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Passion Fruit Juice Beads Production by Reverse Spherification Technique: Effect of Concentration and Soaking Time of Calcium Lactate Solution

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Abstract

This research investigates the impact of calcium lactate concentration and soaking time on the qualities of passion fruit juice beads produced through reverse spherification. Passion fruit juice, xanthan gum, and calcium lactate are dropped into a sodium alginate solution to form beads, which are then immersed in a 0.5-1.0% (w/v) calcium lactate solution for 5-10 minutes. Results indicate that beads soaked in a 1% (w/v) calcium lactate solution for 5 minutes exhibit the smallest droplet size and highest roundness. Increased calcium lactate concentration and soaking time enhance springiness, while hardness, cohesiveness, gumminess, and chewiness decrease. Sensory evaluation shows that beads soaked in a 1% (w/v) calcium lactate solution for 10 minutes have superior taste, texture, and overall preference compared to unsoaked beads.

Keywords: Beads, Droplet, Passion fruit, Reverse spherification

1. Introduction

Currently, food and beverage products are garnering significant interest, particularly with the use of hydrogel beads obtained by encapsulating hydrocolloid substances. These hydrogel beads are applied to preserve the essence and flavor of food within the food and beverage industry, providing an imperceptible experience during eating. The beads, or spheres, can be formed using basic (or direct) and reverse spherification techniques. In direct spherification, sodium alginate is dissolved in juice, the juice mixture is filled in a syringe, and then dropped into a bath of calcium salt solution, forming a gel membrane on the outside of the sphere. Conversely, in reverse spherification, calcium salt is mixed with juice and dropped into sodium alginate, resulting in the gel membrane forming on the inside of the sphere. Essentially, the gel membrane forms at the interface between calcium salt and alginate solutions (Pennsylvania College of Technology, 2024).

Various fruit juices and techniques are employed to produce hydrogel beads. For instance, golden banana syrup beads are produced using extrusion techniques, with the highest acceptance among 50 panelists achieved by adding 0.13% amylase enzyme and 0.06% pectinase enzyme at 50 degrees Celsius for 2 hours, using a 1.0% sodium alginate solution (Musika et al., 2020). Mango juice beads are prepared using reverse spherification, with an appropriate hardness obtained by adding approximately 2.0% xanthan gum (Pratoengjitt & Rungtong, 2019). Additionally, mango sauce beads prepared from a 6:3:1 ratio of mango to sugar to lemon juice, using 0.5% sodium alginate, received moderate to high ratings in terms of color, aroma, and texture, with taste and overall acceptance rated very highly by 200 panelists (Uprarawanna et al., 2021).

Respondents slightly favored vitamin C butterfly pea juice beads produced via reverse spherification, with 82% of respondents (41 out of 50 panelists) accepting the product (Samard et al., 2023). The most acceptable recipe for 20% dragon fruit peel and pineapple juice beads showed that while the acid content in pineapple juice did not significantly affect bead size, it did reduce bead hardness (Suktanarak et al., 2021). Pitaya pearls (PPs) made from hydrocolloids using reverse spherification showed that formulation variables during storage

significantly affected elasticity more than rupture force and moisture content, with optimal storage conditions being at 4 degrees Celsius within 2 days (Bubin et al., 2019). Additionally, the developed Juice Pearl Kit allows for easy creation of flavored juice pearls for bubble tea drinks (Nicholas et al., 2022).

Passion fruit juice, known for its high acidity, sour flavor, and rich nutritional value, including dietary fiber, vitamin A, and vitamin C, was chosen for this study. The benefits of passion fruit juice and insights from related research, this study investigates the effects of calcium lactate concentration and soaking time on the size, weight, texture properties, and organoleptic characteristics of passion fruit juice beads produced using the reverse spherification technique.

