Research article

Enhancing Healthy Salad Dressing Quality with Inulin from Jerusalem Artichoke Powder and Calamondin Peel Essential Oil

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Abstract

Keywords

calamondin;
essential oil;
inulin;
Jerusalem artichoke;
salad dressing

This research aimed to develop a healthy salad dressing recipe by enhancing its refreshing aroma and reducing oil content using inulin from Jerusalem artichoke and calamondin essential oils. Mixture designs were used to create six salad dressing formulas, and the optimal ratio of sunflower seed oil, egg yolk, and vinegar was found to be 65%, 20%, and 15%, respectively. The effects of partial fat replacement with Jerusalem artichoke powder were also examined. The optimal ratio of sunflower seed oil to Jerusalem artichoke powder was found to be 10:3. The lightness (L* value) decreased as the amount of Jerusalem artichoke powder increased. Quality analysis showed that the healthy salad dressing had lower energy and fat content but higher protein and total antioxidant contents when compared to the control. The effects of the addition of synthetic calamondin odor and natural calamondin odor extracted from calamondin peel on sensory evaluation were also investigated. Natural calamondin odor from calamondin peel, at 0.1%, gave the highest scores for odor and taste attributes. The findings from this study provided an alternative option for health-conscious consumers.

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1. Introduction

Salad dressing is a thick creamy sauce or condiment made with oil, egg yolk, lemon juice or vinegar, and condiments. Most salad dressings are emulsions Most salad dressings are emulsions, which normally separate into dressing oil and vinegar phases when mixing is stopped. Therefore, it is necessary to shake the dressing before use. However, some dressings are permanently emulsified which helps to prevent future stratification. An emulsifier such as egg yolk combines the oil and vinegar components in the dressing. In general, salad dressing contains approximately 30-60% of fat content in its total composition [1]. Global demand for salad dressing and mayonnaise is expected to expand from US$ 17.5 billion in 2021 to US$23.5 billion by 2026 [2]. This is accounted for a Compound Annual Growth Rate (CAGR) of 5.5%. Major consumer markets for salad dressing and mayonnaise are North America (US, Canada, and Mexico), Asia Pacific (India, China, Japan, Malaysia, and Singapore), Europe (Germany, UK, Italy, France, Spain, and Netherlands), Middle East, Africa, Central America, and South America [2].

A significant factor that has accelerated the demand for salad dressing and mayonnaise is the growing culture of eating out. Numbers of cafes and restaurants have been on the rise which further stimulate manufacturer desire to provide organic and natural salad dressings. As customers have become more concerned with their consumption, the salad dressing market has expanded. Such health-conscious trends have appeared in both developed and developing countries. However, regular consumption of salad dressing that contains a relatively high fat content may heighten the risk of developing various diseases such as obesity, heart disease, and vascular disease. Using fat substitutes to reduce the oil content in salad dressing is an alternative option for health-conscious consumers. Fat substitutes or fat replacers refer to substances used to replace fat in foods. These substitutes are large molecules carbohydrate substances or hydrocolloid that can provide viscous, smooth and moist products that are similar to that of actual fatty food products. Some substitutions are made from dietary fiber that does not provide calories or provides a low level of energy (low calories). In general, the main property of a fat substitute is its insolubility in water, but still gives a smooth creamy texture when combined with water. It also gives a mouthfeel similar to that of the fat. Examples of fat substitutes include maltodextrin, microcrystalline cellulose, gum, and inulin [3].

Jerusalem artichoke or Sunchoke (*Helianthus tuberosus* L.) is a tuber crop native to North America. It has also been planted in Europe in regions including the cold, semi-cold and tropical regions. The Jerusalem Artichoke's bulbs can be consumed as food. The bulbs are rich in dietary fiber that contains polysaccharides including inulin and oligosaccharides or oligofructose which has prebiotic properties. The Jerusalem artichoke is a functional food that contains carbohydrate which is mostly found as inulin (16-39%), a complex carbohydrate with a long chain of fructose. Its molecules are similar to oligofructose which provides low energy [4, 5]. Inulin is a polysaccharide carbohydrate which is considered as soluble dietary fiber that the human body cannot digest nor derive energy from it. However, inulin can be digested by prebiotic bacteria in the large intestine, offering health benefits. Inulin molecules are classified as heteropolysaccharides which are polymers of various types of sugar molecules. Inulin is a polymer composed of 10-60 fructose monomers, and thus it is sometimes called fructans. However, a glucose molecule can be found at one end of the polymer. The molecular structure of inulin is similar to that of oligofructose, a type of oligosaccharide. On the one hand, inulin is a polymer with a long chain, is slightly soluble, and does not taste sweet. On the other hand, oligofructose has a smaller molecular size of fewer than 10 monosaccharides, which gives it a slight sweet taste (30-50% of relative sweetness) compared to sucrose. Inulin is a nutraceutical substance found in many fruits and vegetables, onions, garlic, chicory, and Jerusalem artichoke bulbs [6]. Inulin is not digested in the human gastrointestinal tract, allowing it to pass through to the colon to be used as a nutrient source by probiotics. Currently, inulin is used as a fat or sugar substitute or fiber source in many food products such as ice cream, sausages, ready-to-drink milk, and yogurt. [7].

