsulation efficiency (\%)} = \frac{TPC_b}{TPC_s} \times 100$$

2.8 Stability to positive potential of the hydrogen ions (pH)

The effect of pH on the stability of total phenolic compounds was assessed by immersing the beads in solutions with different positive potential of the hydrogen ions (pH) are 2, 5, and 8 for 2 hours with magnetic stirring. The amounts of phenolic compound released were analyzed and calculated with the following Eq. (2):

$$\text{Total phenolic release (\%)} = \frac{E}{E_0} \times 100$$

where E is the amount of total phenolic compound determined in the release, and E_0 is the initial amount of total phenolic compound in the beads.

2.9 Quantitative total phenolic compound analysis

Total phenolic compounds were determined in longan extract samples that had undergone microwave-assisted extraction using the Folin–Ciocalteu reagent methods adapted from [10] using gallic acid as a standard. In a test tube, add 2 ml of sodium carbonate solution (Na_2CO_3) at a concentration of 2% w/v and thoroughly mix the 0.1 ml of longan extract sample. Wrap foil around the tube's mouth. 01 ml of Folin Ciocalteu reagent was added and thoroughly mixed. Leave the sample in the dark at room temperature for 30 minutes and measure the absorbance at a wavelength of 750 nm using a spectrophotometer. The data were calculated by comparing it with the gallic acid standard curve and reported the results in milligrams of gallic acid equivalents/mg of sample (mg/g Galic acid equivalent, GAE).

2.10 Quantitative antioxidant activity

The method used in this study was modified from the method by [11]. In the process of preparing the DPPH (2,2-Diphenyl-1-picrylhydrazyl) solution with a concentration of 5 mM. To do this, weigh 0.1972 grams of the chemical (2,2-Diphenyl-1-picrylhydrazyl) and then use methanol to adjust the volume to 100 milliliters. In the next step, pipette 2 ml of a 5 mM concentration of DPPH solution. To obtain a 0.1 mM concentration DPPH solution, adjust the volume with methanol until it reaches 100 ml (this solution should be newly produced every time before use).

The assessment of the antioxidants from longan extract, pipetting 0.1 ml of longan extract into a test tube, adding 2.9 ml of a concentrated 0.1 mM DPPH solution, and thoroughly shaking with a vortex mixer. Leave it at room temperature (in the dark) for 30 minutes. Concurrently, prepare a DPPH solution or control sample devoid of any extract samples that were examined with the same techniques. The absorbance of the longan extract samples and the control samples was then measured absorbance using a spectrophotometer at 515 nm. Antioxidant activity was calculated as a percentage of inhibition (% inhibition) as in Eq. 3.

$$\%Inhibittion = \frac{(A_{control} - A_{sample})}{A_{control}} \times 100$$

2.11 Sterilization by Gamma irradiation

In this study, the ^{60}Co from a Gamma chamber 5000 irradiator (India), which was provided by the Thailand Institute of Nuclear Technology (Public Organization) in Thailand, was used as the gamma-ray source with an absorbed dose rate of 2.0 kGy/h. For preparation before irradiation, the longan beads in the solution were placed in a glass bottle and subsequently irradiated at four different doses: 2.5, 5, 7.5, and 10 kGy. After irradiation, the samples were kept in the refrigerator to avoid the generating of a new microorganisms. The texture of the longan beads was then measured and checked for the presence of bacteria and mold.

2.12 Statistical analysis

For each experimental condition, all tests were performed at least three times, and mean values were presented. Data were analyzed of Variance (ANOVA) were performed, followed by Duncan's New Multiple Range Test (95% confidence interval), using IBM SPSS Statistics 26.0 software. The results were expressed as means $\pm$ standard deviations.

3. Results and discussion

3.1 Optimization of encapsulation of longan extracts beads by extrusion method

Enhance the quality of goods by implementing the process of encapsulation. They enhance the taste, aroma, nutrient absorption, accurate dispersion of beneficial compounds, and longevity of the food. This technique improves the ability to taste, masks bad odors, and intensifies the experience of flavors, so

making it easier to create new drinks. The health benefits of liquids are enhanced through encapsulation [3]. In this study, concentrations of alginate in longan extract (1, 1.5, and 2% w/v), and calcium chloride (3, 4, and 5% w/v) were used to prepare, several formulations by the extrusion method, and then the encapsulation efficiency of total phenolic compound and antioxidant activity were investigated. The results showed that no beads formed when the sodium alginate and calcium chloride concentrations were less than 1% and 3% (w/v), respectively, and when the sodium alginate concentration was higher than 2% (w/v), the resulting beads were not spherical due to high viscosity. The beads began to form into a spherical trough when the sodium alginate concentration was 1% (w/v) or more. Generally, ionotropic gelation is used to cross-link calcium ions with alginate gels. More gel crosslinking will occur as a result of the calcium addition. As a result, low alginate concentrations lack the necessary carboxyl groups to produce calcium ion-containing spherical beads.

