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Original Research Article

Storage stability of mayonnaise using mangosteen nanofibrillated cellulose as a single emulsifier

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ABSTRACT

This research was aimed to study the effects of storage time on properties and stability, including texture, color, pH, particle size, rheology, sensory acceptability, and phase separation of mayonnaise using nanofibrillated cellulose (NFC) as a single emulsifier. NFC was extracted from mangosteen (*Garcinia mangostana* L.) rind using hot aqueous sodium hydroxide solution followed by shearing in a high-pressure homogenizer. A control formula of mayonnaise using egg yolk as an emulsifier was prepared and used as a reference. For non-egg formula, the egg yolk was fully substituted by NFC at levels of 5.0, 7.5 and 10.0% (w/w). All samples were kept in a refrigerator at 4ºC for 8 weeks. The texture, color, pH, particle size, rheology, and sensory acceptability were determined every 2 weeks. The results showed that an apparent viscosity of all formulas were decreased with increasing storage time ($p \leq 0.05$). The lightness (L^*) was slightly decreased while the redness (a^*) and the yellowness (b^*) were increased. Similarly, pH was increased with increasing storage time. However, the oil droplet diameter (*i.e.*, volume average diameter or ($d_{4,3}$) and adhesiveness were not significantly different from the first week for all formulas ($p > 0.05$). In addition, no water layer separation was observed throughout the storage time. After storage, all NFC mayonnaise formulas were accepted by panelists with the sensory acceptability score between like slightly and like moderately. The results confirmed that NFC was an effective emulsifier and this finding exhibited the important implications of the utilization of NFC as a natural emulsifier in the development of label-friendly food emulsion product.

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INTRODUCTION

Mayonnaise is a thick cold sauce or dressing usually used in sandwiches and composed salads. It is a stable oil-in-water emulsion containing oil, vinegar or lemon juice, egg yolk, salt, spice, and herb. Generally, the proteins and lecithin in the egg yolk serve as emulsifiers in mayonnaise (Depree & Savage 2001; Hasenhuettl, 2008). Egg yolk is most critical for the stability of the product (Hasenhuettl, 2008). However, the constraints are the risk of contamination with *Salmonella* sp. on raw chicken eggs, the price and quality of chicken eggs, as well as the high content of cholesterol in egg yolk (Sathivel *et al*., 2004). Moreover, some vegetarians cannot consume egg-based foods. These lead to researches on alternative emulsifying agents in recent years. To produce non-egg mayonnaise, the egg yolk, which is a natural emulsifier from the basic formula, was replaced by other natural emulsifiers for preserving the same quality attributes as the original products. For the quality, mayonnaise must contain at least 65% total fat and the pH should not higher than 4.1. According to the standard of mayonnaise and salad cream as Thai industrial standard (No.1402) B.E.2540 (1997), the color of mayonnaise varies from ivory to light-yellow, and its texture from a light cream to a thick gel.

Emulsifiers are surface active materials that adsorb at interfaces and facilitate the production of small droplets by lowering their interfacial tension during homogenization (Chung *et al*., 2017; Dickinson *et al*., 2004; McClements, 2015). The common food emulsifier such as monoglycerides, proteins, phospholipids, and polysaccharides (Dickinson, 2003, 1992; Garti & Reichman, 1993; Hasenhuettl & Hartel, 1997; McClements, 2005). However, great efforts have been spent on searching for a new natural food-grade emulsifier (Surh *et al*., 2006a, b; Yun et al., 2007) to replace the synthetic one.

