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SODIUM CASEINATE IMPROVES EMULSION STABILITY OF MEAT MODEL SYSTEM FORMULATED WITH PRE-NEUTRALIZED RED PALM OLEIN-CANOLA OIL EMULSION GEL

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ABSTRACT

Replacing animal fat with vegetable fat in comminuted meat products often faces technological property challenges, such as high weight loss after cooking and a texture that is not dense and compact due to the predominant composition of unsaturated fatty acids. The use of emulsifiers from natural ingredients such as sodium caseinate can be a solution to improve the stability of the emulsion. In this research, sodium caseinate was added to the meat emulsion system at several levels: 0%, 0.15%, 0.30%, 0.45%, and 0.60% (w/w) of dough weight. The pH value, emulsion stability of the raw batter, cooking loss, texture profile and color of the final product were tested to prove the capabilities of sodium caseinate. The addition of 0.3% sodium caseinate improved emulsion stability, prevented excessive shrinkage and improved texture, without changing the color of the final product. In conclusion, the addition of sodium caseinate at 0.30% (w/w) is recommended in the manufacturing of comminuted meat products formulated with red palm-canola oil emulsion gel as animal fat replacer.

Keywords*:* Animal fat replacer; casein; emulsifier; texture; vegetable fat

INTRODUCTION

Replacing animal fats in comminuted meat products with vegetable oils has become a topic of interest from the point of view of human nutrition and the food industry. Vegetable oils provide monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) for human needs. One example of unsaturated fat that is often found in vegetable oils is oleic acid. These fatty acids are predominantly found in olive and canola oil. The oleic acid derivative product called oleoylethanolamide is a natural activator of sirtuin 1 (SIRT 1) and is a ligand of the peroxisome proliferator-activated receptor alpha (PPARα) nuclear receptor (Santa-María et al., 2023). For polyunsaturated fatty acids consumption, omega 6 fatty acids intake should also be reduced with moderate intake of omega 3 fatty acids. In fact, the ratio of omega 6 and omega 3 fatty acids intake above 4 in typical Western diet also increases the risk of inflammatory disease occurrence (Simopoulos, 2008). However, replacing solid fat with PUFA-rich liquid oil is a technological challenge, because PUFA-rich oil does not provide plasticity to the meat batter, thereby reducing emulsion stability and damaging the texture of the final product (Baek et al., 2016).

A prospective substitute for solid animal fat is vegetable oil extracted from palm oil without a bleaching process. In this research, red palm oil was used because it still has a fairly balanced saturated fatty acids (SFA), MUFA and PUFA content, plus it is rich in β-carotene and α-tocopherol as antioxidants (Tan et al., 2021). Emulsion gel in this case is referred to as oleogel. It is defined as oil, generally vegetable oil but can also be oil from marine products, which is converted into a semi-solid system with viscoelastic and hydrophobic properties through organogelation. Large amounts of liquid oil are trapped in a three-dimensional network using a small amount or more of organogelators from non-oil materials (Silva et al., 2021). Optimization of the formula for making gel emulsion from red palm oil and canola oil has been carried out previously (Utama et al., 2022). In this case, the meat batter formulation for comminuted meat products still has to be optimized by considering the many potential ingredients that can be used but which can positively influence the technological properties of the product.

Currently, the use of emulsifiers made from natural ingredients containing protein or other natural ingredients is very popular in the food industry. Casein sourced from milk, especially small casein aggregates, has been studied to have the ability to be a good emulsifier for oil-water interfaces because it provides low interfacial tension during rapid emulsification and has strong amphiphilic characteristics (Zhou et al., 2022). Casein in the form of micelles stabilizes emulsions through electrostatic and steric repulsions (Ma and Chatterton, 2021). Sodium caseinate consists of a soluble mixture of disordered hydrophobic proteins that have a strong tendency to associate into small protein particles that coexist in equilibrium with free casein molecules (Aslan Türker et al., 2023). In the casein micelle system, the micelle state is probably the lowest free energy state in the system. Of particular interest is the structure of micelles and the mechanisms that work to determine micelle

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size. Sodium caseinate is obtained by binding sodium with the casein component isolated from skim milk and then reacting with carbonic acid or citric acid. In addition, sodium caseinate is more soluble in water than pure casein (Aslan Türker et al., 2023). It also acts as an excellent emulsifier, and efficiently binds water and fat due to its good solubility and water retention ability (Zhou et al., 2022).