Fresh calamondins have a unique aroma and taste that resemble a blend of mandarin and lemon flavors. It offers orange peel-like aroma and acidic astringency. Most of the acids found in calamondin are ascorbic, dehydroascorbic, and citric [8]. Calamondin essential oil can be extracted from fresh, dried, or frozen calamondin peels. Calamondin peel contains several essential oils that are generally found in citrus fruits (Rutaceae), including limonene, linalool, geraniol, and citral compounds. Calamondin peel oil is a clear liquid which has a unique fragrance. The essential oil contains about 25 types of ingredients, the main one being D-Limomene, which has a molecular formula of $C_{10}H_{16}$, and accounts for about 85% of total ingredients of the oil. Calamondin essential oil offers various health benefits. It can prevent nail fungus, help with sleep, aid headache treatment, reduce appetite, deodorize, reduce blood sugar and flatulence, and help prevent the development of liver, esophageal, colon and skin cancers [9].

The objective of this research was to propose an alternative healthy salad dressing recipe with partial substitution of oil by Jerusalem artichoke powder and enhancement of flavor with the addition of essential oil from calamondin peel. The research also involved study of the physicochemical properties of the salad dressing products, assessment of the sensory acceptance of the product by semi-trained panels, and nutritional evaluation of the newly formulated salad dressing product. The knowledge obtained from this research may result in an alternative product that meets the needs of consumers who prefer to consume healthy salad dressing products. The knowledge may also serve as a foundation for further food production on the industrial scale.

2. Materials and Methods

2.1 Raw materials preparation

To produce Jerusalem artichoke powder, fresh Jerusalem artichoke bulbs were brought from Winview shop, Sing Buri province, Thailand. The fresh Jerusalem artichoke bulbs were cleaned, peeled, and cut into small pieces (2 mm. thickness) before drying at 60°C using oven (Dryer machine, ABC-728 Dehydrator, Thailand) until dry. Then, the dried pieces were ground thoroughly to a fine powder 80 mesh (Sieve stainless, Tokyo screen, Japan) and packed in sealed containers. The Jerusalem artichoke powder was kept in a refrigerator (Samsung refrigerator, RT38CG6020S9ST, Thailand) at 4°C for further use. The method of essential oil extraction from calamondin peel was modified from Chen *et al*. [10]. Calamondins were cleaned, peeled, and squeezed in an oil press machine (Expeller Presser, SHANBEN, China) and then left in a refrigerator at 4°C. The oily fraction was separated by centrifugation (Refrigerated centrifuge, RWD, China) at 6000×g at 4°C for 40 min.

2.2 The effects of different ratios of sunflower seed oil, egg yolk, and vinegar on quality of salad dressing

The optimized formula for salad dressing production was determined by using a mixture design experiment (Minitab® 21 Statistical Software) which varied the sunflower oil, egg yolk, and vinegar in the ranges of 60-80%, 10-20%, and 5-15%, respectively. The mixed-design experiment was scattered in the pentagonal areas to obtain the most comprehensive formula data as per the component variation. Six formulations were selected and are shown in Table 1.

Table 1. Six formulations of salad dressing using mixture design

Main Ingredients	Formulations					
	1	2	3	4	5	6
Sunflower seed oil (g)	75	80	75	65	75	80
Yolk (g)	15	10	20	20	10	15
Vinegar (g)	10	10	5	15	15	5

The main ingredients (sunflower seed oil, egg yolks, and vinegar) were added in various ratios, as shown in Table 1. The other ingredients were added in equal ratios for all formulas, i.e white sugar (15 g), sweetened condensed milk (15 g), mustard (3 g), salt (0.4 g) and ground black pepper (0.03 g). Subsequently, egg yolks were placed in a glass bowl, and stirred with an electric egg stirrer using a whisk head. The egg yolks were stirred until they became fluffy and turned yellow. Then, mustard and vinegar were added into the bowl with continuous stirring for approximately 1 min. Afterwards, the sunflower seed oil was added while the mixture was slowly stirred. The oil was added in a small quantity until it had been completely decanted. The resulting mixture became thicker, more stable, and had a yellow color. Then, the remaining ingredients were added and the mixture was stirred well for another 10 min. Heat was increased to 85°C for 5 min. The ingredients were then kept in a sealed container.

The quality of salad dressing was investigated as follows:

(1) The appearance of salad dressing formulas was observed at 0 min and 30 min.

(2) The color of salad dressing was assessed using a colorimeter (WR10QC, FRU, China). Evaluation was based on the CIE system, where L* represents the lightness (ranging from 0 to 100 indicating from black to white), a* (+a = red, -a = green), and b* (+ b = yellow, -b = blue).

(3) pH was measured by a pH meter (pH Meter 0.01, China).

(4) An emulsion stability (ES) test was conducted according to the method of Pero *et al.* [11]. Thereafter, 25 mL of salad dressing was poured into a glass bottle with 10 mm in diameter and 100 mm in height and kept at room temperature for 3 days. The height of the emulsion separating the top and bottom layers was measured during this period. At the end of the storage period, the ES was determined from the 2 stratified parts of the salad dressing samples, namely the emulsion phase or cream phase and the clear layer. The ES calculation was (ES) = [height of the emulsion phase/the total height of the emulsion] ×100.

(5) The viscosity was measured using a viscometer (CSC scientific Bostwick consistometer, 24925-000, USA).