Nanofibrillated cellulose (NFC), firstly discovered by Turbak *et al.* (1983), is a polysaccharide extracted from natural cellulosic materials with diameters in the nanometer range (5-50 nm) but lengths of several micrometers or more (Nechyporchuk *et al.*, 2016). The diameter and length of NFC depend on raw material, extraction and mechanical methods used in preparation step (García *et al*., 2016). The NFC is generally produced from many sources such as wood, the cellulosic residues, and wastes produced from agricultural and industrial activities (Nechyporchuk *et al*., 2016). Currently, some nanocellulose is allowed to use in commercial as a stabilizer, rheology modifier, and packaging (Gómez *et al*., 2016). Previous studies showed that NFC exhibited emulsifying properties in an oil-in-water emulsion, which is called "Pickering mechanism". NFC could prevent coalescence by forming a steric barrier around oil droplets and could stable the emulsion without any phase separation for 80 days by three dimensional network formation of NFC in continuous phase (Winuprasith & Suphantharika 2013, 2015). Moreover, NFCs are poorly utilized in the human digestion tract and, therefore, functions as a dietary fiber.

For all these reasons, we expect that this NFC should be effectively used as an emulsifier in mayonnaise. In fact, there is no published data in the literature on the storage stability of mayonnaise using NFC as a single emulsifier. The aim of this study was to determine the storage stability of the non-egg mayonnaise using NFC as a single emulsifier. The physicochemical properties and sensory acceptability were also determined throughout the storage time for 8 weeks.

MATERIALS AND METHODS

Materials

Dried mangosteen (*Garcinia mangostana* L.) rind was obtained from a local manufacturer (Chanthaburi, Thailand), grounded through a 100 mesh sieve, and then packed into a polypropylene plastic bag. The mangosteen rind powder was kept at room temperature until used as a raw material for NFC preparation. Sodium hydroxide (NaOH) and phosphoric acid (H_3PO_4) were purchased from Mallinckrodt Baker, Inc. (Phillipsburg, NJ, USA). Hydrogen peroxide (H_2O_2) was purchased from Merck KGaA (Darmstadt, Germany). Turmeric extracted powder, vinegar, lime juice, egg yolk, mustard, sugar, salt, and soybean oil were purchased from local supermarkets.

Nanofibrillated cellulose (NFC) preparation

NFC from mangosteen rind was prepared followed to this method (Winuprasith & Suphantharika, 2013). Briefly, cellulose was extracted using hot NaOH solution (90°C) at pH 12, washed, neutralized, and then bleached using hot H_2O_2 solution (90°C). The yellow-brown, water-swollen purified cellulose was collected by filtration. The purified cellulose was used for the preparation of NFC by re-dispersing in distilled water at a concentration of 1% (w/w) and then passing through a high pressure homogenizer (APV® 1000, SPX Flow Technology Crawley Ltd., West Sussex, UK) at a pressure of 500 bar for 20 passes at room temperature (25°C). The final material was yellow-brown gel-like aqueous matter.

Mayonnaise preparation

Mayonnaise formulas are shown in Table 1. For the NFC mayonnaises, egg yolk was completely replaced by NFC at levels of 5%, 7.5%, and 10% (w/w). All ingredients, except the oil, were blended gently using a hand blender (BOSH® MSM67160, Robert Bosch GmbH, Gerlingen, Germany) at 3,200 rpm for 5 minutes. Then, the oil was gradually added and blended continuously at 3,200 rpm for 2 minutes. The mayonnaises were packed in a polypropylene cup and covered with a lid. The samples were stored at 4°C for 8 weeks.

Table 1. Percentage of each ingredient used in mayonnaise using egg yolk (control) and NFC as a single emulsifier.

Formula Ingredient	Control	NFC concentration (%) 5	7.5	10
Egg yolk	10.00	-	-	-
NFC	-	5.00	7.50	10.00
Vinegar	4.00	4.00	4.00	4.00
Lime juice	4.00	4.00	4.00	4.00
Mustard	0.36	0.36	0.36	0.36
Sugar	3.00	3.00	3.00	3.00
Salt	0.71	0.71	0.71	0.71
Turmeric powder	0.05	0.05	0.05	0.05
Oil	77.88	82.88	80.38	77.88

Particle size measurement

The particle size of the sample was analyzed by a particle size analyzer (Mastersizer 3000, Malvem Panalytical Ltd, Malvern, UK). Droplet size measurements were reported as the volume-weighted mean diameter (*d*4,3) and surface-weighted (*d*3,2) mean particle diameter. Optical properties of the sample were defined as follows: refractive indices of oil and water were 1.46 and 1.33, respectively and absorption was assumed to be 0. The initial particle size of all mayonnaise samples was measured after sample preparation. Then, the samples were randomly sampled two times at 4th and ^{8th} week during storage.