2. Materials and Methods

2.1 Preparation of passion fruit juice bead by reverse spherification

The liquid core is the clear part of boxed Doi Kham brand passion fruit juice mixed with distilled water at a ratio of 1:1, dissolved in 0.8 grams of xanthan gum at a temperature of 70 degrees Celsius, then added calcium lactate 2 grams in a total of 100 grams of solution and refrigerated at 5±2 degrees Celsius for 1 hour. The prepared solution fills in a 10 mL syringe with a diameter of 2 mm of the syringe hole and drop it into the 0.5% (w/v) sodium alginate solution. The hydrogel beads in sodium alginate were gently stirred with a magnetic stick for 5 minutes, washed with distilled water 3 times, and harvested passion fruit juice beads by a strainer as illustrated in Figure 1.

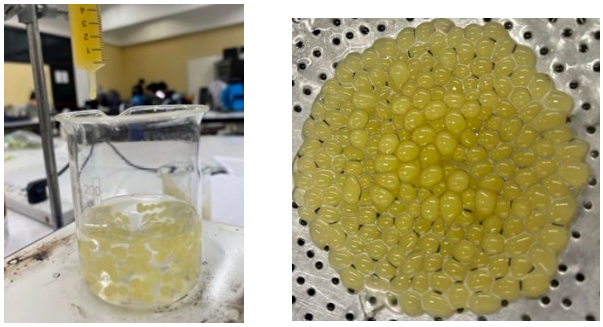

Figure 1. Passion fruit juice beads prepared by reverse spherification.

2.2 Experimental method

The obtained beads were soaked in calcium lactate solution at the concentration of 0.5% (w/v) and 1.0% (w/v) for 5 and 10 minutes. The experiment was repeated 3 times. The soaked beads were compared with unsoaked beads (control). After soaking, all measurements were done within 2 days.

2.3 Measurements of hydrogel beads

Ten beads were used to measure the major and minor diameter sizes using a vernier caliper, and the dimensions were recorded in millimeters. The average major diameter, minor diameter, and the ratio of major to minor diameters (roundness) were then calculated. A ratio close to 1 indicates that the beads are very round. Five replicates of ten beads were weighed using a digital balance with three decimal places (Ohaus brand), and the average weight per bead was calculated. For texture analysis, the texture profile of a bead was determined using a texture analyzer (model TA.XT) with a 1-centimeter cylindrical probe (P/10). The test was conducted at room temperature with the following settings: pre-test speed of 1.0 mm/s, test speed of 1.0 mm/s, post-test speed of 10.0 mm/s, trigger force of 5 g, and 95% strain. Ten replicates were performed.

The organoleptic characteristics of the beads were evaluated by 50 panelists aged 14–25 years. They were randomly assigned to rate color, aroma, taste, texture, and overall acceptability using a 9-point hedonic scale. All measured values were analyzed using one-way ANOVA at a 95% confidence level, and statistical differences between means were determined using Duncan's new multiple range test.

3. Results and Discussion

Figure 2 illustrates the major and minor diameters, as well as the roundness, of passion fruit juice beads under various soaking conditions in calcium lactate solution. Compared to the unsoaked beads, those soaked in 1.0% (w/v) calcium lactate for 5 minutes exhibited the smallest major and minor diameters, while the unsoaked beads were the largest. The differences in minor diameter among the soaked beads, as well as the roundness of both soaked and unsoaked beads, were found to be insignificant. The roundness values for both soaked and unsoaked beads were close to 1, indicating a very round shape for the passion fruit beads.

The size of the beads was influenced by several factors, including the size of the syringe tip, the viscosity of the alginate solution, and the soaking duration in calcium lactate solution. Beads that were not soaked in calcium lactate appeared to be the largest. The soaking process in calcium lactate solution after bead formation led to osmosis from the encapsulated internal calcium lactate solution to the external soaking solution, causing the soaked beads to become smaller compared to the unsoaked beads.