The effect of the concentration of sodium alginate and Calcium chloride solution on the shape changes of longan beads (Fig. 4). The morphologies of longan beads may vary depending on the concentration of sodium alginate solution. The morphologies of the longan beads, which had sperm-like features, changed more clearly as sodium alginate solutions with greater concentrations were utilized. This might be a result of the sticky sodium alginate solution's high concentration. The beads' heads left the needle nozzle when the solution was pumped out through it, but the beads' ends remained and stuck to the needle nozzle due to surface tension forces. The beads did, however, leave the needle with a tail due to gravity and push. Additionally, due to the insufficient sodium alginate solution concentration, the surface layer did not contain enough sodium alginate. As a result, the surfaces of beads began to shrink when the gel was produced that had a structure similar to that of a current.

Preferable position for Fig. 4

The particle size of beads and the optimum conditions for encapsulation of phenolic compounds are shown in Table 1. The results show that the mean particle size of all conditions was between 2.34 mm and 3.86 mm. It was found that each formulation's particle size distribution remained within a narrow band, however, the particle size varied slightly with a concentration of calcium chloride, but a concentration of sodium alginate has a big impact on particle size. The sodium alginate solution's concentration significantly impacted the strength and size of the longan granules. The high concentration of sodium alginate solution resulted in larger and stronger longan beads. The solution is very viscous, so when it is dropped into the calcium chloride, it does so slowly [12]. It can be concluded that viscosity is an important parameter for particle size. The percentage of encapsulation efficiency ranged from 51.05 to 66.95%. The study showed that the encapsulation efficiency of phenolic compounds was improved with higher sodium alginate concentrations. The encapsulation efficiency was not significantly affected by the concentration of calcium chloride, and the optimal concentration of sodium alginate was 1.5%. This study's alginate concentration is consistent with that of the earlier investigation on phenolic encapsulation employing *Clitoria ternatea* petal extract [13].

Table 1

Study the effect of sodium alginate and calcium chloride on encapsulating beads by extrusion method

Treatment	Concentrate of Sodium alginate (%)	Concentrate of CaCl ₂ (%)	Beads diameter (mm)	Encapsulation Efficiency of TPC (%)	Total phenolic compound (mgGAE/g beads)	Antioxidant activity (%)
1	1	2	3.86	51.05 ± 0.387 ^e	2.944 ± 0.027 ^d	28.52 ± 0.156 ^e
2	1	4	3.83	55.09 ± 0.571 ^d	3.176 ± 0.119 ^c	32.84 ± 0.107 ^d
3	1	6	2.75	60.53 ± 0.101 ^c	3.551 ± 0.054 ^b	46.49 ± 0.300 ^b
4	1.5	2	3.44	58.48 ± 0.801 ^c	3.459 ± 0.178 ^b	40.28 ± 0.641 ^c
5	1.5	4	3.51	66.95 ± 0.451 ^a	3.845 ± 0.113 ^a	55.06 ± 0.899 ^a
6	1.5	6	2.47	63.41 ± 0.533 ^b	3.698 ± 0.082 ^a	53.83 ± 0.862 ^a
7	2	2	3.22	52.63 ± 0.315 ^e	2.811 ± 0.156 ^d	28.16 ± 0.254 ^e
8	2	4	3.27	58.45 ± 0.770 ^c	3.506 ± 0.278 ^b	45.92 ± 0.723 ^b
9	2	6	2.34	54.28 ± 0.613 ^d	3.221 ± 0.117 ^c	32.31 ± 0.212 ^d
Different superscripts (a to h) in the same column indicate statistical significance ($p \leq 0.05$).						