Color measurement

The color of the mayonnaise was measured in the *L**, *a**, *b** system by a Hunter lab color Flex® colorimeter (EZ, Hunter Associates Laboratory Inc., Virginia, USA). *L** represents the lightness, and *a** and *b** are color coordinates: where *+a* is red, *-a* is the green, *+b* is yellow, and *-b* is the blue directions. The difference of color between week 0 and other weeks calculated by the following equation:

$$\Delta E = ((\Delta L^*)2 + (\Delta A^*)2 + (\Delta B^*)2)1/2$$

The initial color of freshly prepared mayonnaise was measured after preparation step. The samples were randomly sampled every 2 weeks for 8 weeks during storage.

Texture profile analysis

Texture measurement was carried out using a Texture Analyzer (TA.XT plus, Stable Micro Systems Ltd, Surrey, UK). The aluminum cylinder probe p/25 was used. The probe height calibration was set to return distance at 50 mm, return speed at 10 mm/sec, and contact force of 5 g. The sequence menu was set pre-test speed at 1 mm/sec, test speed at 2 mm/sec and post-test speed at 5 mm/sec with a distance and time of 20 mm and 5 sec, respectively. Each sample contained in a plastic cup each cup containing 50 g of mayonnaise was used for analyzing. The initial texture of the freshly prepared mayonnaise was measured after preparation step. The samples were randomly sampled every 2 weeks for 8 weeks during storage.

pH measurement

The pH of mayonnaise was measured using a pH meter (Starter 2100, Ohaus Corp., New Jersey, USA) at room temperature (25°C). The initial pH of the freshly prepared mayonnaise was measured after preparation step. The samples were randomly sampled every 2 weeks for 8 weeks during storage.

Rheological measurement

The rheology measurement was performed using a rheometer (HAAKE™ MARS 400, Thermo Fisher Scientific Inc., Massachusetts, USA.) with a cone and plate (35 mm diameter, 2° cone angle) at 25°C. The apparent viscosity measured at room temperature. The shear rate increased continuously up to 300 s-1 followed by the shear rate in a decreasing mode from 300 s^{-1} to 0.1 s^{-1} in 6 minutes. The initial rheological properties of the freshly prepared mayonnaise were measured after preparation step. The samples were randomly sampled two times at 4th and 8th week during storage.

Sensory evaluation

Sensory evaluation of the freshly prepared mayonnaise was conducted immediately after mayonnaise preparation and then the samples were sampled two times at 4th and 8th week. The sensory parameter includes appearance, texture, flavor, and overall acceptability was evaluated by 30 untrained panelists using the 9-point hedonic scale (1= Dislike extremely and 9 = Like extremely). Drinking water was served to panelists between the samples to cleanse the palate.

Statistical analysis

A one-way analysis of variance (ANOVA) and Duncan's Multiple Range Test ($p \leq 0.05$) were used to determine the significant difference between the physicochemical properties and sensory characteristic of all samples for all storage time. The analyses were performed using the SPSS version 19 for window program.