Figure 3 shows the weight per unit of soaked and unsoaked beads. The weight per unit of soaked beads increased with soaking time but was independent of the concentration of calcium lactate. The highest weight per unit of soaked beads did not surpass that of the unsoaked beads. Therefore, bead size was not directly associated with weight per unit.

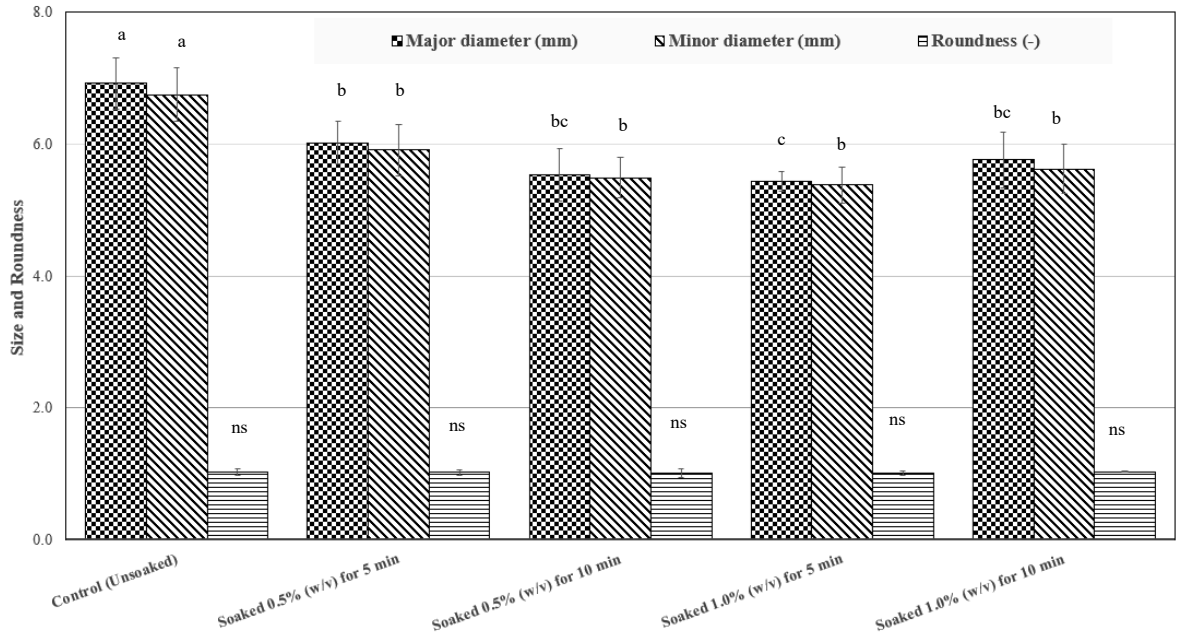

Figure 2. Size and roundness of passion fruit juice bead at the different concentrations and soaking times of calcium lactate solution.

*Note: Different letters means significant different values
ns means not significant different value with Duncan's statistical analysis

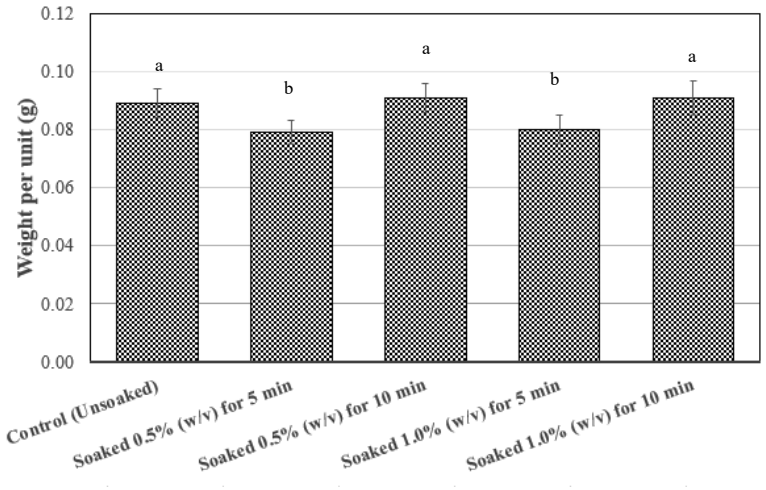

Figure 3. Weight per unit of passion fruit juice bead at the different concentrations and soaking times of calcium lactate solution.

