The physical properties of coffee caviar as influenced by sodium alginate concentration and calcium sources

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Abstract. Coffee caviar is a product of spherification technique, which is one of well-known technique in molecular gastronomy. Spherification is a process when liquid turns into spheres in a bath due to the reaction such as between sodium alginate, calcium chloride, and calcium lactate in the gelation process. The objectives of this study are to know the effect of different formula used for caviar making to the physical characteristics of coffee caviar, and to choose the best formula for coffee caviar. Research was conducted under Randomized Block Design involving two variables i.e. the different concentration of sodium alginate (1%, 1.5% and 2%) and different calcium sources (calcium lactate or calcium chloride). Evaluation was performed on the coffee-alginate solution (alginate sol) for viscosity, color (L*a*b*), total soluble solids, and pH, while the produced caviar was analyzed for texture, syneresis, as well as sensory properties (appearance, color, aroma, flavor, texture, overall liking, chewiness and gel strength). The result showed that the physical characteristic of the coffee caviars were diverse depending on the different formula used. The sodium alginate concentrations and calcium sources had significant effects (α=0.05) on the caviar texture, chewiness and gel strength. The best proportion for coffee caviar based on Derringer’s desirability function was 1.5% concentration of sodium alginate with the use of calcium chloride as calcium ions sources.

1. Introduction

Basic spherification is one of the molecular gastronomy techniques, introduced by El Bulli in 2003. Spherification can transform any liquid into spheres as a result of jellification process such as between sodium alginate and calcium bath. Any kind of liquid can be used as a base as long as the pH is higher than 3.6 and the calcium content is low [1]. There are two common different spherification techniques such as basic and reverse spherification, where the difference is in the sequence or protocols of adding the gelling agent. In the basic spherification, the gelling agent such as sodium alginate is added in the base and further submitted into the calcium bath, while in the reverse, the gelling agents are added in the bath and the calcium is mixed with the base.

Coffee is getting more popularity and highly demanded these days. Coffee caviar is another form of coffee-based product that can be made by adding sodium alginate into coffee extract before further submission to calcium bath using syringe to create spheres. The calcium bath can be made either with calcium chloride or calcium lactate, which is providing the missing ions for sodium alginate to start the cold gelling process. The product looks like tapioca bubble, but it can be burst / popped with a slight pressure. Sodium alginate as gelling agent will be cross-linked with Ca^{2+} ion from calcium bath to create an ‘egg-box’ model [2]. The solution will be gelled from the outer film at first, but the gelling will not...
stop even though the spheres were rinsed with water [3], and therefore coffee caviar should be served immediately in order to get the “popped” sensation.

The physical characteristic of coffee caviar could be influenced by the proportion of sodium alginate as gelling agent and calcium sources used to make the bath, and hence will influence consumer acceptance. the objectives of this study are to know the effect of different formula used for caviar making to the physical characteristics of coffee caviar, and to choose the best formula for coffee caviar.

2. Materials and Method

2.1. Materials

Materials used in this research were roasted Arabica Gayo wine coffee, food grade calcium chloride (Molecularinno), calcium lactate (Molecularinno), and sodium alginate (Molecularinno). Mineral water for making solution was purchased locally.

2.2. Methods

Experiment was conducted in Randomized Block Design with two factors i.e. different concentrations of sodium alginate added (0.5%; 1%; 1.5%; 2%) and 1% calcium sources (calcium chloride and calcium lactate). The method used for spherification was basic spherification [1] where the ratio between coffee extract: sugar: hot water was 15: 15: 310. Sodium alginate was added and homogenized to the cold extract (±5-8°C) and the mixture was kept in a refrigerator (~5°C) in a sealed container for ~24 h. Coffee-alginate solution was evaluated for viscosity [4] by using viscometer (Elcometer), color (L*a*b*) [5] by using color reader (Konica Minolta), total soluble solids [4] by using hand refractometer (Atago), and pH level [4] by using pH meter (Senz-pH), in triplicates.

The caviar making involved dripping coffee-alginate solution using syringe into calcium bath (~15°C) and further rinsing with mineral water. Samples were subject to sensory evaluation immediately (less than 15 minutes). Texture analysis was modified based on Instrumental Texture Profile Analysis [6] where 35 g caviars were placed in a cup. The force-deformation to compress the materials were measured and expressed as hardness. Caviar gel appearance was evaluated visually based on pictures obtained from a digital camera [7]. Statistical data analysis was performed using SPSS and Minitab 17 Statistical Software (Minitab Inc., State College, Pennsylvania, USA) followed by a Fisher LSD post-hoc test with a confidence interval of 95% for any significant difference. The best treatment was chosen based on Derringer’s desirability function.

3. Results and Discussion

Evaluation of the coffee and alginate solution conducted includes viscosity, color, total soluble solids, and pH level. These evaluations were used to determine the effect of sodium alginate added in a solution. The result of the test can be seen in Table 1.