RESULTS AND DISCUSSION

Particle size measurement

The droplet diameter, including surface-weighted mean particle diameter ($d_{3,2}$) and volume-weighted mean particle diameter ($d_{4,3}$) of the formulated mayonnaise using egg yolk (control) and NFC as a single emulsifier at various concentrations from 5-10 % (w/w) are shown in Table 2. The droplet diameters, for both $d_{3,2}$ value and $_{d4,3\ v}$alue of all NFC formulas were larger than those of control formula. The reason for this difference is that they are sensitive to different aspects of the particle size distribution, i.e. $d_{3,2}$ is more sensitive to the presence of small particles, whereas $d_{4,3}$ is more sensitive to the presence of large particles in the size distribution (McClements, 2005). The droplet size was decreased when the NFC concentration was increased. At high NFC concentration, the NFC formed three-dimension network which helped to stabilize and prevented the oil droplets from coalescence. (Aveyard *et. al.,* 2003; Dickinson *et. al.,* 2004; Frelichowska *et. al.,* 2010; Gao *et. al*., 2017; Kalashnikova *et. al.,* 2011; Li *et al.,* 2018; Rayner *et. al.*,2014; Tambe & Sharma, 1994, 1995; Tzoumaki, 2011). After 8 weeks of storage, the $d_{4,3}$ value of the NFC and control formulas did not significantly (p > 0.05) change. This result agrees with Tzoumaki (2011), that $d_{4,3}$ values of 10%(w/w) corn oil-in-water emulsion stabilized by 0.01-1.0%(w/w) chitin nanocrystal was decreased when a concentration of chitin nanocrystal was increased and did not change after storage for 4 weeks. Similarly, *d*4,3 values of an emulsion stabilized by insoluble starch nanoparticle (ISNP) did not significantly increased after storage for 4 weeks. In the other hand, the $d_{4,3}$ of an emulsion stabilized by octenyl succinylation treated soluble starch nanoparticle (OSA-SSNP) was significantly increased (Ye *et al.,* 2017). In addition, *Li et al.* (2012) studied starch nanocrystals -stabilized O/W Pickering emulsion. The results showed that after storage for 8 weeks, droplets size did not different and no coalescence occurred when starch nanocrystal concentration was higher than 0.02% (w/w). However, after storage for 5 and 12 months, the droplets size was significantly increased for both $d_{3,2}$ and $d_{4,3}$.

Table 2. Surface-weighted ($d_{3,2}$) and volume-weighted ($d_{4,3}$) mean diameter of mayonnaise samples.

Particle size (µm)	Formula Week	Control	5%NFC	7.5%NFC	10%NFC
	0	2.04±0.17[a]	28.13± 2.84[a]	28.27±4.18[ab]	25.93±2.60[ab]
$D_{3,2}$	4	1.99±0.00[a]	28.57±0.06[a]	26.27±0.06[b]	24.87±0.06[b]
	8	1.90±0.01[a]	30.73±0.06[a]	33.07±0.06[a]	28.90±0.90[a]
	0	3.53±0.29[ab]	75.31±4.32[a]	74.72±4.21[a]	65.57±3.06[a]
$D_{4,3}$	4	3.21±0.01[b]	79.03±0.15[a]	76.07±0.15[a]	66.33±0.06[a]
	8	3.61±0.04[a]	76.33±0.15[a]	78.10±0.10[a]	68.17±0.06[a]

Mean ± SD value followed by letter in each column for the same parameter are significantly different at $p \leq 0.05$ by ANOVA and Duncan's Multiple Range Test.

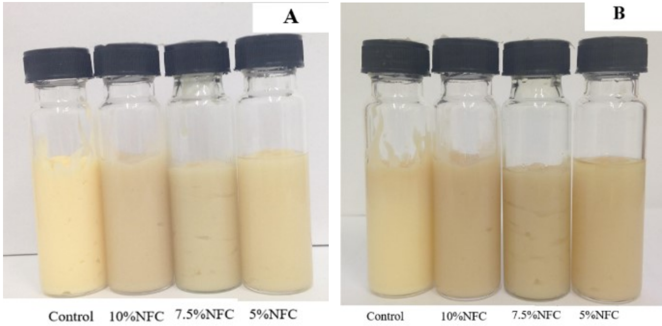

Figure 1. Optical images of mayonnaise using egg yolk (control) and NFC as a single emulsifier storage at 25°C for 1 day (A) and 90 days (B).

