

2018 Pratama Optimum carrageenan concentration

by Setya Budi Muhammad Abduh

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Optimum carrageenan concentration improved the physical properties of cabinet-dried yoghurt powder

Y Pratama¹, S B M Abduh, A M Legowo, Y B Pramono, AN Albaarri^{1,2}

¹Department of Food Technology, Faculty of Animal and Agricultural Sciences,
Diponegoro University, Semarang, Central Java Indonesia

²Integrated Laboratory, Diponegoro University, Semarang, Central Java Indonesia

Email: albari@undip.ac.id

Abstract. Carrageenan is a hydrocolloid which able to improve the characteristic of dried powder. The purpose of this study was to produce and evaluate the characteristics of yoghurt powder which incorporated carrageenan as stabilizer and dried in a cabinet dryer. Carrageenan of 1 %, 2 % and 3 % (w/v) concentration were added to yoghurt prior to cabinet drying process. Physical properties of the yoghurt powder and the reconstituted one were evaluated. The best result was shown in carrageenan concentration of 2 % where it showed the highest bulk density (0.62 g/ml), and best particle size distribution (65.49 % in the range of 250-500 μ m). Moisture and water activity (a_w) were 8.02% and 0.37, respectively. The value is lower than what spoilage microorganisms require to grow ($a_w > 0.6$) thus ensuring its long shelf life when combined with proper packaging. Reconstitution at 50°C showed that 2 % carrageenan resulted in a stable yoghurt product with no visible syneresis even after 3 hours. The proposed method shows promising application in the production of long shelf-life yoghurt powder production.

Keywords: cabinet, carrageenan, drying, powder, yoghurt

1. Introduction

Yoghurt is a kind of fermented food which is recognized to poses some health benefits due to a better nutrient utilisation as influenced by more digestible protein, more calcium, certain B group vitamins, and hypocholesterolaemic effect [1]. However the shelf life of yoghurt is relatively short, about 1 day at ambient temperature and 4-5 days at 7 °C refrigeration. Such a short shelf life is a big limitation for archipelago country such as Indonesia to achieve the goodness of yoghurt for people around the country. In order to cover the problem, preservation is necessary to be performed. Dried product is one popular form of preserved food product due to its practical aspect as well as economical.

Convective cabinet drying technique is one of popular drying practices. The technique is relatively available around the country due to the fact that the system does not require sophisticated technology. The technique is based on flowing of dehumidified air through the product surface to carry the water vapour freed from the product. Dehumidification is usually performed by heating the atmospheric ambient air. The heated air is then blown over the products surface. The drying cabinet system is usually consisted of two chamber for heating the atmosphere and drying the freed vapour of the product respectively [2].

Prior to consumption, dried yoghurt is reconstituted by addition of certain amount of water, considering the initial moisture content of the fresh yoghurt. The emulsion stability of the



reconstituted yoghurt is critical for consumer preference due to the fact that syneresis is easily observable. The stability can be maintained by using plant origin polysaccharides [3].

Indonesia is the second longest coastal line country over the world, approximately 54,716 km providing abundant number of seaweed that part of them are potential as the source of carrageenan. Carrageenan is popularly used in dairy industry to prevent phase separation [4]. Studies have already carried out on its influence on the yoghurt [5, 6] and on reconstituted yoghurt [4]. In the present paper, its influence on the physical properties of yoghurt powder dried by convective drying cabinet is discussed.

2. Material and Methods

2.1. Material

Bacterial culture containing *L. delbrueckii subsp. bulgaricus* and *S. thermophilus* was obtained from the Diponegoro University culture collection. UHT sterilized full cream milk was obtained from the market. The raw milk was obtained from the Faculty of Animal and Agricultural Sciences' farm. The kappa (κ)-carrageenan was obtained from the collection of Faculty of Fisheries and Marine Sciences, Diponegoro University.

2.2. Inoculum preparation

Freeze dried bacterial culture amounting 1.4 g was inoculated into 50 ml UHT sterilized full cream milk prior to incubation at 38°C for 6 h. The liquid inoculum obtained then was inoculated into similar UHT sterilized full cream milk to achieved 10 % (v/v) and incubated at the same condition. The same procedure was repeated to obtain the working inoculum.