(6) Sensory evaluation was conducted by 30 semi-trained panels to assess sensory characteristics, including appearance, odor, taste, texture, and overall likeness. The 9-pointed hedonic scale was applied to this assessment, for which 9=Like extremely, 5=Neither like nor dislike, and 1=Dislike extremely, respectively. The assessment was done to determine one suitable formula to produce a newly formulated salad dressing in the next steps of the process.

2.3 The use of Jerusalem artichoke powder as a fat replacement for the quality of low-fat salad dressing

To evaluate partial fat replacement with Jerusalem artichoke extract powder at various ratios (sunflower seed oil: Jerusalem artichoke extract powder of 13:0, 12:1, 11:2, 10:3, 9:4, and 8:5) in comparison to the formula without Jerusalem artichoke extract powder, salad dressing formulae chosen in the previous step were utilized. The quality of salad dressing was investigated as follows:

(1) The content of inulin was assessed: sample preparation and inulin nutritional content measurement were analyzed using a spectrophotometric method with some modification from

Puttha *et al*. [12]. The amount of inulin was determined using a periodate reaction. The reaction was performed by adding 150 µL of the sample solution with 4.4 mL of distilled water and 5 mL of 70 mM citrate buffer (pH 6.0) into a 15 mL test tube. Then, 200 µL of 10 mM sodium periodate reagent ($NaIO_4$) was added into the test tube and shaken for 5 min. After that, 250 µL of 100 mM potassium iodide (KI) was added, and the mixture was left for an additional 5 min. The absorbance was measured using a spectrophotometer (SP8001, Metertech, Taiwan) at 390 nm. The concentration of free fructose was deduced from the calibration curve of standard fructose. The fructose standard curve formula was $y = 0.8742^{e\text{-}0.058x}$ (R^2=0.99) where x is the fructose content in 1,000 mL and y is the absorbance. The values obtained from the formula were calculated to determine the quantity of inulin as a percentage on the dry weight basis.

(2) The rheology of salad was investigated using an Anton-Modular Paar's Compact Rheometer 302 (MCR) with a measuring system: PP50 at 50°C following a modified method described by Zhang *et al*. [13]. The cone and plate were separated by a mm-wide gap. A 10 mL sample was placed in the center of the circular plate, and the cone was then placed on top of the sample. Excess sample that had been pushed out from the plate's edge was cleaned up with a paper towel. To ascertain the linear viscoelastic (LVE) range, amplitude sweeps at 1 Hz frequency were conducted on all samples with strains ranging from 0.01% to 400%. The LVE designates the portion of the sample's rheological characteristics that are just a function of time and temperature and are unaffected by shear strain or shear stress. Frequency sweeps between 0.1% strain and 100 s-1 angular frequency were carried out on data within the LVE range. The rheological behavior of the salad dressing sample can be represented by the power model equation $\eta = K\gamma^{n-1}$, where the viscosity follows the power law model and has indices smaller than a certain value. The variables K and n in the equation denote the apparent viscosity, shear rate, consistency index, and power law index, respectively. An increase in inulin leads to a higher power law index of the fat droplets, while also resulting in an increase in temperature. When the shear rate increases, there is a corresponding decrease in the viscosity of the salad dressing.

(3) The color of the salad dressing were measured by a colorimeter using the same method as described in Section 2.2 (2).

(4) Sensory evaluation was conducted by 30 semi-trained panels using the method described in Section 2.2 (6). The assessment was done to determine the most suitable formula for use in the next steps of the process.

2.4 The effect of adding calamondin essence on the sensory evaluation of salad dressing

Improving the odor of salad dressings was investigated. In the experiment, the odor of the original sample was compared with commercial calamondin synthetic odor and odor extracted from the calamondin peel, at ratios of 0.1, 0.2, and 0.3 of the total ingredients. Sensory evaluation was conducted by 30 semi-trained panels using the method described in Section 2.2 (6).

2.5 Quality analysis of salad dressings

The chemical composition of salad dressings including protein, lipids, carbohydrates, ash, moisture, total energy value [14], inulin content [12], and total antioxidant using DPPH assay (unit of mg equivalent Trolox/100g of sample) [14] were investigated. In terms of biological content, the total microorganisms, Lactic acid bacteria, *Staphylococcus aureus*, *Escherichia coli*, *Salmonella*, yeast, and mold [15] of healthy salad dressings were analyzed. The healthy salad dressing was compared with the control formula.

2.6 Statistical analysis

Minitab® 21 Statistical Software was used for mixture design. All experiments were conducted in triplicate, and the results were expressed as the mean±standard deviation. A one-way analysis of variance (ANOVA) and Duncan's multiple range test were employed to analyze the statistical significance of the mean values. SPSS software for Windows (v12) was used for the statistical analyses in this study.

3. Results and Discussion

3.1 Effects of ratio variations of sunflower seed oil, egg yolk and vinegar on quality of salad dressing

The six salad dressing formulas showed different observable appearances (Figure 1). Formula 1 or 4 were light yellow, homogeneous and unseparated thick liquid, and the ingredients were uniformly distributed. Moreover, the samples had a natural odor and had tastes that were the tastes of the ingredients. The color of formulas 2, 3, and 6 ranged from yellow to dark yellow, and the samples clearly became stratified after 30 min of non-stirring. According to the distribution of the mixture, the fat started to aggregate and the product contained the natural taste and odor of the ingredients used. Formula 5 showed yellow color, light liquid, homogeneous, and slowly stratified after stirring. The ingredients were uniformly dispersed, and the product had a natural odor and the taste of the ingredients used. The colors of six formulas of salad dressings ranged from light to dark yellow. Data obtained from physical quality analysis in terms of color value, emulsion stability, viscosity, and pH of the six salad dressing formulas were significantly different ($p \leq 0.05$). From the mixture response surface contour plots as shown in Figure 2a-2c, the six salad dressing formulas showed that the lightness (L* value) tended to increase with higher quantity of vinegar content, a* value was negative in the green range, and b* value was in the yellow range.