Color measurement

The color of all mayonnaise formulas are shown in Table 3. The *L**, *a** and *b** values of the mayonnaise formulas containing NFC were lower than those of the control. The lightness (*L**) and yellowness (*b**) values decreased with increasing level of NFC, while the redness (*a**) values increased. Representing, the mayonnaise with the high concentration of NFC was darker than the one with lower NFC concentration, due to a relatively high color intensity of NFC itself which was yellow-brown color (*L** = 31.73, *a** = 0.74, *b** =8.37) (Winuprasith & Suphantharika, 2015). In the presence of NFC, some of the light was absorbed by the chromophores in the NFC and therefore did not contribute to the light scattering, resulting in a lower lightness and higher color intensity. The change in color of the samples was supported by Δ*E** values. Normally, Δ*E** value less than 1.0 is imperceptible and any Δ*E** greater than 1.0 is noticeable (Mokrzycki & Tatol, 2011). The Δ*E** values of all NFC mayonnaise were less than 1.0. The results indicated that the panelist could not notice any change in the color of the samples. A variety of studies have shown that the lightness decreases and the color intensity increases as the concentration of chromophoric material in the emulsion increases (McClements, 2005). After storage for 8 weeks, the *L** values of the control, 5% NFC, and 10% NFC formulas were significantly ($p < 0.05$) decreased, while the *L** values of 7.5% NFC formula was significantly ($p < 0.05$) increased. However, it has been reported that the color of emulsions was less sensitive to droplet flocculation (Chantrapornchai *et. al*., 1999; McClements, 2005), which in this case occurred at high NFC concentrations and longer storage time. The reason is that the individual emulsion droplets are spherical, homogenous particles, whereas flocs are nonspherical, heterogenous particles that have many internal boundaries, and therefore one cannot expect a floc to behave like a droplet of the same diameter (Chantrapornchai *et al*., 2001). After storage, the color was changed support by ΔE value. Normally, ΔE value less than 1, observer did not notice and 1-2, trained observer can notice.

Table 3. The color of mayonnaise using egg yolk (control) and NFC as a single emulsifier and storage for 8 weeks at 4°C.

Parameter	Formula Week	Control	5%NFC	7.5%NFC	10%NFC
	0	86.16±0.02[a]	66.33±0.06[ab]	66.06±0.06[c]	65.67±0.16[ab]
	2	85.70±0.28[ab]	66.43±0.04[a]	66.04±0.06[c]	65.01±0.02[c]
L*	4	85.23±0.47[c]	66.32±0.10[ab]	66.23±0.12[b]	65.22±0.28[c]
	6	86.05±0.05[a]	66.43±0.05[a]	66.37±0.03[ab]	66.13±0.43[a]
	8	85.56±0.03[bc]	66.19±0.11[b]	66.46±0.09[a]	65.29±0.05[bc]
	0	3.64±0.12[a]	0.75±0.04[c]	1.79±0.01[d]	3.13±0.03[b]
	2	3.23±0.20[b]	0.74±0.04[c]	1.79±0.02[d]	3.15±0.04[b]
A*	4	3.25±0.16[b]	0.80±0.04[bc]	1.89±0.03[c]	3.15±0.03[b]
	6	3.09±0.03[b]	0.87±0.06[b]	2.01±0.01[b]	3.01±0.08[b]
	8	3.51±0.01[a]	1.05±0.05[a]	2.16±0.01[a]	3.30±0.05[a]