Table 1 showed that concentration of sodium alginate factors was found to be significant (α=0.05) on viscosity, lightness, redness, yellowness, pH, and total soluble solids. ] Coffee extract without sodium alginate showed the lowest viscosity (210.00 cP ± 10.00) meanwhile the addition of 2% of sodium alginate showed the highest viscosity (4666.67 cP ± 165.63). As a hydrocolloid, sodium alginate can absorb water and form a gel. Adding sodium alginate to water activates components to make a sol [8]. If the amount of sodium alginate is increased, it can absorb more water and the solution becomes thicker.

Lightness (L*) of the solution was also increased by the amount of sodium alginate added. The decrease in L* value means the color is darker and vice versa [9]. Concentration of 2% sodium alginate showed the highest L* value meanwhile darker color was found in coffee extract without sodium alginate. The addition of sodium alginate results in the decrease of redness (a*) while the yellowness (b*) was increased. Sodium alginate has the characteristic of colorless, odorless, and thickens when dissolved in water [10]. The addition of this polysaccharides powder to create a thicker solution will have an impact on color change.
Total soluble solids in a solution shows the total solids that is dissolved in liquid. Without sodium alginate, coffee has a low TSS of 4.03±0.06°Brix but with addition of sodium alginate, the TSS was twice higher. Alginate can bind to another particle in the solution, causing an increase of total soluble solids in solution [11]. Total soluble solids of solutions can be increased when the free water activity is decreased. When more particles are bound with stabilizers, total soluble solids will increase as the sediment is decreased [12].

**Table 1.** Results of coffee-alginate solution evaluated under different concentration of sodium alginate added (n=3)

| Parameter | Concentration of Sodium Alginate |
|-----------|----------------------------------|
|           | 0% | 0.5% | 1% | 1.5% | 2% |
| Viscosity | 210.00 ± 10.00a | 293.33 ± 15.28ab | 360.00 ± 26.46b | 1070.00 ± 10.00c | 4666.67 ± 165.63d |
| L*        | 50.63 ± 0.51a | 50.67 ± 0.25a | 56.10 ± 0.50b | 56.43 ± 0.49b | 58.33 ± 1.20c |
| a*        | -12.73 ± 1.40a | -8.47 ± 0.97c | -10.77 ± 1.10b | -11.46 ± 0.22ab | -12.60 ± 0.70a |
| b*        | 27.29 ± 1.67c | 21.90 ± 0.82a | 24.60 ± 0.95b | 24.67 ± 0.70b | 25.87 ± 0.70bc |
| TSS (°Brix)| 4.03 ± 0.06c | 7.80 ± 0.20b | 8.07 ± 0.12b | 8.07 ± 0.12b | 8.73 ± 0.12a |
| pH        | 4.87 ± 0.06a | 4.83 ± 0.12a | 4.90 ± 0.00a | 5.00 ± 0.00b | 5.07 ± 0.06b |
| n         | 3 | 3 | 3 | 3 | 3 |

Notes: Data mean ± standard deviation (n=3). Different notations show significant differences (α = 0.05)

The pH value of coffee extract was between pH 3.89 and 4.91. This value tends to increase along with the increase of sodium alginate concentration in the solution since sodium alginate has a higher pH than coffee and contribute to more OH-ions from carboxyl groups. When the two solutions blended together, ratio of hydrogen ions and hydroxyl ions will be adjusted. If there are more hydroxyl ions in the solution, the pH will be increased [13].

Both factors of sodium alginate concentrations and calcium sources used had significant effects (α=0.05) on the texture of coffee caviar. However, the interaction of two factors was not significantly different. Results of hardness on coffee caviar is provided in Figure 1. Based on Figure 1, it can be seen that the hardness of coffee caviar are increased along with the concentration of sodium alginate. Caviar also has a harder texture when submerged in calcium chloride bath. This can be explained due to calcium content of calcium chloride (0.36 w/w) which is higher than calcium lactate (0.18 w/w) [14]. These factors also affect the gelation time where calcium chloride showed a faster gelation time. Since the gelation is faster by using calcium chloride, then coffee caviar can reach the maximum hardness faster than in calcium lactate. Therefore, the hardness level is higher. Hardness was explained as related to the strength of gel structure under compression, as the peak force during the first compression cycle [6]. More calcium ions were contributed by calcium chloride that the calcium lactate counterparts to the solution. When calcium ions are diffused in alginate solution, cross-linking between polymers occurs and will increase the elastic components of gel [14].

Besides physical characteristics evaluation, sensory quality of the samples was further explored. Sixty untrained panelists were submitted to assess appearance, color, aroma, flavor, texture, overall liking, chewiness and gel strength of coffee caviar. Table 2 presented the result of consumer’s liking on coffee caviar in each parameter.
**Figure 1.** Hardness of coffee caviar made with different concentrations of sodium alginate and calcium salts.