Emulsion stability is the ability of an emulsion to resist changes in its properties over time (Ravera et al., 2021). Effective strategies to prevent undesirable changes in emulsion properties in certain foods depend on the physicochemical mechanisms responsible for these changes. In practice, two or more of these mechanisms can work simultaneously. The addition of sodium caseinate to processed minced meat products, such as sausages and forcemeat, has been known to have a positive impact on physical quality (Okuskhanova et al., 2023; Yu et al., 2023). However, the use of sodium caseinate in these studies involved more than one food ingredient and/or food additive and provided a combined effect. This may be different when using different combinations of food ingredients and/or food additives from previous studies. In addition, sodium caseinate is used when preparing pre-neutralized oleogel to replace animal fat in lamb sausages (de Carvalho et al., 2020). Therefore, the objective of this study was to observe the impact of using sodium caseinate in a meat model system formulated with a gel emulsion from red palm-canola oil.

MATERIALS AND METHODS

Emulsion Gel Preparation

The oil-in-water (o/w) emulsion gel of red palm oil and canola oil was prepared according to the procedure of Utama et al. (2018). The oil phase comprised of 50% w/w of the total emulsion. The aqueous phase contained emulsifier E471, soy protein isolate, and inulin was mixed with 50°C water. Red palm oil, canola oil, emulsifier E471, soy protein isolate, and inulin were food grade and purchased from local supplier. The mixture was cooled down and let rest until stable weight after homogenization and stored in a refrigerator (4 ± 2°C) for 12 h until being used for meat model system manufacture.

Meat Model System Preparation

The meat batter was made according to Utama et al. (2018) with 60% (w/w) ground chicken breast, 20% (w/w) ice and 20% (w/w) red palm-canola oil emulsion gel with 30:70 ratio. Table salt containing 98% NaCl (1.5%, w/w) and sodium tripolyphosphate (0.30%, w/w) were mixed into meat batter. All ingredients were mixed and homogenized using a food processor for 2 min (HR7310/10, Philips Indonesia). The red palm-canola oil emulsion gel was then mixed in to the batter and homogenized for another 2 min. Sample was then immediately used for determining emulsion stability, cooking loss, texture profile, and color.

pH and Emulsion Stability

Sample (raw batter, 5 g) was homogenized in distilled water (DW) with 1:9 ratio and homogenized at max speed for 60 s using a hand blender (HR2533, Philips Indonesia). The pH value was determined in triplicate using a calibrated pH meter. The electrode was calibrated with acid and neutral technical buffer solutions according to manufacturer's instructions.

The meat batter was weighed as much as 10 g, put in a graduate centrifuge tube with 19-mesh sieve inside and prepared in triplicate. The tubes were covered with thin aluminum foil, sealed with petri film and put in a water bath set at 75°C for 30 min. After heating, the tubes were then cooled down to room temperature for 30 min. The amount of oil released (mL/kg) and the total fluid released (mL/kg) were determined gravimetrically using the scale on the tubes.

Cooking Loss and Texture Profile Analysis

The meat batter was weighed (100 g) and put in aluminum foil. The thickness of the batter was adjusted to 3 cm. Samples were then cooked at 80°C in a water bath for 30 min. Cooked meat batter were then cooled down to room temperature and weight was recorded. Cooking loss (%) was determined according to the differences in weight of raw and cooked samples.

Cooked samples were cut into one cm^3 size and placed on the plate under the probe. Texture profile of cooked samples was determined using TA-XT2i Plus (Stable Micro Systems Ltd., UK) with a 5 kg load cell. Texture profile of the sample included hardness (kg), springiness (ratio), cohesiveness (ratio), and chewiness (kg) were. The probe was cylindrical with 10-mm diameter. Samples were pressed at a compression rate of 60%. The probe was set to move downwards at a constant speed of 1.0 mm/s.

Instrumental Surface Color

The color of cooked samples that was sliced, was determined using a portable chroma meter with product type of CR-400 (Konica Minolta Inc., Tokyo, Japan). Lightness (L*), redness (a*), and yellowness (b*) values were recorded. The whiteness of samples was estimated according to Park (1994) using the following formula: $100 - [(100 - L^*)^2 + (a^*2 \times b^*2)]^{1/2}$. The color was assessed at 5 different locations on the surface of the sliced samples.