Parameter	Formula Week	Control	5%NFC	7.5%NFC	10%NFC
b*	0	34.08±0.38^{c}	33.10±0.18^{b}	32.15±0.32^{b}	29.84±0.05^{b}
	2	34.84±0.32^{ab}	32.96±0.06^{b}	32.03±0.15^{b}	29.88±0.09^{b}
	4	34.93±0.53^{ab}	32.34±0.49^{c}	32.10±0.12^{b}	29.87±0.11^{b}
	6	34.66±0.17^{bc}	33.85±0.14^{a}	32.69±0.21^{b}	30.41±0.33^{a}
	8	35.35±0.13^{a}	33.77±0.05^{a}	32.16±0.36^{a}	30.35±0.04^{a}
Δ*E**	0	-	-	-	-
	2	1.10±0.38	0.18±0.15	0.19±0.18	0.69±0.15
	4	1.47±0.63	0.77±0.30	0.37±0.18	0.50±0.26
	6	0.83±0.28	0.78±0.29	0.70±0.38	0.80±0.45
	8	1.42±0.22	0.75±0.15	0.62±0.07	0.70±0.12

Mean ± SD value followed by letter in each column for the same parameter are significantly different at $p \leq 0.05$ by ANOVA and Duncan's Multiple Range Test.

pH and Texture profile analysis

The pH the mayonnaise samples after storage at room temperature (25°C) for 8 weeks are shown in Table 4. The results found that the initial pH values of all NFC formulas were lower than that of control. Since, the amount of water increased with increasing the amount of NFC used, one might expect that the pH of the NFC formula would be higher than that of the control sample due to the dilution of acid in the aqueous phase of the NFC formulas (Hathcox *et al.,* 1995). However, this was not the case in our study. The possible reasons to explain our findings may be due to the phosphoric acid residue remained in the NFC preparation. From microbiological aspect, it is generally recommended that mayonnaise made with unpasteurized egg is prepared with vinegar to a pH of 4.1 or less and held at room temperature for at least 24 h to reduce the risk from microorganisms (Radford & Board, 1993). After storage for 8 weeks, the pH values of all formulas were significantly (p < 0.05) increased from but all pH values after storages were still lower than 4.1, which meant that all samples were safe in term of microbiological aspect. In contrast, pH of mayonnaise added fat substituted with psyllium mucilage gel was not significantly different on the first day and after storage 60 days (Aghdaei *et al.*, 2014).

The hardness and adhesiveness of formulated mayonnaise are shown in Table 4. The initial hardness values showed that 5% of NFC formula was softer than other formulas. The increasing in NFC concentration from 5 to 10% (w/w) significantly ($p \leq 0.05$) increased the hardness of the mayonnaise. The concentration of NFC influenced the structure of the mayonnaise because NFC itself could form the three-dimensional network, thereby affecting the strength and hardness of samples. (Fujisawa *et al.,* 2017; Li *et al.,* 2018; Xhanari *et al.*, 2011). After storage for 8 weeks, the hardness of 10% NFC formula was significantly ($p \leq 0.05$) decreased while there were no significant ($p > 0.05$) differences for other formulas. The increase in droplet diameter in 10% (w/w) NFC formula might cause the decrease in hardness after storage (Wendin, 1999, 2000).

Rheological measurement

The apparent viscosity at a shear rate of 10 s^{-1} and 100 s^{-1} of mayonnaise using egg yolk (control) and NFC as a single emulsifier at various concentrations after storage for 8 weeks are shown in Figure 2. The apparent viscosity of all formulas was decreased after storage for 8 weeks. The decrease in apparent viscosity was as expected due to some coalescence of oil droplets which accelerated the creaming process. The results also corresponded with the results of mean droplet size. Droplet size was increased as the storage time increased. In addition, the increase in shear rate affected to the decrease in apparent viscosity for all formulated mayonnaise, which was a simple behavior of mayonnaise called shear-thinning behavior (Chang. 2017; McClements, 2015), or this process related to flocculation-deflocculation in continuous phase (Cheung, 2002). This behavior was also observed in the oil-in-water emulsions stabilized by chitin nanocrystal particles (Tzoumaki *et al*., 2011), modified maize starch-based nanoparticles (Ye *et al.,* 2017).