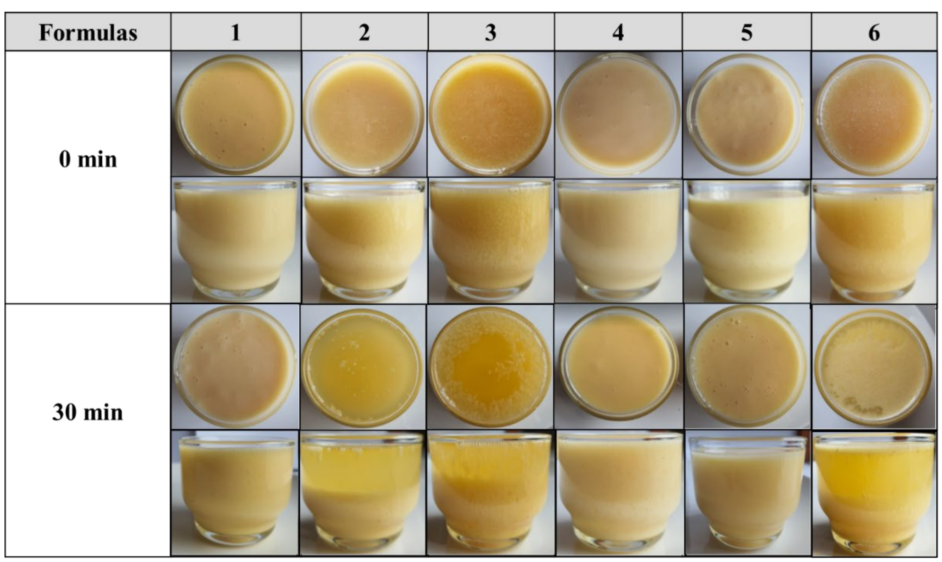

Figure 1. The appearances of six salad dressing formulas at 0 min and 30 min

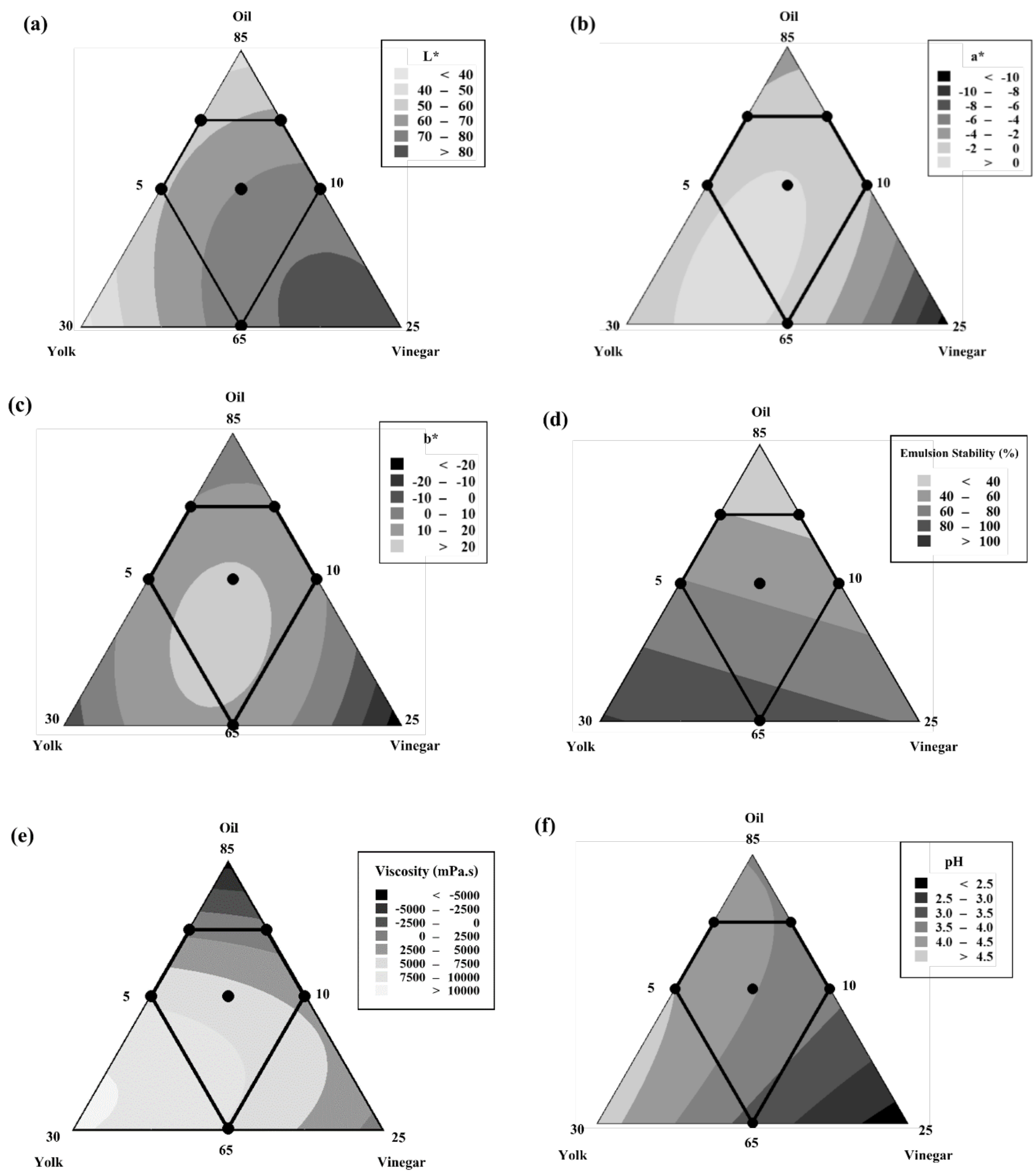

Figure 2. Mixture response surface contour plots displaying combined effects of sunflower seed oil, yolk, and vinegar on color (L*, a*, and b* values), emulsion stability, viscosity and pH of the six salad dressing formulations

The results reflected the observable appearance of dressings color was in the yellow range and this was a product of the natural color of the raw materials used, especially in sunflower seed oil and egg yolk. Moreover, the yellow color observed was likely due to the presence of carotenoids which produce the yellow, orange, red and orange-red pigment commonly found in plants and organisms capable of photosynthesis. Carotenoid works together with chlorophyll, a green pigment which absorbs energy from the sun for photosynthesis, plant growth, and photoprotective agents. A carotenoid typically consist a of 40 atom unsaturated hydrocarbon chain, which has many double bonds. Carotenoids can be classified into 2 subgroups: carotene, an orange or orange-red pigment with long hydrocarbon chains and xanthophyll, a yellow or orange-yellow pigment with long hydrocarbon chains and oxygen atoms. There are many types of xanthophylls, with varying oxidation levels. In natural foods, there are approximately 600 types of carotenoids, most of which are alpha-carotene, beta-carotene, beta-cryptoxanthin, lycopene, lutein, and zeaxanthin [16, 17].

Emulsion stability was measured by measuring the volume of the cream phase formed after centrifugation or during long-term storage of the emulsion. A high relative volume of cream phase indicates that oil droplets are spread far apart, signifying the high stability of the emulsion. The results of emulsion stability revealed an upward trend when higher egg yolk content was added (Figure 2d). Egg yolk acts as an emulsifier that stabilizes emulsions by reducing the surface tension of the liquid in the salad dressing (oil-in-water emulsion) preventing the emulsion from stratification. Emulsifier molecules consist of hydrophilic and hydrophobic parts [18]. Fresh egg yolk generally contains 50% solids, with a lipid to protein ratio of 2:1. Triacylglycerol constitutes the main fraction of egg yolk lipid, followed by various phospholipids such as phosphatidyl choline or lecithin, and cholesterol. Insoluble granules form approximately 20% of fresh egg yolk whilst light plasma constitutes the remaining 80%. The granules were found to consist of 64% protein (high density lipoproteins (HDLs), and