Statistical Analysis

Four batches of meat model system for each control and treatment group were manufactured. Analysis of variance was performed to determine the significant effect of different addition levels of sodium caseinate on emulsion stability, cooking loss, texture profile, and color. After significance level was observed, Duncan's multiple range test was employed to discriminate the means among treatment groups at $P < 0.05$. All analysis was performed using R-version 4.2.2 with the "Agricolae" library (De Mandiburu, 2017; R Core Team, 2022).

RESULTS AND DISCUSSION

pH

Significant differences were not found on the pH of meat batter formulated with red palm-canola oil emulsion gel. The pH of raw meat batter was in the range of 7.10-7.17 (Table 1).

In fact, pH can determine the technological properties of an oil-in-water emulsion and vice versa. The pH value which tended to be neutral in this case indicates that the functional properties of the meat protein can be optimal in binding fat- and water-soluble components.

The pH value did not change significantly due to the ability of sodium caseinate to stabilize the emulsion in both acidic and alkali conditions, while sodium caseinate itself did not change the pH of the emulsion. The isoelectric point of modified sodium caseinate can be altered to stabilize emulsion in different range of pH (Ma et al., 2009). This is supported by the recent findings of Xi et al. (2020) that sodium caseinate can maintain emulsions with acidic and alkaline pH values, even those with high salinity (with NaCl levels up to 6.1 M).

Table 1. Effect of sodium caseinate addition levels on pH, emulsion stability and cooking loss of meat batter formulated with red palm-canola oil emulsion gel

Variable	Sodium caseinate addition level (% w/w)					SEM
	0	0.15	0.30	0.45	0.60	
Meat batter pH	7.12	7.10	7.16	7.15	7.17	0.01
Emulsion stability						
Total fluid loss (mL/kg)	8.87[a]	6.13[b]	4.69[c]	4.52[c]	4.44[c]	1.87
Fat loss (mL/kg)	4.12[a]	2.14[b]	1.54[c]	1.45[c]	1.42[c]	0.32
Cooking loss (%)	11.72[a]	9.18[b]	7.27[c]	7.18[c]	7.20[c]	2.69

SEM, standard error of the mean.
[a–c]Means are significantly different ($P < 0.05$).

Emulsion Stability

The ability of meat protein in the meat model system formulated with red palm-canola oil to bind water- and fat-soluble components increased when sodium caseinate was added to a level of 0.30%. This ability does not change significantly even though the additional level increased up to 0.60%. This is indicated by the amount of liquid and fat released from the meat batter during heating (Table 1). The highest amount of fluid and fat loss was found in control (without the addition of sodium caseinate). This significant difference is caused by the ability of sodium caseinate to stabilize fat-in-water emulsions in the meat model system. In addition, maintaining a pH in the neutral range can optimize the ability of meat protein to form a stable emulsion.

Naturally, protein extracts isolated from meat can stabilize fat emulsions in water in a wide pH range 3-11 (Li et al., 2020). However, combining pale, soft and exudative meat and additives that increase batter pH close to 6.0 provides emulsion with improved stability (Chen et al., 2023; Zou et al., 2022). Interestingly, the addition of more than 0.30% sodium caseinate in this case apparently had no additional impact on the emulsion stabilization ability. Prevention of loss of fluid and fat from the emulsion during heating is possible, reaching its peak point by adding 0.3% sodium caseinate. Okuskhanova et al. (2023) and Yu et al. (2023) formulated processed minced meat products with sodium caseinate and other ingredients. Although the findings were similar to this study, the ingredients were different and not comparable to this study.