2.3. Yoghurt preparation

Milk containing 3 % of fat was pasteurized at 75°C for 20 s. One percent (v/v) of working culture was inoculated into the pasteurized milk prior to incubation at 38° C for 6 h. The yoghurt resulted then was refrigerated for approximately 15 min prior to addition of carrageenan in varied concentration: 1, 2, and 3 % (w/v) and gently mixed with spoon then homogenized using Ultra Turax Homogenizer (IKA, Germany) at 10,000 rpm for 5 min.

2.4. Yoghurt drying and powdering

The fresh yoghurt was spread on 40 cm x 50 cm trays and kept in convective drying cabinet for 20 h at 50 °C. The dried yoghurt was then kept in water-vapor tight boxes prior to be milled in beater bar miller Maksindo FCT-Z300 for 45 s. The powdered yoghurt was kept in PET bags prior to further analysis.

2.5. Yoghurt powder rehydration

Rehydration was carried out on the dried yoghurt with aquadest at ambient temperature to achieve 10% (w/v).

2.6. Water-activity and moisture content measurement

The water activities of the dried yoghurt were measured with Novasina Aw meter. The moisture content of the dried yoghurt was measured by mean of gravimetry.

2.7. Microscopy analysis

The microscopy analysis was carried out to observe the structure of the powder particle. The analysis was carried out under a software assisted Olympus microscope, coupled with Mshot camera. The device was set on 400x magnification under controlled light to get clear images.

2.8. Particle size distribution

One hundred gram of dried yoghurt was passed through Retsech AS200 Control (Germany) using DIA X sieve with 500, 250, 125 μm mesh size.

2.9. Bulk density

The bulk density of the dried yoghurt was determined by putting 10 g of it in measuring glass cup. The measured volume after 10 times knocking was recorded. The bulk density is expressed in g/ml.

2.10. pH and viscosity

pH measurement was carried out using pH meter (Hanna, Italy). An Ostwald viscometer was used for viscosity measurement.

2.11. Sedimentation index

Slight modification from method by [7] was used to measure sedimentation index. Fifteen ml of reconstituted yoghurt was centrifuged in 6000 rpm for 25 min. The centrifuge tube were then put upside-down for 30 min. Sedimentation index was calculated as the weight of sediment left in the tube divided by initial weight of reconstituted yoghurt and expressed in % (w/w).

2.12. Syneresis observation

Only for syneresis observation, two methods were used to reconstitute the yoghurt powder. First was the aforementioned method using aquadest at ambient temperature to get 10% (w/v). The second method was the same procedure, only the aquadest used was at 50°C. Subsequently, 10 ml of reconstituted was poured into flask and visually observed for syneresis/whey layer formation.

2.13. Statistics

All measurements were taken in triplicate and presented as mean value and standard deviation. Experimental data were then analyzed by analysis of variance (ANOVA) which coupled with Duncan test wherever significant result found. All statistical analysis was performed using SAS (Statistical Analysis System, Version 9.13) software.

3. Results and discussions

Yoghurt powder has been successfully created by the proposed method using carrageenan as stabilizer and utilizing cabinet drying technique. Carrageenan concentrations added (1%, 2% and 3% (w/v)) were quite high compared to the normal carrageenan and other hydrocolloid incorporation in yoghurt product which normally 0.5 % (w/v) max [8]. Its high concentration aimed to help drying process by increasing the mixture's dry matter prior to drying step and at the same time to improve the characteristics of the resulted yoghurt powder. An increase in carrageenan concentration will increase the dry matter of the yoghurt's mixture prior to drying step, which is essential. A certain degree of dry matter is needed as a seed for crystallization during drying process. For example, an operation for milk powder which includes spray drying step normally requires the mixture to be brought into 45% - 55% dry matter before drying takes place [9].

3.1. Moisture content and water activity (A_w) of yoghurt powder

The results of the effect of carrageenan addition on yoghurt powder physical characteristics are shown in **Table 1**. The result showed that the moisture content were in the range of 6.44-8.04 %. It is higher than yoghurt powder produced by other procedures such as spray drying and freeze drying technique which range 0.3-0.6% [1]. The possible reasons were the drying temperature was not high enough and high hydrocolloid concentration. The drying temperature was set at 50°C in order to keep lactic acid bacteria survival on the finish product, which resulted in 3 log reduction from the initial load (data not shown). As an addition, carrageenan as hydrocolloid has water binding characteristics, thus it may reduce the drying rate and the finish product's moisture content will be higher. However, the

moistures of the yoghurt powder were not significantly different despite different carrageenan concentration. Authors assumed that after 20 hours of drying, the process has reached equilibrium where the moisture level was kept unchanged.