**Table 2.** The effect of sodium alginate concentration and different calcium sources on sensory attributes of coffee caviar

| Factors     | Sodium Alginate | Appearace | Color | Aroma | Flavor | Texture | Overall Liking | Chewiness | Gel Strength |
|-------------|-----------------|-----------|-------|-------|-------|---------|----------------|-----------|--------------|
| Calcium Chloride | 0.5% | 4.20 | 4.70 | 4.85 | 4.25 | 3.98 | 4.35 | 6.82 | 5.37 |
|              | 1%    | 4.65 | 5.00 | 4.67 | 4.28 | 4.35 | 4.53 | 6.89 | 5.32 |
|              | 1.5%  | 5.15 | 5.15 | 4.72 | 4.30 | 4.60 | 4.85 | 7.85 | 7.30 |
|              | 2%    | 4.83 | 5.05 | 4.72 | 4.20 | 4.30 | 4.80 | 7.70 | 7.01 |
| Calcium Lactate | 0.5% | 4.32 | 4.72 | 4.57 | 4.15 | 4.42 | 4.62 | 7.93 | 7.64 |
|              | 1%    | 4.63 | 4.93 | 4.52 | 3.93 | 4.58 | 4.62 | 8.80 | 7.57 |
|              | 1.5%  | 4.80 | 4.98 | 4.62 | 4.12 | 4.43 | 4.73 | 8.75 | 8.43 |
|              | 2%    | 4.58 | 4.95 | 4.83 | 4.55 | 4.57 | 5.10 | 8.66 | 7.73 |

Overall, the panelists liked coffee caviar with proportion of 2% sodium alginate and calcium lactate. Based on statistical analysis, different proportion of sodium alginate and calcium lactate has significant effect ($\alpha=0.05$) for overall liking. Meanwhile for chewiness, sodium alginate concentration, calcium salts used, and panelists factors has a significant effect, but the interaction was not significant. All factors including the interactions had a significant effect on caviar gel strength. Based on the physical and sensory properties, the best proportion for coffee caviar was by addition of 1.5% sodium alginate with calcium chloride as calcium source.

Coffee caviar was evaluated for syneresis during storage. The result of syneresis in coffee caviar submerged in calcium chloride was shown visually in Table 3 and Table 4. The shape of gels formed vary such as mushroom, tail, and hemispheric since it was affected by interfacial tension between alginate solution and calcium bath. High concentration of sodium alginate increases the interfacial tension so that the shape of the gel can be more spherical.
Table 3. Coffee caviar gel made of sodium alginate and calcium chloride during 6 hours of storage

| Time | Sodium Alginate Concentration |
|------|------------------------------|
|      | 0.5% | 1%   | 1.5% | 2%   |
| 0 h  | ![Image](image1) | ![Image](image2) | ![Image](image3) | ![Image](image4) |
|      | ![Image](image5) | ![Image](image6) | ![Image](image7) | ![Image](image8) |
| 3 h  | ![Image](image9) | ![Image](image10) | ![Image](image11) | ![Image](image12) |
|      | ![Image](image13) | ![Image](image14) | ![Image](image15) | ![Image](image16) |
| 6 h  | ![Image](image17) | ![Image](image18) | ![Image](image19) | ![Image](image20) |
|      | ![Image](image21) | ![Image](image22) | ![Image](image23) | ![Image](image24) |

Table 4. Coffee caviar gel made of sodium alginate and calcium lactate during 6 hours of storage

| Time | Sodium Alginate Concentration |
|------|------------------------------|
|      | 0.5% | 1%   | 1.5% | 2%   |
| 0 h  | ![Image](image25) | ![Image](image26) | ![Image](image27) | ![Image](image28) |
|      | ![Image](image29) | ![Image](image30) | ![Image](image31) | ![Image](image32) |
| 3 h  | ![Image](image33) | ![Image](image34) | ![Image](image35) | ![Image](image36) |
|      | ![Image](image37) | ![Image](image38) | ![Image](image39) | ![Image](image40) |
| 6 h  | ![Image](image41) | ![Image](image42) | ![Image](image43) | ![Image](image44) |
|      | ![Image](image45) | ![Image](image46) | ![Image](image47) | ![Image](image48) |
Syneresis happened when water from gel is coming out so the gel will shrink to a smaller form [15]. The outside surfaces of the gel beads reflect changes in syneresis: the lower the syneresis of the gel beads, the less sticky the outside surfaces of the gel beads due to less water weeping out. Coffee caviar made with calcium chloride and calcium lactate has different results of syneresis.

Coffee caviar with calcium chloride may shrink but the gel is still solid and not melted except for the gel with 0.5% sodium alginate. Therefore, the caviar submerged in calcium chloride or use calcium chloride as calcium ion source showed a stronger gel structure. In contrast, the caviar made by using calcium lactate has a weaker gel strength where the gel easily loses the moisture and melt. The gelation time of calcium lactate is slower than calcium chloride, so that the gel may have not reached the maximum hardness when syneresis occurred and therefore, gel structure will decrease along with storage time [13].

4. Conclusions
In conclusion, sodium alginate concentration has significant effect for viscosity, total soluble solids, pH value and color of coffee caviar base solution. Higher concentration of sodium alginate made an increase for viscosity, total soluble solids, pH value, lightness, and yellowness meanwhile a decrease noted for redness. Different calcium salts used also has a significant effect on texture, chewiness and gel strength of coffee caviar. Interaction of two factors (sodium alginate and calcium salts) has significant effect for gel strength. The best proportion for coffee caviar was 1.5% concentration of sodium alginate with calcium chloride.

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