low-density lipoproteins (LDLs), 30% lipids, 6% ash, and 0.5% divalent cations such as calcium. Plasma in the egg yolk is approximately 80 %. It is highly soluble and has small particles spread freely throughout its body [18]. All of the lipids in egg yolk were found to be associated with proteins called lipoproteins (livetin, LDL, and phosvitin). In the plasma phase, lipids were approximately twice the quantity of those found in the granules. On the other hand, the granules contain more cholesterol than plasma. The stability of egg-based salad dressing depends on two factors. First factor is the ability of yolk constituents to reduce the interfacial tension between the water and oil phases. This tension causes colloidal particles to break down into small oil droplets dispersed in the medium (dispersion) and mechanism of formation of an interfacial film around the oil droplets. This further controls colloidal interaction, leading to flocculation, creaming and coalescence of oil droplets during long-term storage of the product [10, 18].

Viscosity is a rheology parameter often used as a quality control reference in salad dressing production. The viscosity measurement of the experimental salad dressing showed that the viscosity tends to increase with higher yolk content (Figure 2e). In general, dressing stability is controlled by interfacial composition, emulsion droplet size, and continuous phase rheology. The salad dressing emulsions are relatively stable because the emulsion droplets are in small size and are coated by emulsifiers such as egg yolk. Emulsifier helps stabilize the emulsion by reducing the surface tension of the oil-in-water emulsion, and prevents the emulsion from separating into layers. While egg yolk proteins contain both hydrophilic and hydrophobic amino acid residues, protective film-forming emulsion composition brings the hydrophilic part towards water and the hydrophobic part towards fat [1, 18]. Previous studies suggested that heating egg yolk at 68°C increased the apparent viscosity rapidly between the 4 and 8 min of heating, after which the viscosity started to decrease again. During the initial stage of the heating, apoprotein (LDLs), present in the egg yolk plasma, lost their original stability and relaxed before reacting with each other due to hydrophobic interactions and disulfide linkages, finally leading to lattice formation. At this stage, the concentration gradually increased to the critical concentration of protein. Therefore, increasing the heat made the egg yolk suspension gelatinized and dispersed in solution. This circumstance eventually led to precipitation [18].