Preferable position for Table 1

Table 2 shows the optimized encapsulate parameters using alginate and different polymers using a ratio of 1:0.5%v/v. It can be assumed that the combination of sodium alginate with other natural polymers may reduce the porosity of sodium alginate particles and affect the release of encapsulated beads. Further, the addition of other polysaccharides to the alginate matrix raises the viscosity of the beads and allows for a synergistic interaction that enhances their stability [14]. Thus, this experiment aimed to investigate the sodium alginate with gelatin, gum Arabic, and pectin that affect encapsulation efficiency. It was found that sodium alginate combination with gum Arabic had the highest encapsulation efficiency at 74.86 ± 0.171%. Gum Arabic is an emulsifier that is used to improve the mixing of components. Gum

Arabic can be added to alginate in CaCl₂ solution to help reduce side-by-side aggregation, which can cause alginate to swell because of the electrostatic repulsive force between carboxylate anions. It also aids in the retention of water within the product [6].

Table 2
Study effect of sodium alginate combined natural polymers on encapsulation efficiency

sample	Bead diameter (mm)	Encapsulation efficiency (%)	Hardness (N)	Springiness	Cohesiveness
Sodium Alginate	3.54	65.54 ± 0.048 ^d	4.210 ± 0.244 ^c	0.927 ± 0.020 ^b	0.446 ± 0.064 ^c
Sodium Alginate + Gelatin	3.32	69.69 ± 0.225 ^b	5.654 ± 0.217 ^b	0.935 ± 0.024 ^a	0.453 ± 0.031 ^b
Sodium Alginate + Gum Arabic	3.25	74.86 ± 0.171 ^a	7.125 ± 0.167 ^a	0.601 ± 0.019 ^c	0.525 ± 0.026 ^a
Sodium Alginate + Pectin	3.29	71.35 ± 0.187 ^b	5.267 ± 0.136 ^b	0.893 ± 0.167	0.414 ± 0.129 ^b

Preferable position for Table 2

3.2 Stability to pH of longan beads

The total phenolic compound release from the longan beads was investigated for 2 hours at 2, 5, and 8, as shown in Fig. 5. The released amount of total phenolic compounds is minor at pH 2 in the beginning since alginates are water-soluble polysaccharides but will not dissolve in acidic conditions. Numerous positively charged ions are present at low pH levels, and there is less electrical repulsion between negatively charged alginate molecules. As a result, the protons of alginate are therefore present as insoluble alginic acid [15]. Therefore, the penetration of the total phenolic through the wall of alginate is slower in acidic pH, resulting in a lower total phenolic compound release. At a high pH (pH 8), the phenolic compounds are highly released due to the deprotonation of alginic acid formed at higher pH, where it draws external fluids to the inside of the beads, thus causing the beads to swell and release phenolic compounds [16]. Woo et al. [17] reported that sodium alginate forms a gel at an acidic pH. At low pH, the rate of the cracking strength of alginate beads reduces. The excellent gelling ability of low pH sodium alginate is attributed to the exchange of calcium and sodium ions. Longan beads were observed to have exceptional stability in acidic conditions throughout this experiment. The rate of release is comparatively slower and lower in meals with high pH levels.

Preferable position for Fig. 5

3.3 Assay of sterilization effect

Longan beads were disinfected with gamma radiation at 2.5, 5, 7.5, and 10 kGy. To determine the effectiveness of gamma radiation at the lowest concentration dose of destroying microorganisms in longan beads shown in Table 3. The disinfection effect was monitored by counting viable microorganisms produced in 3M Petrifilm™ plates. The results of the tests revealed that before sterilization, the total aerobic bacteria were 3.3×10^2 CFU/g. The populations in the longan beads were 28×10^{-1} and 8×10^{-1} CFU/mg, respectively, following irradiation at 2.5 and 5 kGy, while the populations in the sample fell to undetectable after sterilization at 7.5 kGy. The molds were 2.5×10^2 CFU/mg in non-sterilized longan beads and not detected after sterilized longan beads at 7.5 kGy. The standard by Codex [18] stipulated that the maximum absorption amount that can be provided to food is now limited to 10 kGy unless it's required to carry out a legitimate technological procedure. The findings suggest that microorganisms can be efficiently sterilized by irradiation dose of 7.5 kGy.

Table 3

Inactivation of microbial population in longan beads by gamma irradiation

Microorganism (CFU/mg)	Not sterilized	Gamma irradiation			
		2.5 kGy	5 kGy	7.5 kGy	10 kGy
Total aerobic bacteria	3.3×10^2	28×10^{-1}	8×10^{-1}	ND	ND
Yeast/molds	2.5×10^2	30×10^{-1}	16×10^{-1}	ND	ND
*ND: not detectable within a detection limit < 1.00 CFU/mg.					

