ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Food Science 1 (2011) 315 – 321
Procedia Food Science

11th International Congress on Engineering and Food (ICEF11)

# Stability and rheological properties of fat-reduced mayonnaises by using sodium octenyl succinate starch as fat replacer

Siwatt Thaiudom *, Kallaya Khantarat

*School of Food Technology, Suranaree University of Technology, Nakhon Ratchasima 30000 Thailand*

**Abstract**

Sodium octenyl succinate starch (SOS) was used as fat replacer in 25, 50 and 75% fat-reduced mayonnaise (FR). The stability of mayonnaises: mean droplet size diameter ($d_{43}$), phase separation by centrifugal technique, brightness (L*), color different index (ΔE), storage and loss moduli (G' and G"), consistency index (K), apparent viscosity (η), and thixotopic loop were examined, compared with a full fat mayonnaise (FF). There was no effect of fat substitution on $d_{43}$ and phase separation. L* value of FR was significantly higher than those of FF. All samples showed gel-liked structure (G′>G″) and exhibited the thixotropic shear thinning behavior. G′, K, η, and thixotropic loop of FR tended to decrease when the fat substitution level increased. The $d_{43}$ and ΔE of 50% FR did not significantly change throughout a storage time while the others did. Thus, 50% fat-substituted with SOS could be applied as a fat replacer to stabilize and increase the storage time of such mayonnaise.


Selection and/or peer-review under responsibility of 11th International Congress on Engineering and Food (ICEF 11) Executive Committee.

*Keywords*: Starch; Sodium octenyl succinate; Fat replacer; Mayonnaise; Rheology

## 1. Introduction

The relationship between dietary fat and the development of cardiovascular disease and hypertension has prompted consumers to be more aware of the amount of fat in their diet. Therefore, food manufacturers have responded to that of consumer demands, resulting in a rapid market growth of products with a healthy image. However, as a major of food component, fat contributes to some sensory and physiological properties in the products. Those properties could be related to flavor, mouthfeel, texture, and stability of fat-based product such as emulsion. Modification of this product by using fat replacers is often viewed as an effective way to overcome such problems due to the reduction in fat content [1-3] but those properties might be changed.

* Corresponding author. Tel: +66-44-223099; fax: +66-44-223053
*E-mail address*: *thaiudom@sut.ac.th*


Selection and/or peer-review under responsibility of 11th International Congress on Engineering and Food (ICEF 11) Executive Committee.
doi:10.1016/j.profoo.2011.09.049

Mayonnaise is an O/W emulsion, typically containing high oil content (70-80%), egg yolk, vinegar and additives. To produce fat-reduced mayonnaise, it is necessary to decrease the dispersed phase and to increase the water content. Modified starches are common used as fat replacer because of their low cost, tasteless, and uniqueness providing creamy texture. Modified starches are also used as a thickening agent [4] to prevent phase separation during the storage of mayonnaise [2,5]. Some of modified starches have been found highly suitable for obtaining desirable organoleptic as well as physical properties of various food products.

Sodium octenyl succinate starch (E1450) is a product by substituting hydroxyl groups in the polysaccharide chains by octenyl succinic acid [6,7]. This polysaccharide exhibits amphiphilic character which enhances its emulsifying property. E1450 are also used as thickening agent by forming network with other polymer in aqueous solution through hydrophobic interaction. This increases the viscosity of the system and can stabilize droplet particles [8].

However, so far, there is less information about the effects of E1450 on functional properties of fat-reduced mayonnaises as a function of storage time. Thus, the objective of this research was to study the rheological properties and stability of such mayonnaise including mean droplet size diameter ($d_{43}$), phase separation under centrifugal technique, lightness ($L^*$), color different index ($\Delta E$) and rheological properties during 12 week-storage time at 25°C.