In Figure 2f, pH values ranged from 3.3 to 4.5 for all of the six dressing formulas and the pH increased with greater quantity of vinegar. The pH of the salad dressing is a second factor that affects the stability of the emulsion. For the combination of acidic and thermal processing, the protein gel network is ultimately considered to be the result of a balance between thermally induced interactions (mainly hydrophobic interactions and disulfide bonds) and pH-dependent electrostatic repulsion. Apparently, the final viscoelastic properties achieved after heat processing was in the same order of magnitude regardless of the acidic process applied [19, 20]. As a result, salad dressing stability could be achieved. The surface charge of the natural egg yolk granule is positive under pH 2.0 to 4.0, and it turns negative under pH 6.0 to 9.0. Egg yolk at pH 2.0-4.0 breaks down granules which are consequently dissolved. When the pH was in the acidic range, the number of positively charged NH^+ increased which induced electrostatic repulsion [20]. The adsorption mechanism and interfacial film formation around droplets was related to solubility, hydrophobicity and flexibility of protein molecules. Thus, proteins were highly soluble in a wide range of pH and ionic strengths [21]. For instance, LDL micelles had low stability and were prone to losing their original structures. As LDL micelles come into contact with the surface of the oil/water interface, they are absorbed faster than other soluble proteins due to their higher hydrophobicity and flexibility. This was especially more apparent in LDL apoproteins with small molecular sizes such as HDL, a common component of egg yolk granules, which were insoluble at low pH and ionic strengths. Therefore, HDL had little influence on reduction of the oil-water surface tension [21]. Under acidic conditions (pH 3), plasma offered better emulsifying properties than egg yolk granules as granule-based emulsions under these conditions had larger oil droplets and low emulsion stability [22].

The overlapping area (letter A) shown in Figure 3 indicates the optimal area for th main ingredients used in the salad dressing formula: formula 1 (75% sunflower seed oil, 15% egg yolk and 10% vinegar) and formula 4 (65% sunflower seed oil, 20% egg yolk and 15% vinegar). The obtained data were considered together with the results of the sensory tests (Table 2) which demonstrates that the six formulas had average scores tht were statistically significant at the confidence level of 95% ($p \leq 0.05$). Formula 1 and 4 showed no significantly different average scores for appearance, odor, taste, texture and overall likeness. The average scores for both formulas were higher than those of formulas 2, 3, 5 or 6. Upon considering the observable appearance, quality value, and results from the sensory quality assessment, formula 4 was selected for further studies. Formula 4 had a sunflower seed oil content of 65% which was lower than formula 1 (75% of sunflower seed oil content).

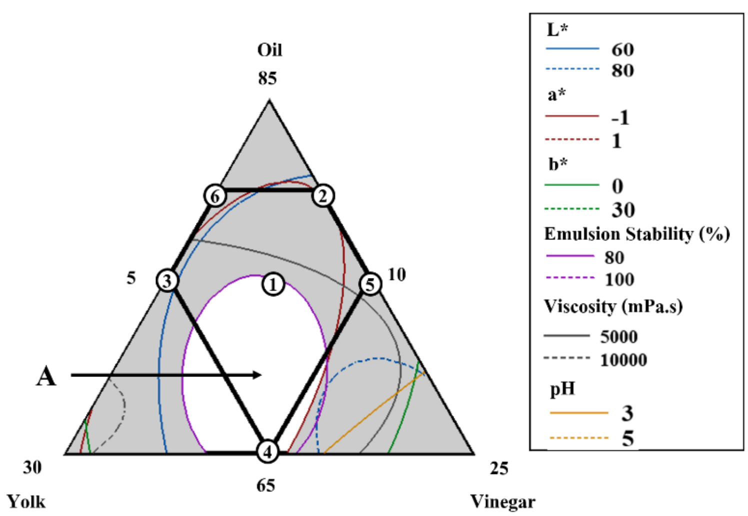

Figure 3. Contour plot for optimum overlapping (A) of the six salad dressing formulations. The cycle number is the number of salad dressing formula (No. 1, 2, 3, 4, 5, and 6).

Table 2. The liking score (n = 30) for the six formulas of salad dressing

Formulas	Appearance	Odor	Taste	Texture	Overall liking
1	8.00 ± 0.37^{a}	7.83 ± 0.83^{a}	7.87 ± 0.73^{a}	8.00 ± 0.83^{a}	7.97 ± 0.76^{a}
2	2.67 ± 0.80^{c}	2.93 ± 1.20^{c}	2.80 ± 1.65^{c}	1.57 ± 0.82^{c}	1.67 ± 0.66^{c}
3	2.70 ± 1.15^{c}	3.00 ± 1.29^{c}	2.93 ± 1.57^{c}	1.83 ± 0.91^{c}	1.87 ± 0.73^{c}
4	7.87 ± 0.51^{a}	8.03 ± 0.89^{a}	8.07 ± 0.69^{a}	7.73 ± 0.78^{a}	7.83 ± 0.75^{a}
5	6.70 ± 0.95^{b}	6.07 ± 0.94^{b}	6.17 ± 1.02^{b}	5.53 ± 0.73^{b}	5.57 ± 0.77^{b}
6	2.00 ± 0.98^{d}	1.93 ± 0.83^{d}	1.87 ± 1.01^{d}	1.17 ± 0.38^{d}	1.37 ± 0.49^{d}

$^{a\text{-}c}$ Means$\pm$S.D with the different superscripts in each column indicate significant differences ($p \leq 0.05$).