Preferable position for Table 3

3.4 Effect of gamma irradiation on the physical and morphology characterization of longan

beads

The shape and morphological analysis of longan beads before and after gamma-irradiated exposure were analyzed using SEM photographs at different magnifications (Fig. 6). After freeze-drying, unirradiated longan beads were found to have a collapsed and shrunken morphology, which may have been caused by the phenolic compound within the beads sublimating. When compared with irradiated longan beads at 2.5, 5, 7.5, and 10 kGy, these beads were found to have a more homogenous, compact, and spherical structure than un-irradiated longan beads. When the radiation dose is increased beyond 5 kGy, the structure fills the matrix's voids, reducing porosity and smoothing the surface since the polymers are homogeneous. Detailed examination, the non-irradiated longan beads had a surface wall tear, shrunken shape, and surface gaps; in contrast, the irradiated longan beads had a stronger surface and no rip scars on the bead wall. Gamma radiation has a significant impact on alginates. The formation of free radicals and the molecules cross-linking at low radiation doses provides the alginate gel with enhanced mechanical strength [19]. After a dose of 7.5 kGy dose, however, the strength of the beads began to

decline due to high concentrations of gamma radiation, leading to a decrease in gelling stability and gel strength of alginate. Alginate, a polysaccharide, typically degrades when exposed to a greater dosage of gamma radiation by breaking the glycosidic bond [20]. Therefore, the proper concentration of gamma irradiation contributes to the strength of the longan beads.

Preferable position for Fig. 6

Mechanical textural parameters were obtained using TPA compression analysis (Table 4). Longan beads exhibited a significant difference in hardness under various settings ($p < 0.05$). Longan beads exposed to gamma radiation at 5 kGy had the highest strength, springiness, and cohesiveness, with values of 7.426 ± 0.397 N, 0.691 ± 0.197 , and 0.655 ± 0.014 , respectively. The rate of gel swelling in irradiation longan beads improved as a result of the values. When the concentration is higher than 5 kGy, the beads expand and the wall breaks, weakening the longan beads.

Table 4
Mechanical textural parameters of longan beads on different radiation doses

Radiation dose (kGy)	Bead diameter (mm)	Hardness (N)	Springiness	Cohesiveness
Un-irradiated	3.34 ± 0.078^d	6.784 ± 0.163^d	0.637 ± 0.214^{cd}	0.575 ± 0.064^c
2.5 kGy	3.42 ± 0.124^c	7.246 ± 0.134^b	0.678 ± 0.245^b	0.591 ± 0.167^b
5 kGy	3.58 ± 0.172^a	7.426 ± 0.397^{ab}	0.691 ± 0.197^a	0.659 ± 0.014^a
7.5 kGy	3.57 ± 0.031^a	7.442 ± 0.241^a	0.648 ± 0.321^c	0.644 ± 0.089^a
10 kGy	3.48 ± 0.218^b	7.016 ± 0.172^c	0.633 ± 0.157^d	0.561 ± 0.052^c

Preferable position for Table 4

4. Conclusion

The encapsulation of the total phenolic compounds by the extrusion method using sodium alginate as the encapsulation polymer results in spherical beads and high encapsulation efficiency. Particles with the highest encapsulation efficiency were those made with sodium alginate at a concentration of 1.5% (w/v). and studied the combination of alginate with natural polymers and found that gum arabic helps to cover the pores of sodium alginate, the phenolic compound can be retained in the longan beads when sodium alginate is combined with gum Arabic, resulting in the longan bead encapsulation efficiency increasing to 74.86%. The longan beads were also stronger after being irradiated with gamma rays at 5 kGy, and an irradiation dose of 7.5 kGy can effectively sterilize microorganisms on longan beads. These findings

suggest that irradiating longan beads can yield richer beads with antioxidant activity and total phenolic compounds, which can be added to various food products or consumed as dietary supplements.

Declarations

Authors' contributions

Varunya Fuangchoom: Conceptualization, Methodology, Experiments and Data Analysis, Manuscript Writing and Editing. **Nukrob Narkprasom, Somkiat Jaturonglumert, Jaturapatr Varith, Rajeswaran Ramaraj:** Manuscript Writing and Editing, **Thitirat Rattanawongwiboon :** Resources, Supervision, Conceptualization **Kanjana Narkprasom:** Methodology, Experiments and Data Analysis, Funding Acquisition, Resources, Supervision, Proofreading, Editing.

Funding Not applicable.

Availability of data and materials Not applicable.

Acknowledgments

The authors gratefully appreciate gratitude is also extended to the Faculty of Engineering and Agro-Industry, Maejo University for providing the research facilities and support.