Table 1. Moisture content, water activity and bulk density of yoghurt powder

Treatment	Moisture (%)	Aw	Bulk Density (g/ml)
1%	7.18±0.05	0.31±0.01	0.50±0.00 ^a
2%	8.02±1.09	0.37±0.01	0.62±0.02 ^b
3%	6.44±1.21	0.35±0.04	0.52±0.02 ^a

Means within a column with different superscript are significantly different ($P < 0.05$)

Water activity (A_w) signifies the amount of free water in the product which available to microorganism to grow. A low A_w value is an important characteristic for a powder product so that it will prevent microbial growth, especially mould. It was shown that A_w values of yoghurt powder were 0.31, 0.37, and 0.35 for 1%, 2% and 3% carrageenan, respectively. P value > 0.05 showed that the result were not significantly different. It was similar to the moisture result, showing the relation between two parameters. However, it indicated that carrageenan's ability to bind free water did not give a significant difference in the product. Availability of free water would be reduced, thus reducing A_w value, if it is bond to water-binding substances such as sugar and salt. Albeit the insignificant result, the A_w values were lower than the least demanding xerophilic moulds which need around A_w 0.6 minimum to grow [10]. Therefore, the resulted yoghurt powder has the ability to prevent most microbial growth, in the condition that it is properly packaged so that the A_w value remains unchanged.

3.2. Bulk density of yoghurt powder

Bulk density is an important parameter in powder filling and packaging operation. A consistent bulk density will ensure a consistent product weight when volumetric-type filler is used. Bulk density value also determines the amount of packaging material would be needed. When its value is low, it means that the powder is bulky and thus needs more packaging material to pack a certain mass. The highest yoghurt powder's bulk density was observed from 2% carrageenan which was 0.62 g/ml ($P < 0.05$), while 1% and 3% carrageenan were 0.50 g/ml and 0.52 g/ml, respectively. It might be due to the 2% carrageenan had slightly higher moisture level compared to other treatments. Water which has density of approximately 1 g/ml is significantly higher than the yoghurt powder bulk density. Hence, moisture level influences bulk density of yoghurt powder greatly, where higher moisture leads to higher bulk density.

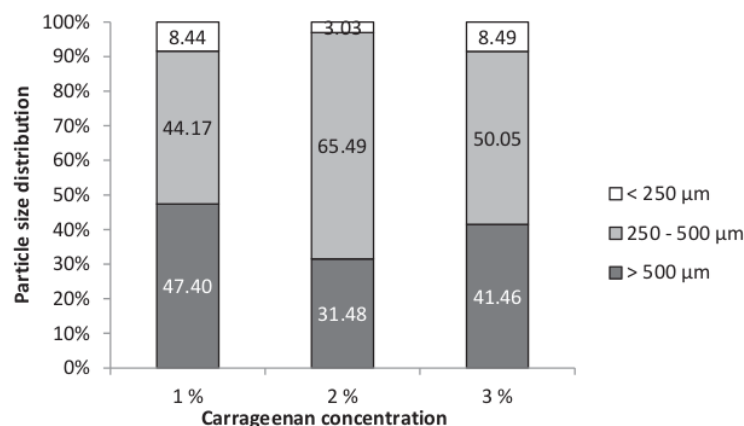


Figure 1. Yoghurt powder particle size distribution

3.3. Particle size distribution of yoghurt powder

Particle size distribution analysis result is shown in **Figure 1**. The carrageenan concentration of 2 % resulted in smaller particle size distribution than the 1 % and 3 % concentration with 65,49 % in the range of 250 – 500 μm. This result was in agreement with the bulk density data, as the 2 % carrageenan has the highest value. Given the composition similarity among the three treatments, smaller particle size means denser and leads to higher bulk density.