## 2. Materials and Methods

### *2.1 Mayonnaise preparation*

The recipe and method of mayonnaise preparation were modified from Lui et al. [1] as showed in table 1. The mayonnaise samples were prepared using food mixer (Moulinex, France). Water, sugar, salts, egg yolk and 0.5 % benzoic acid were mixed together at the mixer speed 1 for 5 min. Then, E1450, purchased from Siam modified starch Co., Ltd., was dispersed in oil and vinegar and gradually added into the mixer blow at speed 4 within 5 min. Samples were homogenized using Moulinex portable homogenizer (speed 4) for 10 min. The samples were kept in glass container with hermitical seal and wrapped with aluminum foil to protect light. Then, they were stored at 25$^0$C overnight before analysis.

Table 1**.** Mayonnaise formulations based on 1.5 kg for each formulation

| **Ingredients (g)** | **FF[1]** | **25FR[1]** | **50FR[1]** | **75FR[1]** |
|---|---|---|---|---|
| Oil | 1200 | 900 | 600 | 300 |
| Vinegar | 120 | 120 | 120 | 120 |
| Egg yolk | 120 | 120 | 120 | 120 |
| Sugar | 10 | 10 | 10 | 10 |
| Salt | 10 | 10 | 10 | 10 |
| Water | 20 | 290 | 560 | 830 |
| E1450 | 0 | 30 | 60 | 90 |

Remark: [1]FF, 25FR, 50FR and 75FR referred to full fat, 25, 50 and 75% fat-substituted mayonnaise, respectively.

### *2.2 Rheological properties*

Rheological properties of mayonnaise were carried out using a controlled stress Rheometer (GR-2 TA instruments, New Castle, DE, US) with 40 mm diameter parallel plates. The measurements were conducted at a 1 mm. gap distance at 25 $^{0}$C. The linear viscoelastic range (LVR) was determined under mode of strain sweep (0.1-100%) at a fixed frequency of 5 Hz. The viscoelastic properties were studied through a dynamic frequency sweep (0.1 - 100 Hz) by applying a constant strain of 0.5% which was within LVR. The steady flow behavior of mayonnaise was carried out following the method of Worrasinchai et al., [3]. All rheological data were calculated following Power's law model using TA instrument software program (TA Instruments Advantage Software, 5.0.1, US).

*2.3 Particle size measurement*

Mayonnaise samples (0.05g) were diluted with 100 ml. of 0.1% sodium dodecyl sulfate solution. The mixes were gently stirred before analysis using a particle size analyzer (Mastersizer, Malvern Instrument Ltd, UK). Droplet size measurements were reported as the volume-weighted mean diameter ($d_{43}$).

*2.4 Optical microscopy*

The mayonnaise structure was observed using Nikon 641463 microscope (Nikon corp., Japan). A drop of mayonnaise sample was mixed with 2% (w/v) iodine solution and placed on a slide. The samples were covered with a cover slip glass and were observed at a magnification of 100x at room temperature.

*2.5 Color*

The mayonnaise samples were measured for color (L*, a*, b*) using Minolta Colorimeter CR-300 (Konica Minolta, Osaka, Japan). Color different index (ΔE) was calculated using following equation.

$$\Delta E = [(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2} \quad (1)$$

*2.6 Phase separation*

Twenty grams ($F_0$) of samples were transferred to 50 ml centrifuge tubes with tightly sealed by plastic caps and stored at 50 $^{0}$C for 48 h. After storage, the samples were centrifuged at 3000 rpm for 10 min (Centrifuge, Legand Mach 1.6L, Germany). The weight of the oil phase ($F_1$) was measured and percentage of separated oil was characterized using following equation.

$$\text{Separated oil portion (\%)} = (F_0- F_1/F_0)\times 100 \quad (2)$$

*2.7 Statistical analysis*

A one-way analysis of variance (ANOVA) and Duncan's New Multiple Range Test were used to establish the significance of differences of all property data. The result was performed using the SPSS version 11.0 windows program.

## 3. Results and Discussion

*3.1 Rheology property*

Rheological properties of FR and FF mayonnaise following Power's law model are listed in Table 2.