References

1. Sudjaroen Y, Hull WE, Erben G, Würtele G, Changbumrung S, Ulrich CM, Owen RW (2012) Isolation and characterization of ellagitannins as the major polyphenolic components of Longan (*Dimocarpus longan* Lour) seeds. *Phytochemistry* 77:226–237
2. Walter M, Marchesan E (2011) Phenolic compounds and antioxidant activity of rice. *Brazilian Archives of Biology and Technology* 54:371–377
3. de Souza VB, Thomazini M, Barrientos MAE, Nalin CM, Ferro-Furtado R, Genovese MI, Favaro-Trindade CS (2018) Functional properties and encapsulation of a proanthocyanidin-rich cinnamon extract (*Cinnamomum zeylanicum*) by complex coacervation using gelatin and different polysaccharides. *Food Hydrocolloids* 77:297–306
4. Lupo B, Maestro A, Gutiérrez JM, González C (2015) Characterization of alginate beads with encapsulated cocoa extract to prepare functional food: Comparison of two gelation mechanisms. *Food Hydrocolloids* 49:25–34
5. Pereira KC, Ferreira DCM, Alvarenga GF, Pereira MSS, Barcelos MCS, Costa JM G. D (2018) Microencapsulation and release controlled by the diffusion of food ingredients produced by spray drying: A review. *Braz J Food Technol*, 21
6. Annisa V, Sulaiman TNS, Nugroho AK, Nugroho AE, Kutsyk R (2022) Characterization of Alginate with Natural Polymers Combination for Drug Encapsulation. *Iraqi J Pharm Sci (P-ISSN 31(2):1683–3597*

7. Byun EH, Kim JH, Sung NY, Choi JI, Lim ST, Kim KH, Lee JW (2008) Effects of gamma irradiation on the physical and structural properties of β -glucan. *Radiat Phys Chem* 77(6):781–786
8. Narkprasom N, Narkprasom K, Upara U (2015) Optimization of total phenolic from *Cleistocalyx nervosum* by microwave-assisted extraction. *Am J Eng Appl Sci* 8(3):302
9. Chatterjee D, Bhattacharjee P (2015) Encapsulation of colour from peels of eggplant in calcium alginate matrix: Characterisation and food application. *Nutrafoods* 14:87–96
10. Namjouyan F, Azemi ME, Rahmanian VR (2010) Investigation of antioxidant activity and total phenolic content of various fractions of aerial parts of *Pimpinella barbata* (DC.) Boiss
11. Shimada K, Fujikawa K, Yahara K, Nakamura T (1992) Antioxidative properties of xanthan on the autoxidation of soybean oil in cyclodextrin emulsion. *J Agric Food Chem* 40(6):945–948
12. Ouwerx C, Velings N, Mestdagh MM, Axelos MA (1998) Physico-chemical properties and rheology of alginate gel beads formed with various divalent cations. *Polym Gels Networks* 6(5):393–408
13. Pasukamonset P, Kwon O, Adisakwattana S (2016) Alginate-based encapsulation of polyphenols from *Clitoria ternatea* petal flower extract enhances stability and biological activity under simulated gastrointestinal conditions. *Food Hydrocolloids* 61:772–779
14. Mohamed HN, Mustafa S, Fitrianto A, Manap A, Y (2016) Development of alginate-gum arabic beads for targeted delivery of protein. *SMU Med J*, 486–508
15. González-Rodríguez ML, Holgado MA, Sánchez-Lafuente C, Rabasco AM, Fini A (2002) Alginate/chitosan particulate systems for sodium diclofenac release. *Int J Pharm* 232(1–2):225–234
16. Ghosal K, Ray SD (2011) Alginate/hydrophobic HPMC (60M) particulate systems: new matrix for site-specific and controlled drug delivery. *Brazilian J Pharm Sci* 47:833–844
17. Woo JW, Rob HJ, Park HD, Ji CI, Lee YB, Kim SB (2007) Sphericity optimization of calcium alginate gel beads and the effects of processing conditions on their physical properties. *Food Sci Biotechnol* 16(5):715–721
18. Yoon YH (2011) Current status of food irradiation: benefits, regulations and acceptance. *Safe Food* 6(2):28–33
19. Huq T, Khan A, Dussault D, Salmieri S, Khan RA, Lacroix M (2012) Effect of gamma radiation on the physico-chemical properties of alginate-based films and beads. *Radiat Phys Chem* 81(8):945–948
20. Gul-E-Noor F, Khan MA, Ghoshal S, Mazid RA, Chowdhury S, A. M., Khan RA (2009) Grafting of 2-ethylhexyl acrylate with urea on to gelatin film by gamma radiation. *J Macromolecular Science® Part A: Pure Appl Chem* 46(6):615–624