Table 4. Hardness (g) and pH of mayonnaise using egg yolk (control) and NFC as a single emulsifier and storage for 8 weeks at 4°C.

Parameter	Formula Week	Control	5%NFC	7.5%NFC	10%NFC
Hardness (g)	0	256.26±32.99[a]	85.55±5.96[a]	89.41±6.40[b]	114.48±4.59[b]
	2	221.51±35.60[ab]	70.56±5.07[b]	63.39±4.89[c]	64.37±9.83[d]
	4	204.53±0.99[b]	91.55±1.51[a]	105.01±4.15[a]	128.44±1.95[a]
	6	232.6±5.30[ab]	88.22±7.48[a]	88.41±7.01[b]	114.15±4.10[b]
	8	232.68±18.43[ab]	89.67±1.38[a]	92.69±6.44[b]	95.96±10.56[c]
pH	0	2.95±0.05[d]	1.89±0.09[b]	1.71±0.02[d]	1.72±0.02[d]
	2	2.95±0.03[d]	1.75±0.18[b]	1.70±0.02[d]	1.75±0.05[d]
	4	3.11±0.01[c]	1.88±0.04[b]	1.93±0.02[c]	1.95±0.03[c]
	6	3.17±0.02[b]	1.91±0.00[b]	1.99±0.01[b]	2.02±0.01[b]
	8	3.26±0.01[a]	2.10±0.08[a]	2.14±0.01[a]	2.13±0.01[a]

Mean ± SD value followed by letter each parameter each column are significantly different at $p \leq 0.05$ by ANOVA and Duncan's Multiple Range Test.

Sensory evaluation

The results of sensory evaluation of the mayonnaise using egg yolk (control) and NFC as an emulsifier during storage for 8 weeks are shown in Table 5. Four parameters, including appearance, flavor, texture, and overall acceptability, were evaluated. All parameters decreased with increasing NFC levels. After storage for 8 weeks, the overall acceptability scores were significantly ($p < 0.05$) increased. There was no phase separation after storage for 8 weeks. After storage, the acceptability scores of NFC formula were in the range between like slightly and like moderately, while the acceptability scores of the control formula were in the range between like moderately and like very much. Normally, the sensory attributes with scores higher than 5 are considered acceptable when compared with control. Thus, all formulations of non-egg mayonnaise using NFC as a single emulsifier were judged to be sensory acceptable.