The more fat substitution, the less of K, thixotropic, G' and viscosity. In contrast, the more total fat content in FR, the more of those values. Even FF contained more fat compared with FR, the viscosity of FF was lower than that of 25FR. This might be because FF comprised bigger droplet sizes of fat (data not shown) which less resisted to an applied force during flow behavior measurement, resulting in a low viscosity [1]. All mayonnaise samples exhibited thixotropic shear thinning behavior (Fig. 1). However, 25FR and 50FR had more thixotropic loop than the rest (Table 2). This implied that the structure of those mayonnaises was easier to be broken down and vice versa more difficult to return to their original structure compared with structure of FF and 75FR [3,8]. This might be because there were more hydrophobic interaction and gel-net work formation as microparticulated gel in FF and 75FR, respectively than in 25FR and 50FR [1].

The viscoelastic properties of all mayonnaises were conducted at 0.5% controlled strain which was in LVR. The results showed that all samples except 75FR were classified into gel-like structure because G' was larger than G" throughout the tested frequency range (Fig. 2). This might be attributed to the interlinked network structure of egg yolk proteins which induced fat particles rearranged to form fat particle networks [10]. However, all FR samples gave less tanδ than FF (data not shown). This meant that FR samples had less gel-like characteristic compared with FF. Thus, this confirmed that the more fat substitution, the more liquid-like characteristic since there were more water-occupy spaces in a continuous phase. In addition, Ma and Barbosa-Cánovas [11] reported that the more fat content, the more G'. However, the results showed that G' was relevant to fat droplet size that was the smaller droplet size could contribute to a higher G', resulting in more solid-like structure [3,12,13]. Thus, even there were less fat content but smaller fat droplet size in FR samples compared with FF, G' of these sample, especially 25Fr and 50FR, was higher than that of FF (Table 2 and Figure 2). However, at tested shear rate (50 1/s) for flow behavior test, 75FR showed the least G' (Table 2) while, for an oscillatory test, it showed a concentrated solution spectra (Fig. 2) [14]. This might be due to the high content of microparticulated gel networks of E1450 in 75FR sample that was not strong enough when they were compared to those in 25FR and 50FR samples. Consequently, such networks of 75FR were easily broken down when they were applied shear forces for flow behavior test.

### *3.2 Particle size measurement, color attribute and phase separation*

Fat particle size and color of mayonnaises were shown in Table 3. Fat particle size ($d_{43}$) of FF was the highest since fat in this sample was easily broken down and coalesced, respectively due to the effect of high fat volume fraction which was close to the critical volume fraction (~0.8) [3,9]. In contrast, droplet size of FR samples was smaller than that of FF because E1450 might contribute as an emulsifier [7] and enhance egg yolk to stabilize fat droplet more completely in these samples than in FF.

Table 2. Flow behavior by using Power's law model fit to the upward curve

| Sample | $D_{43}$ (μm) | L* | a* | b* | % Phase separation |
|---|---|---|---|---|---|
| FF | 10.14 ±1.76$^{b}$ | 91.63 ±0.41$^{a}$ | -6.20 ± 0.67$^{a}$ | 25.85±0.49$^{c}$ | 58.07±2.75 |
| 25FR | 4.25 ±0.24$^{a}$ | 96.11±0.39$^{b}$ | -4.67±0.14$^{b}$ | 19.71±0.47$^{b}$ | nd |
| 50FR | 3.56 ±0.01$^{a}$ | 96.71±0.49$^{b}$ | -4.21±0.26$^{b}$ | 18.01±0.31$^{a}$ | nd |
| 75FR | 2.16 ±0.56$^{a}$ | 96.21±0.45$^{b}$ | -4.53±0.39$^{b}$ | 19.55±0.21$^{b}$ | nd |

Remark: [1] storage modulus at 1 Hz and 0.5% strain, [2] viscosity at shear rate 50 1/s