Beater bar miller employs impact force as the main size-reducing force. Impacted particle will react based on its brittleness, where brittle substance will break and less brittle one will only deform [11]. Therefore, considering the particle size and bulk density, it can be safely assumed that the 2 % carrageenan yoghurt powder had more brittle characteristic compared with the other two treatments. It considers the fact that the moisture and A_w values were not significantly different. In addition, the appearances of yoghurt powder's optical microstructure were also similar, as can be seen in **Figure 2**. The only notable difference was that the 2 % treatment has smaller size compared to the other treatments which is in agreement with bulk density and particle size distribution data.

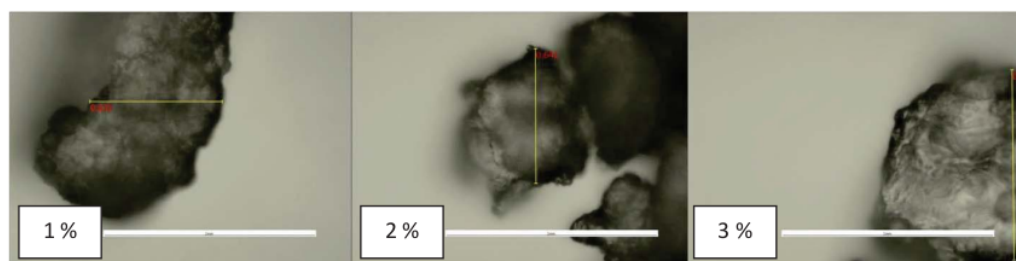


Figure 2. Optical microstructure of yoghurt powder with 400 magnifications (scale bar = 1 mm)

3.4. pH of reconstituted yoghurt powder

Reconstitution of the yoghurt powder was carried out by diluting the powder in both cold water (aquadest in ambient temperature) using spoon to mix it manually. The yoghurt powder was mixed

easily, and although some small lumps were formed, it could be immediately broken. The reconstituted yoghurts were then evaluated for its physical characteristics, as can be seen in **Table 2**. It was shown that carrageenan concentration did not affect pH significantly. The mixture pH was 3.93 to 3.96, as a result of 6 hours fermentation period. This is lower than isoelectric point of casein which is at pH 4.6, resulting in the casein positively charged. Carrageenan as an anionic hydrocolloid interacts with this positively charged casein micelles and thus strengthens the casein network and reduces syneresis and is classified as adsorbing polysaccharides [12, 13].

Table 2. Physical parameters of reconstituted yoghurt powder

Treatment	pH	Viscosity (cp)	Sedimentation (%)
1%	3.96±0.01	6.14±0.30 ^a	2.61±0.07 ^a
2%	3.93±0.01	10.81±0.22 ^b	3.40±0.19 ^b
3%	3.95±0.02	17.14±1.35 ^c	3.87±0.44 ^b

Means within a column with different superscript are significantly different ($P < 0.05$)

3.5. Viscosity, sedimentation and syneresis of reconstituted yoghurt powder

Significant increase of viscosity was observed from the increasing concentration of carrageenan. This result is expected, however the value is very low considering the amount of carrageenan added. Furthermore, the sedimentation index result showed increasing trend ($P < 0.05$) as the carrageenan concentration increased. Both results indicate that the increasing viscosity was caused by the increasing total solid rather than due to three-dimensional network formed by carrageenan as hydrocolloid. Three-dimensional network was formed into gel during mixing the yoghurt with carrageenan prior to drying, however the network was destroyed during heating and milling process.

Stability of reconstituted yoghurt is one of the most important physical parameters for the consumer acceptance. A visually separated product is deemed unacceptable, thus a stable product is essential. Cold-water reconstitution showed syneresis after only 1 hour. A big layer of whey was observed in both 1% and 2% carrageenan concentration, meanwhile smaller but visible layer was observed in 3% carrageenan. Warm-water reconstitution showed a better performance. Only 1% carrageenan showed small layer of separation, whereas other treatment kept its stability even after 3 hours of observation. Kappa carrageenan is better dissolved in warm water [14] thus give better stabilizing effect than in cool water solution. Therefore it is proposed that the better reconstitution should be done by a portion of warm water to dilute the powder and subsequently added with cool water for organoleptical reason.

4. Conclusions

Yoghurt powder was successfully created using the proposed method. Optimum concentration of carrageenan was 2 % where the resulted yoghurt powder showed the highest bulk density, and smallest particle size distribution. The water activity of the resulted products was low enough to ensure the long shelf life. Better reconstitution was achieved using warm water which resulted in a stable solution with no visible separation.

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