3.2 Effects of partial fat replacement with Jerusalem artichoke extract powder on the quality of low-fat salad dressing

Table 3 and Figure 4 show that the physical quality including, inulin content, viscosity and color values of the six salad dressing formulas with the different ratio of fat replacing with Jerusalem artichoke powder were significantly different ($p\leq0.05$). The content of inulin tended to increase with increasing quantity of Jerusalem artichoke extract powder which was related to the change in viscosity of salad dressing. Such viscosity was directly proportional to the amount of the Jerusalem artichoke extract powder. On the other hand, the brightness (L*) values of the salad dressing tended to decrease as the amount of Jerusalem artichoke extract powder increased. However, a* and b* values tended to increase when the quantity Jerusalem artichoke extract powder was higher.

Table 3. Effects of the ratios of sunflower seed oil (S) per Jerusalem artichoke powder (J) on inulin, and color of salad dressing

Sample (ratio S:J)	Inulin Content (g .100 g^{-1} of sample)	Color		
		L* value	a* value	b* value
1 (13:0)	0.00 ± 0.00^{f}	75.69 ± 0.08^{a}	-0.53 ± 0.01^{f}	17.15 ± 0.09^{f}
2 (12:1)	0.59 ± 0.01^{e}	65.58 ± 0.05^{b}	2.58 ± 0.02^{e}	17.75 ± 0.06^{e}
3 (11:2)	1.15 ± 0.13^{d}	59.84 ± 0.08^{c}	4.26 ± 0.02^{d}	17.85 ± 0.10^{d}
4 (10:3)	1.91 ± 0.10^{c}	56.49 ± 0.05^{d}	5.48 ± 0.02^{c}	18.04 ± 0.03^{c}
5 (9:4)	2.49 ± 0.08^{b}	54.69 ± 0.05^{e}	7.25 ± 0.01^{b}	19.28 ± 0.02^{b}
6 (8:5)	2.86 ± 0.07^{a}	50.90 ± 0.07^{f}	7.85 ± 0.01^{a}	20.50 ± 0.02^{a}

$^{a\text{-}d}$ Means$\pm$S.D with the different superscripts in each column indicate significant differences ($p \leq 0.05$).

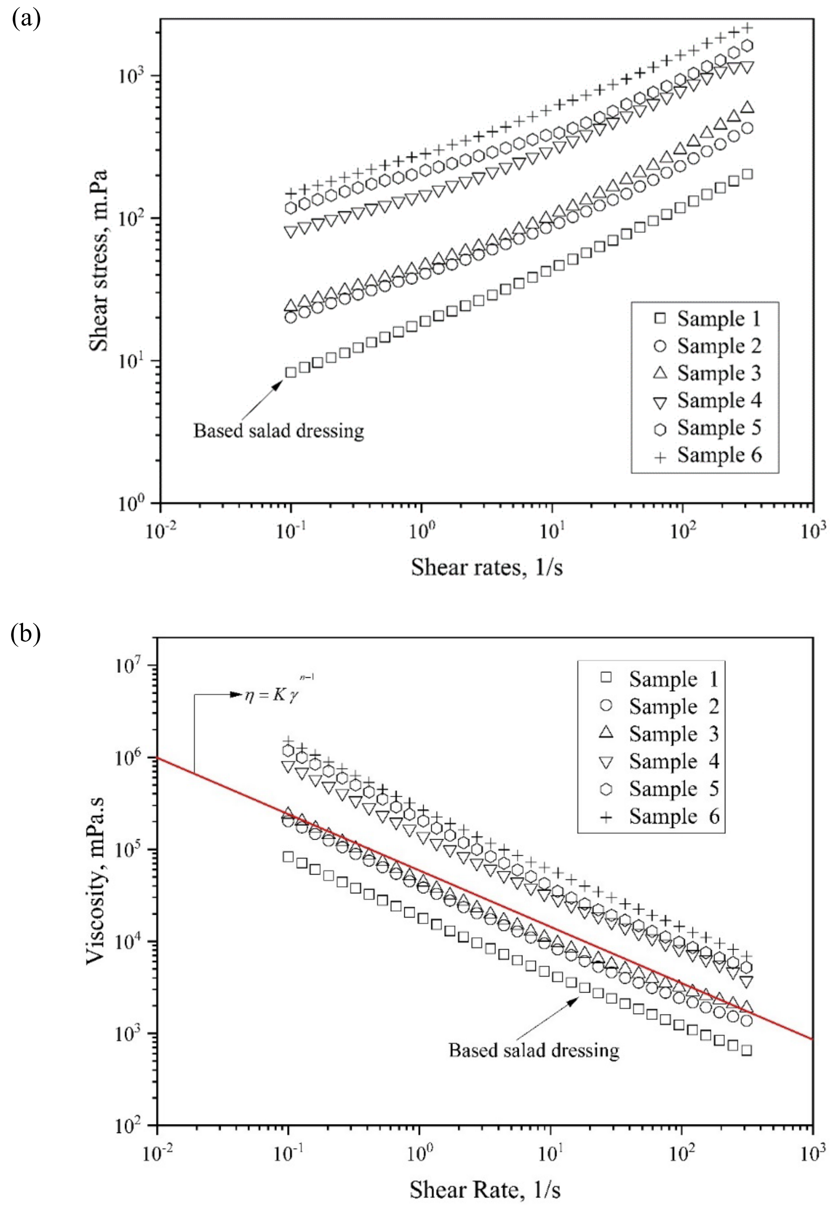

Figure 4. Effects of the ratios of sunflower seed oil per Jerusalem artichoke powder on rheology properties of salad dressing, (a) shear rates vs viscosity and (b) shear rates vs shear stress