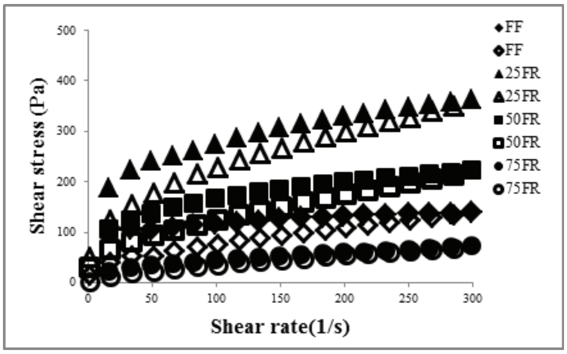


Fig. 1. Flow curves of mayonnaise samples.
Full symbols represent the up curve and empty symbols present the down curve

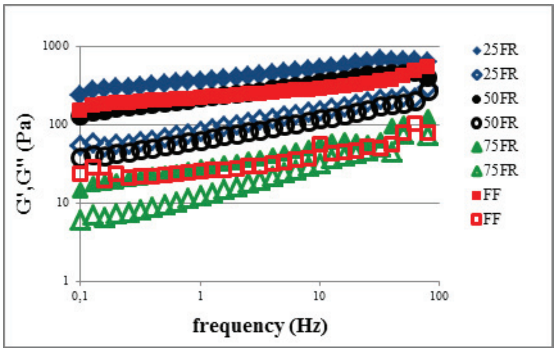


Fig. 2. Dynamic mechanical spectra of mayonnaise samples measured at 05% strain. Full symbols are storage modulus (G') and empty symbols are loss modulus (G'')

L* and a* of all FR samples were higher than those of FF (Table 3) because of the addition of E1450. Theoretically, samples with higher fat content and smaller fat droplet size always have a high L*, resulting in good refraction of light [9]. Even though all FR samples contained less fat, their droplet size was smaller than that of FF. Thus, in this case, the addition of E1450 and smaller particle size could help sample to be brighter, resulting in high L* and a*.

All FR samples did not show phase separation while FF did. This might be due to E1450 could stabilize and prevent fat coalescence from centrifugal force, resulting in no phase separation.

### *3.3 Stability of mayonnaise as function of storage time*

The stability of mayonnaises was showed in Figure 3, 4 and 5. There was a little change of $d_{43}$ for all FR samples throughout a storage time while $d_{43}$ of FF seemed to decrease at the beginning and to increase at the end of storage time. This implied that E1450 could prevent a change of fat droplet size by stabilizing fat particles, resulting in a less change of $d_{43}$. As mentioned previously, particle size in terms of $d_{43}$ related to G' of sample thus, if $d_{43}$ was constant, G' should also be constant. This could be seen in Figure 3 and 4. Even though $d_{43}$ and G' had a less change, color change index ($\Delta E$) did change a lot. The $\Delta E$ of FR samples substituted by high percentage of E1450 was higher than that of FR samples substituted by less E1450 and FF. This might be because of a change of b* that was affected by lutein and β-carotene degradation during storage time [15-17]. Moreover, such pigments are hydrophobic thus, they rarely dissolved in continuous phase which was water and also could less dissolve in dispersed oil phase because of a limitation of fat content in such samples. This consequently had more pigment degradation during storage. However, substitution fat with E1450 in 50FR gave a constant $\Delta E$ as in FF while substitution at 25 and 75% E1450 seemed to have high color change throughout storage time.

Table 3. Physical properties of full fat and fat-reduced mayonnaises

| Sample | K (Pa.s) | Flow behavior index | Thixotropic (Pa/s) | $G'^{1}$(Pa) | Viscosity $^{2}$(Pa.s) | $R^2$ |
|---|---|---|---|---|---|---|
| FF | 43.54±3.85$^{b}$ | 0.285 ±0.021$^{b}$ | 6,802 ± 112$^{b}$ | 288.3±5.23$^{b}$ | 2.663±0.002$^{b}$ | 0.968 |
| 25FR | 97.68±8.67$^{c}$ | 0.2423± 0.036$^{a}$ | 16,412±805$^{d}$ | 529.20±5.59$^{c}$ | 4.887±0.104$^{c}$ | 0.995 |
| 50FR | 51.24±2.21$^{b}$ | 0.2558±0.009$^{ab}$ | 12,193±603$^{c}$ | 340.85±7.23$^{b}$ | 2.790 ±0.121$^{b}$ | 0.998 |
| 75FR | 6.885±2.72$^{a}$ | 0.4104±0.005$^{c}$ | 3,026±1146$^{a}$ | 56.23 ±23.5$^{a}$ | 0.942± 0.011$^{a}$ | 0.997 |