*Note: Different letters means significant different values
ns means not significant different value with Duncan's statistical analysis

As shown in Figure 4, when compared to the unsoaked calcium lactate solution (control), the springiness of a bead increased with both the concentration and duration of soaking in the calcium lactate solution. Conversely, hardness, cohesiveness, gumminess, and chewiness decreased. This phenomenon can be attributed to the loss of calcium lactate solution concentration within the beads through osmosis.

These findings align with the observations regarding bead sizes mentioned in Figure 2. Specifically, the concentration and soaking time had a more pronounced effect on the chewiness and gumminess of the passion fruit juice beads.

As depicted in Figure 5, the impact of calcium lactate solution concentration and soaking time on the organoleptic characteristics, including odor, taste, and overall preference, shows slight variations. In terms of color, consumers tend to accept the beads soaked in calcium lactate solution with slight dislike or neutrality, which is lower than the acceptance level for unsoaked beads (slight preference). However, the texture of beads soaked in solutions with concentrations of 0.5% (w/v) for 10 minutes and 1.0% (w/v) for 10 minutes is moderately preferred by consumers compared to unsoaked beads.

Regarding the physical appearance of the beads after soaking in calcium lactate solution, as indicated in Table 1, the beads exhibit very thin, clear skin and appear firm under all conditions. The calcium lactate concentration and soaking time do not affect the physical appearance.