Figures



Figure 1

Longan powder

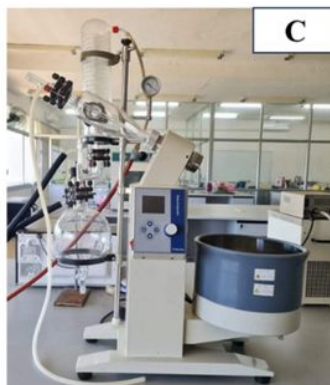
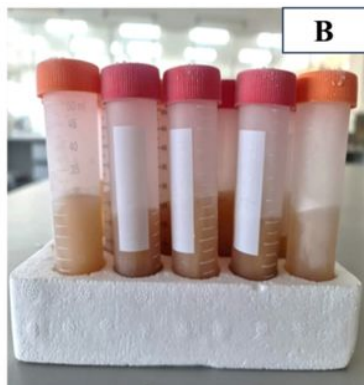


Figure 2

Extraction procedure by Microwave-Assisted Extraction (A) Microwave oven with a Soxhlet extractor set, (B) Longan extracts, (C) Evaporator, (D) Spectrophotometer



Figure 3

Extraction procedure by Microwave-Assisted Extraction (A) Microwave oven with a Soxhlet extractor set, (B) Longan extracts, (C) Evaporator, (D) Spectrophotometer