Remark : nd = not detected

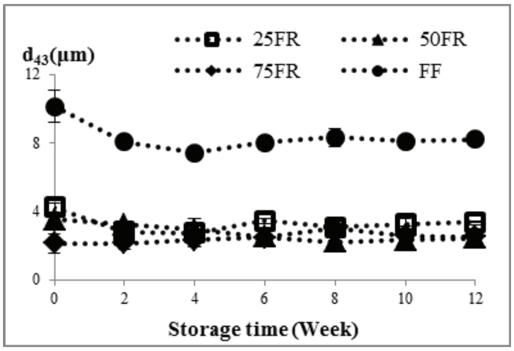


Fig. 3. Particle size of mayonnaise during storing period

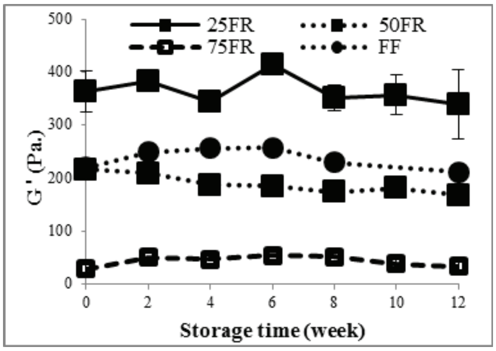


Fig. 4. Viscoelastic stability of mayonnaise during storage time

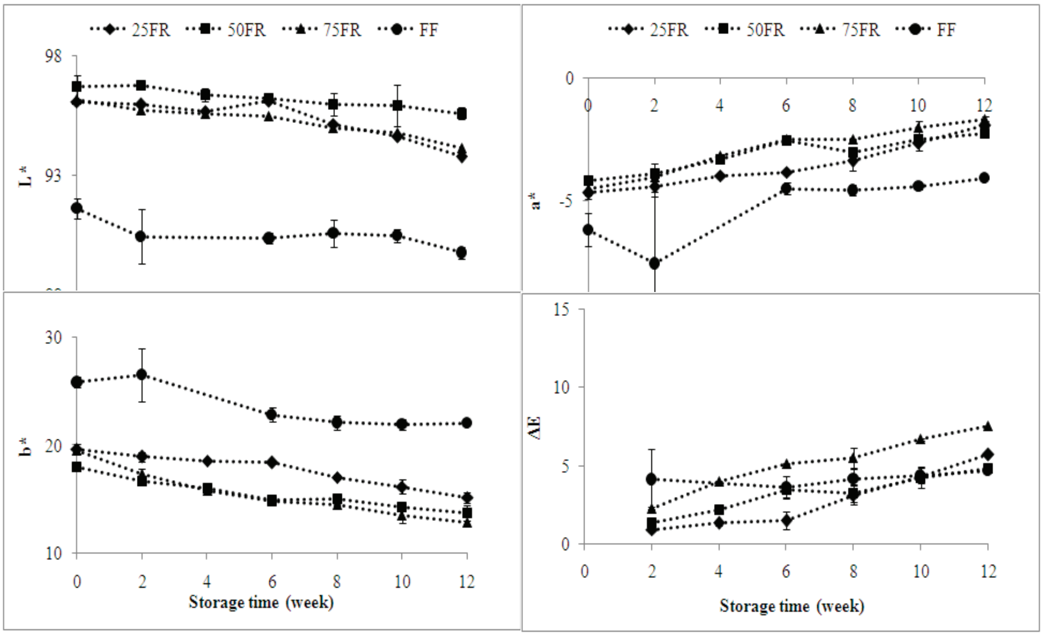


Fig. 5. Color stability of mayonnaise during storage time

## 4. Conclusion

From the results, it can be concluded that sodium octenyl succinate starch could be used as fat replacer at 50% in order to reduce fat content in mayonnaise while its rheological properties and stability, especially color were still the same throughout a storage time.