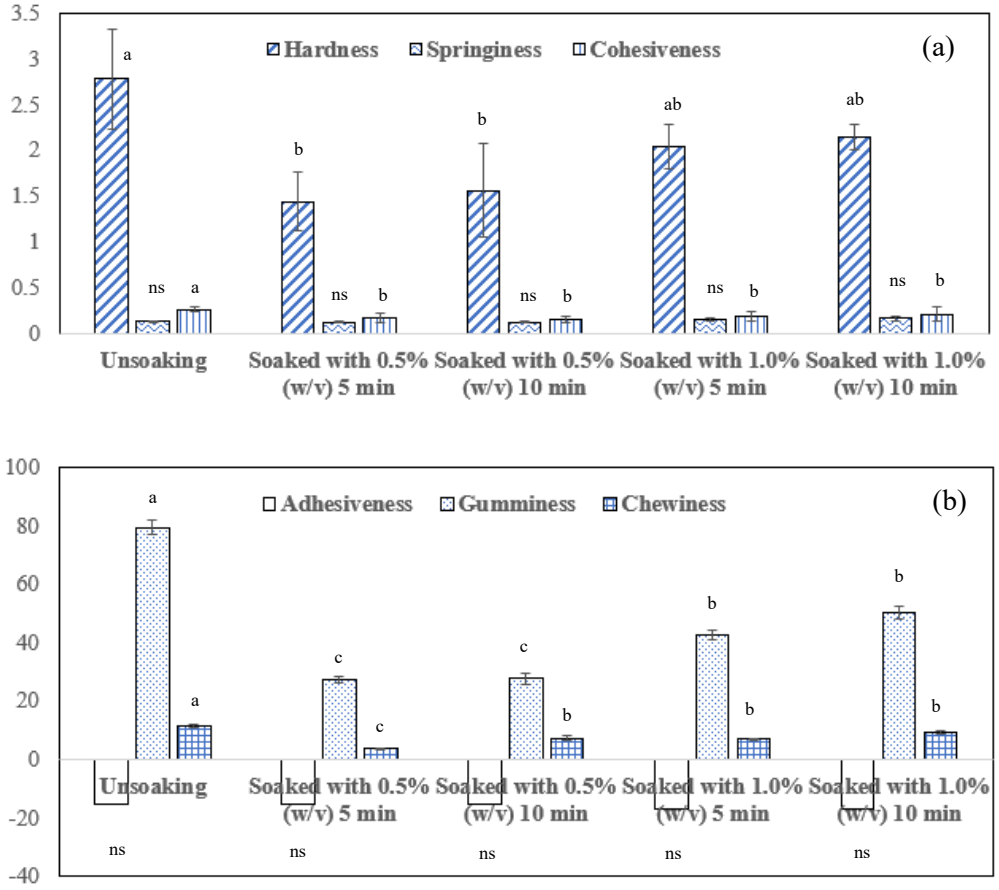

Figure 4. Texture Profile Analysis (TPA) of passion fruit juice bead at the different concentrations and soaking times of calcium lactate solution (a) hardness, springiness and cohesiveness (b) adhesiveness, gumminess and chewiness

*Note: Different letters means significant different values
ns means not significant different value with Duncan's statistical analysis

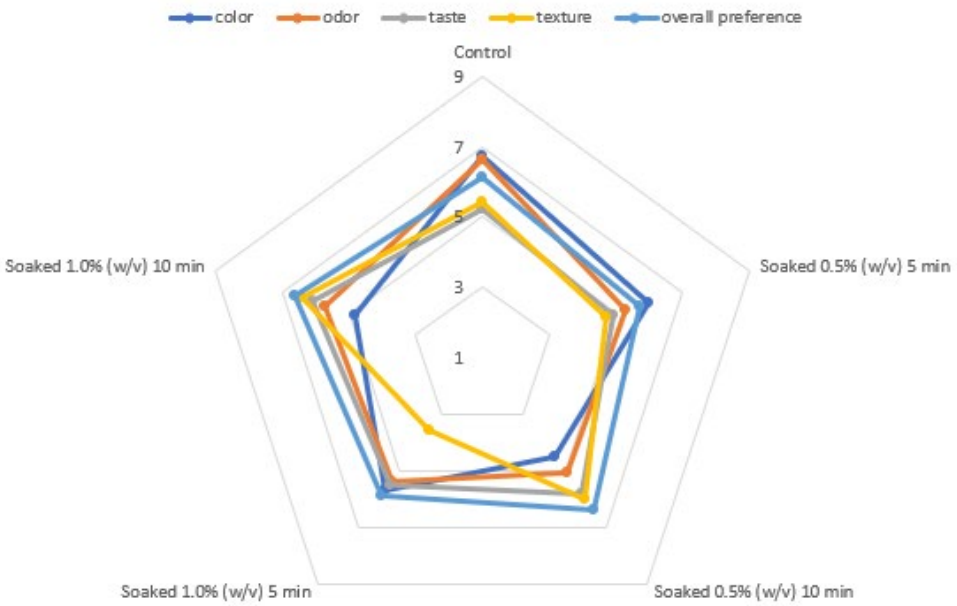

Figure 5. Organoleptic characteristics of passion fruit juice bead at the different concentrations and soaking times of calcium lactate solution.

Table 1. Bead appearance at the different concentrations and soaking times of calcium lactate solution.

Concentration (% w/v)	Soaking time (min)	Bead appearance
0.5	5	
0.5	10	
1.0	5	
1.0	10	
Control		

4. Conclusion

Soaking passion fruit juice beads in calcium lactate solution post bead formation via reverse spherification technique results in a reduction in bead size, while the weight per unit remains uncertain. There is no discernible difference in roundness between soaked and unsoaked hydrogel beads. Texture profile analysis indicates a decrease in almost all properties except for springiness. According to sensory evaluation by consumers, acceptance ranges from neither liking nor disliking to slight preference levels. Future research endeavors are necessary to further study and enhance the consumer acceptance of passion fruit juice beads. In the practical, the beads can be formed by dropping with many tips of syringe for increasing production capacity.

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