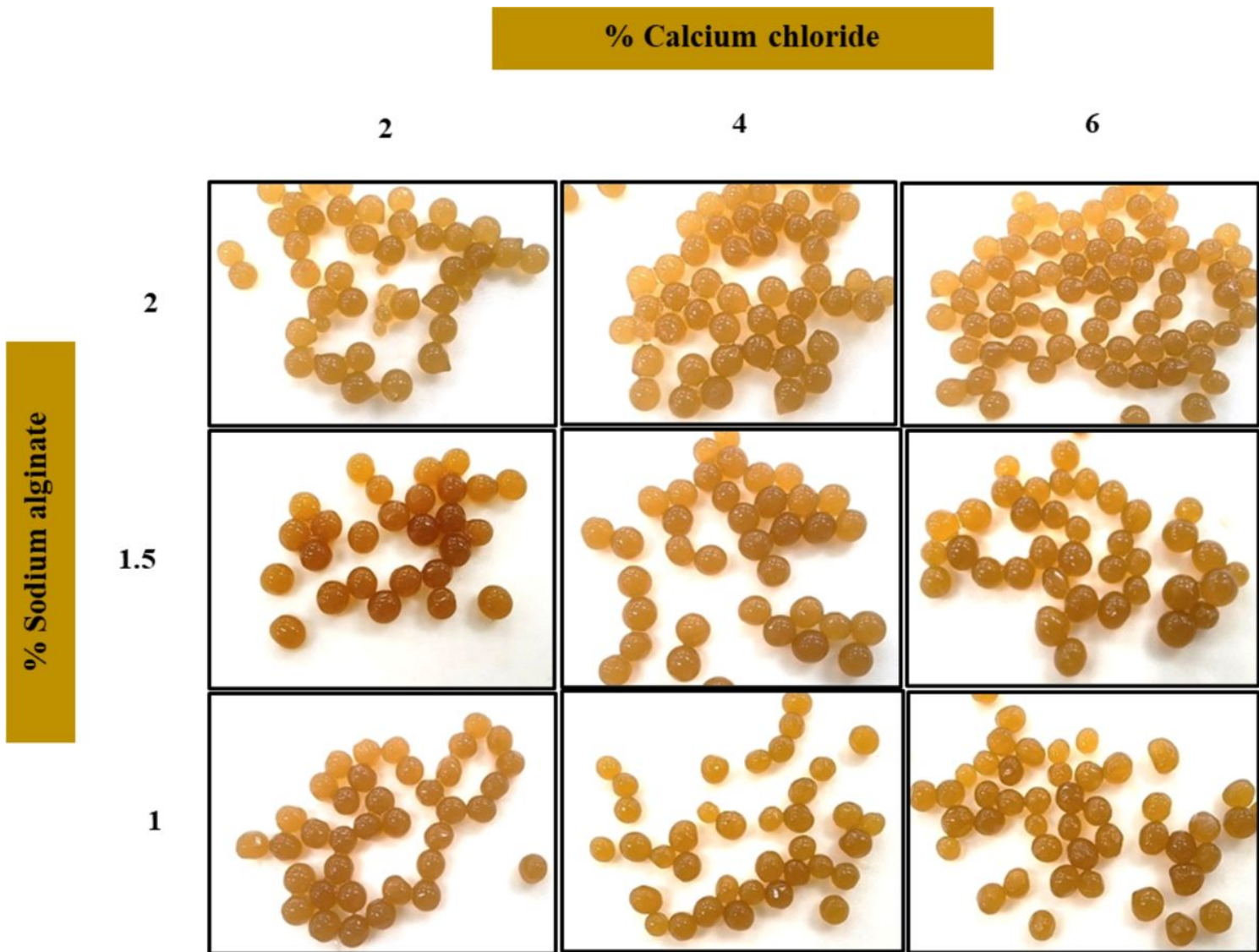


Figure 4

Physical characteristics of longan phenolic beads

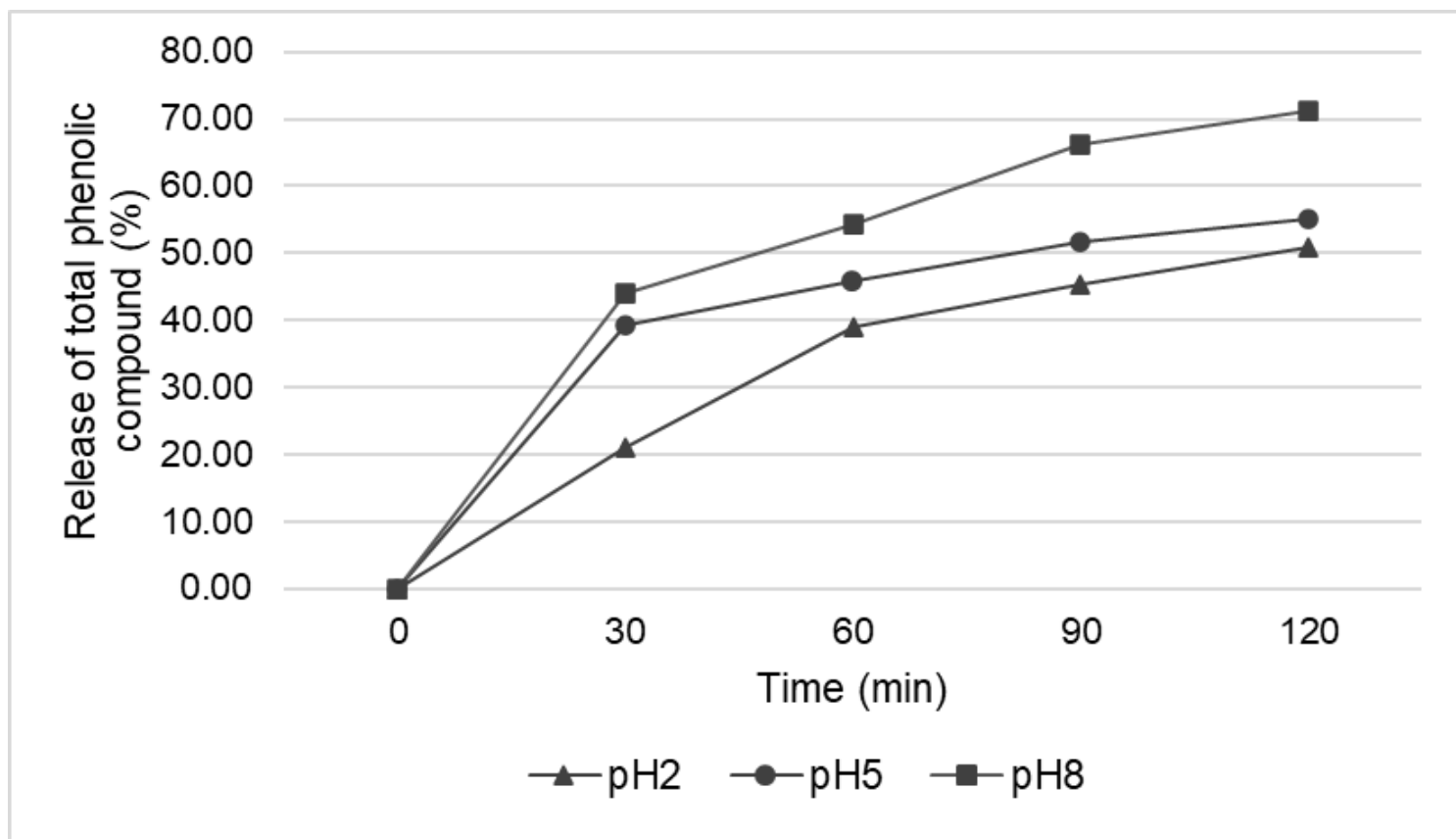


Figure 5

Release profile of total phenolic compound from the longan beads in pH 2, pH5, and pH8