## Acknowlegements

This study was supported by Thailand Research Fund (TRF) project code MRGWI 52S163 and Suranaree University of Technology.

## References

1] Lui, H., Xu, X. M. and Guo S. D. Rheological, texture and sensory properties of low-fat mayonnaise with different fat mimetics. *Food Sci Technol*. 2007; **40**: 946-954.

[2] Mun, S., Kim, Y. L., Kang, C. G, Park, K. H., Shim, J. Y. and Kim,Y. R. Development of reduced-fat mayonnaise using 4αGTase-modified rice starch and xanthan gum. *Int J Biol Macromol* 2009; **44** (5):400-407.

[3] Worrasinchai, S., Suphantharika, M., Pinjai, S. and Jamong, P. β-Glucan prepared from spent brewer's yeast as a fat replacer in mayonnaise. *Food Hydrocolloids* 2006; **20**: 68-78.

[4] Depree, J. A. and Savage, G. P. physical and flavour stability of mayonnaise. *Trends Food Sci Tech* 2001;**12**: 157-163.

[5] Cheung, I., Gomes, F., Ramsden, R. and Roberts, D. G. Evaluation of fat replacers Avicel , N Lite S and Simplesse in mayonnaise. *IJCS* 2002; **26**:27-33.

[6] Nilsson, L., Leeman, M., Wahlund, K. G. and Bergenstáhl, B. Mechanical degradation and changes in conformation of hydrophobically modified starch. *Biomacromolecules* 2006; **7**: 2671-2679.

[7] Tesch, S., Gerhards, C. and Schubert, H. Stabilization of emulsions by OSA starches. *J Food Eng* 2002; **54**: 167-174.

[8] Ortega-Ojeda, F. E., Larsson, H. and Eliasson, A. C. Gel formation in mixtures of hydrophobically modified potato and high amylopectin potato starch. *Carbohyd Polym* 2005**; 59**:313-327.

[9] McClements, D.J. *Food Emulsion: Principle, Practice and Techniques*. 2$^{nd}$ ed. Boca Rota: CRC Press. USA. 2005.

[10] Kiosseoglou, V. D. and Sherman, P. Influence of egg yolk lipoproteins on the rheology and stability of O/W emulsions and mayonnaise. *J Texture Stud* 1983; **14**: 397-417.

[11] Ma, L.and Barbosa-Cánovas, G. V. Rheological characterization of mayonnaise. Part II: Flow and viscoelastic properties at different oil and xanthan gum concentrations. *J Food Eng* 1995; **25**: 409-425.

[12] Langton, M., Jordansson, E., Altskär, A., Sörensen, C. and Hermansson, A. Microstructure and image analysis of mayonnaises. *Food Hydrocolloids* 1999; **13**: 113-125.

[13] Maruyama, K., Sakashita, T., Hagura, Y. and Suzuki, K. Relationship between rheology, paticle size and texture of mayonnaise. *Food Sci Technol Res* 2007; **13**(1): 1-6.

[14] Steffe, J.F. *Rheological Methods in Food Process Engineering*. 2nd ed. Freeman Press. USA. 1996.

[15] Aman, R., Schieber, A. and Carle, R. Effects of heating and illumination on trans-cis isomerization and degradation of β-carotene and lutein in isolated spinach chloroplasts. *J Agr Food Chem* 2005; **53**: 9512–9518.

[16] Lennersten, M. and Lingnert, H. Influence of wavelength and packaging material on lipid oxidation and colour changes in low-fat mayonnaise. LWT 2000; **33**: 253-260.

[17] Santipanichwong, R. and Suphantarika, M. Carotenoids as colorants in reduced-fat mayonnaise containing spent brewer's yeast β-glucan as a fat replacer. *Food Hydrocolloids* 2007; **21**: 565-57.

Presented at ICEF11 (May 22-26, 2011 – Athens, Greece) as paper FMS643.