Cooking Loss

The addition of sodium caseinate had a positive impact on the yield of meat model system. Table 1 shows that adding sodium caseinate up to 0.30% reduces cooking loss significantly but adding more than 0.30% to 0.6% did not increase the yield any further. This increase in yield is evidence that the emulsion stability improved due to the addition of sodium caseinate up to a level of 0.30%. Yield is an important quality indicator for comminuted meat products because it is related to its economic value. The higher the yield will have implications for profits because the weight loss due to the production process will be reduced (Kumar, 2021). Many studies have shown that comminuted meat products made from vegetable fat as a fat source have poor properties in the final product, but this can be improved by adding sodium caseinate as an additive (Okuskhanova et al., 2023; Yu et al., 2023). One emulsifier that comes from natural ingredients is casein. Binding casein with sodium extends the shelf life of sodium caseinate and makes it easier to powder. Sodium caseinate is obtained from casein micelles which are acidified and then added with alkaline NaOH (Ma and Chatterton, 2021).

Texture Profile

One of the determining indicators of the quality of comminuted meat products is the texture of the final product. In this study, the textures measured included hardness, springiness, cohesiveness and chewiness. Hardness is determined from the magnitude of the first force in kg, springiness is the ability of the sample to return to its initial shape after being applied a force, cohesiveness is the work area in the second force compared to the work area in the first force, and finally chewiness is the combination of hardness, springiness and cohesiveness (Utama et al., 2019).

The addition of sodium caseinate to the level of 0.30% increases the overall variables related to the texture profile. This is influenced by the amount of dry material and liquid retained in the emulsion system during heating. Reducing the amount of liquid and fat released during the cooking process in the meat model system improves the texture profile. Previous studies have shown that comminuted meat products with vegetable fat as a fat source have poor textural properties in the final product, but this can be improved by adding sodium caseinate as an emulsifier (Okuskhanova et al., 2023; Yu et al., 2023). The final product becomes more compact, so the force required is greater. Both sausages and meatballs are expected to have a chewy and dense texture. Sausages have a higher fat content than meatballs so, in terms of chewiness, the meatballs that are popular with the public have a chewier texture than sausages. However, compact and dense contents are a must for both sausages and meatballs that are suitable for sale.

Table 2. Effect of sodium caseinate addition levels on texture profile of cooked meat model system formulated with red palm-canola oil emulsion gel

Variable	Sodium caseinate addition level (% w/w)					SEM
	0	0.15	0.30	0.45	0.60	
Hardness (kg)	1.85[c]	1.96[b]	2.44[a]	2.34[a]	2.48[a]	0.06
Springiness (ratio)	0.88[c]	0.95[b]	0.98[a]	0.97[a]	0.99[a]	0.01
Cohesiveness (ratio)	0.40[c]	0.45[b]	0.48[a]	0.49[a]	0.49[a]	0.01
Chewiness (kg)	0.65[c]	0.83[b]	1.15[a]	1.11[a]	1.20[a]	0.04

SEM, standard error of the mean.
[a–c]Means are significantly different ($P < 0.05$).

Instrumental Surface Color

The addition of sodium caseinate did not have a significant effect on the color measured instrumentally.

Table 3 shows that lightness, redness, yellowness and whiteness do not change with the addition of sodium caseinate up to 0.60%. This indicates that the use of sodium caseinate in comminuted meat products is permissible because it does not alter the surface color. Color also determines quality and is the initial benchmark for consumers when buying processed food products. The addition of additives often changes the appearance, especially the color of the product. However, sodium caseinate does not show this.

This finding was also aligned with previous studies (de Souza Paglarini et al., 2019; Jin et al., 2019).

Table 3. Effect of sodium caseinate addition levels on instrumental surface color of cooked meat model system formulated with red palm-canola oil emulsion gel

Variable	Sodium caseinate addition level (% w/w)					SEM
	0	0.15	0.30	0.45	0.60	
L* (lightness)	82.51	81.14	82.74	83.11	82.08	0.91
a* (redness)	0.87	0.85	0.88	0.84	0.83	0.04
b* (yellowness)	12.09	12.31	12.14	11.98	12.44	0.05
Whiteness	79.59	78.43	79.70	80.33	79.32	1.56

SEM, standard error of the mean.

CONCLUSION

Sodium caseinate is proven to be used as an additive in comminuted meat products formulated with red palm-canola oil emulsion gel as animal fat replacer. The use of sodium caseinate at 0.3% (w/w) of meat batter made of chicken breast and red palm-canola oil emulsion gel, stabilizes the emulsion of meat batter and improves the texture of cooked meat model system without altering its color. The next challenge is to substitute or replace the use of sodium in food additives so that the products have a smaller risk to consumer groups with hypertension.

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