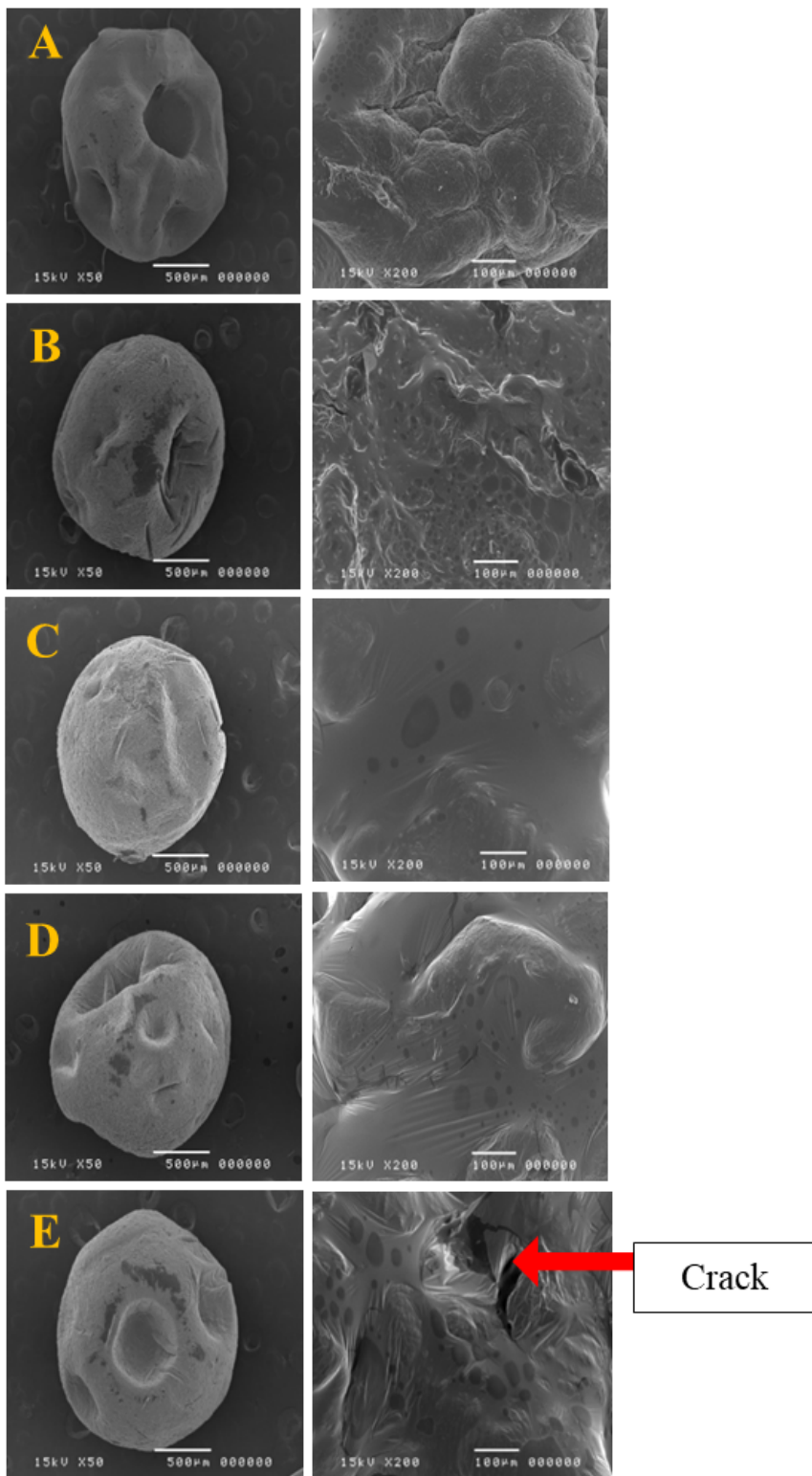


Figure 6

SEM micrographs at magnification 50x and 200x of longan bead (A) control, (B) 2.5 kGy, (C) 5 kGy, (D) 7.5 kGy, and (E) 10 kGy