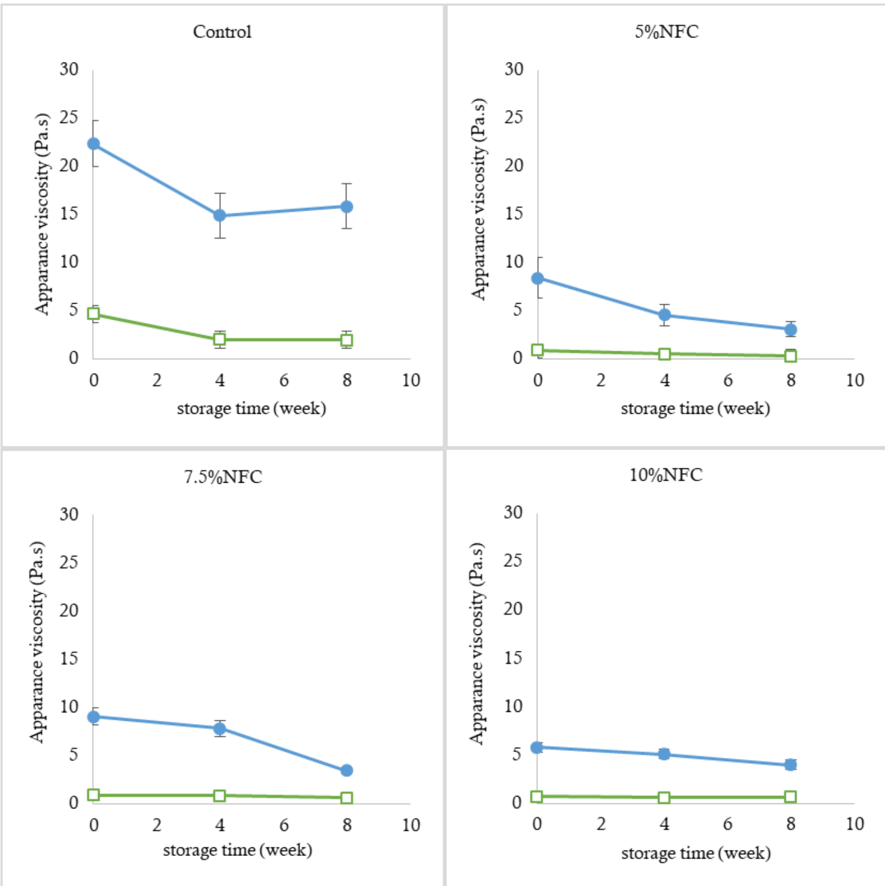

Figure 2. Apparent viscosity at a shear rate of 10 s-1 (closed symbols) and 100 s-1 (opened symbols) of mayonnaise using egg yolk (control) and NFC as a single emulsifier at various concentrations during storage for 8 weeks at 4°C. All measurements were performed at 25°C.

Table 5. Sensory scores of mayonnaise using egg yolk (control) and NFC as a single emulsifier at various concentrations during storage for 8 weeks at 4°C.

parameter	Week Formula	control	5%MFC	7.5%MFC	10%MFC
Appearance	0	7.50±1.43^{a}	5.80±1.75^{a}	5.80±1.62^{a}	5.00±1.83^{b}
	4	7.28±1.10^{a}	5.80±1.40^{a}	6.09±1.22^{a}	6.00±1.18^{ab}
	8	7.00±1.61^{a}	5.91±1.81^{a}	6.55±1.29^{a}	6.82±0.98^{a}
Flavor	0	7.30±1.06^{a}	6.40±1.58^{a}	6.10±1.52^{a}	5.20±1.48^{b}
	4	7.09±1.51^{a}	6.23±1.74^{a}	6.91±1.22^{a}	6.46±1.37^{a}
	8	6.46±1.44^{a}	4.82±1.94^{a}	6.18±1.60^{a}	5.46±0.93^{ab}
Texture	0	7.40±1.71^{a}	6.20±1.40^{a}	6.20±1.14^{a}	5.80±1.55^{a}
	4	6.64±0.92^{a}	6.18±1.66^{a}	7.09±0.70^{a}	6.82±0.87^{a}
	8	6.23±2.28^{a}	6.18±1.47^{a}	6.27±1.35^{a}	6.82±0.98^{a}
Overall acceptability	0	7.30±1.60^{b}	6.00±1.49^{a}	5.83±1.53^{b}	5.57±1.57^{b}
	4	7.10±1.16^{b}	6.37±1.38^{a}	6.87±1.14^{a}	6.63±1.25^{a}
	8	8.03±0.96^{a}	5.80±2.02^{a}	6.27±1.62^{ab}	6.50±1.43^{a}

Mean ± SD value followed by letter each parameter and each column are significantly different at $p \leq 0.05$ by ANOVA and Duncan's Multiple Range Test.

CONCLUSIONS

From the results of the present work, it can be concluded that NFC extracted from mangosteen rind played an important role as an emulsifier in mayonnaise, thereby obtaining the mayonnaise with high stability for 8 weeks and acceptability score between like slightly and like moderately. However, the using of this NFC slightly adversely affected mayonnaise appearance and color. Thus, this study shows good potential for nanofibrillated mangosteen cellulose to be used as a single emulsifier in mayonnaise.

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