The Jerusalem artichoke is a source of inulin, a type of polysaccharide that is not well digested by human. Inulin, however, provides health benefits as a nutrient for probiotics. Inulin which provided low energy can be used as a fat replacement, sweetener and a source of dietary fiber. It can be used to replace fat in various products due to its functional properties in gel formation and viscosity [6]. The viscosity of Jerusalem artichoke is influenced by elements such as its kind and variety, chemical content, and cultivation process. Previous studies on the use of starch from two

Jerusalem artichoke starch varieties, Albik and Rubik, which had been grown organically in South Lithuania and incorporated in yoghurt products showed that yoghurt enriched with starch from Rubik variety had a higher apparent viscosity compared to yoghurt with the Albik variety starch [23]. Abou-Arab *et al*. [24] found that the physicochemical properties of Jerusalem artichoke extract powder were different. Starch prepared by oven drying at 60°C for 7 h showed high viscosity (220 to 319 mPa.s). The starch's water and oil absorption capacity were evaluated based on the drying procedure and the level of heat applied during drying. As a result, the relationship between viscosity and shear rate did not correlate in a linear way. In contrast, viscosity decreased with increasing temperature and shear rate that caused the salad dressing mixed with Jerusalem artichoke powder displayed Newtonian behavior of the salad dressing. Moreover, heating caused molecular entanglement and bonds to break, stabilizing the molecular structure and reducing viscosity. As the temperature was raised, unstable protein became apparent and subsequently decreased the viscosity. The use of dried Jerusalem artichoke extract powder as a raw material for fat replacement in dairy beverages revealed that milk products containing the powder had similar rheological behavior to that of commercially available inulin. Thus, the powder was used as a thickener agent. When inulin absorbs water, it gives a smooth and creamy texture that has similar mouth feel to that of fat [25]. The use of finely ground Jerusalem artichoke extracts as a replacement for milk fat in yogurt products revealed that adding 1% of the extract yielded yogurt of similar quality. The experimental product was not significantly different to the control yogurt made entirely from milk. The added artichoke extracts also facilitated the growth of lactic bacteria [26].

The change in color values of the salad dressing when Jerusalem artichoke powder was added may be due to enzymatic reaction and non-enzymatic reaction, a unique characteristic of the artichoke powder. In general, freshly peeled Jerusalem artichoke changes from white to brown color, due to the action of phenolase enzymes. Moreover, Jerusalem artichoke darkens when heated at high temperature in a type of non-enzymatic browning process. The enzymatic browning reaction is an oxidation reaction that occurs when the Jerusalem artichoke cells are bruised, torn, crushed, sliced, or chopped. These types of cell damage induce phenolase enzymes such as polyphenol oxidase to catalyze the reactions of precursors such as monophenol compounds in plant cells and oxygen to form colorless diphenols. These compounds are further oxidized to produce orthoquinone, a brown substance, which congregates to form polymers [5, 25]. The polymers are brown macromolecules such as melanin, which can be observed when freshly peeled and sliced Jerusalem artichoke is left exposed to the air. In general, enzymatic-related browning can be controlled by several methods. One of the methods is heat or acidification treatment that leads to protein denaturation. For instance, lower pHs lead to enzyme inhibition as proteins get denatured. Other methods to control browning are using reducing agents to convert O-quinone to its colorless phenol compound, or immersion in honey or saline to prevent oxygen exposure [27]. Heating is used in the salad dressing process to kill pathogenic microorganisms [28]. High temperature is one of the factors that cause the Maillard reaction, a non-enzymatic browning reaction. This reaction, which is catalyzed by heat, occurs between reducing sugars and amino acids, proteins, or other nitrogenous compounds. The products of the Maillard reaction are various compounds that cause brown colors and various flavors to form [29, 30]. Ozgoren *et al*. [31] suggested that higher quantities of the Jerusalem artichoke extract powder increased the browning of crackers but the reduction of the lightness (L*) of the crackers could be applied to control color change. This was consistent with the studies of Chirsanova *et al*. [32], who reported on color change in bread with added Jerusalem artichoke extract powder. At higher quantity of the Jerusalem artichoke extract powder, the bread turned darker brown as a result of the Maillard reaction.

Table 4 shows the results of the consumer acceptance test of the salad dressing products that had sunflower seed oil partially replaced with Jerusalem artichoke extract powder. The formulas with the ratios of sunflower seed oil to Jerusalem artichoke extract powder of 13:0, 12:1, 11::2 and

Table 4. The liking score (n = 30) for salad dressing with the different ratios of sunflower seed oil (S) to Jerusalem artichoke powder (J)

Ratio S:J	Appearance	Odor	Taste	Texture	Overall Liking
13:0	7.87 ± 0.51^{a}	8.03 ± 0.89^{a}	8.07 ± 0.69^{a}	7.73 ± 0.78^{a}	7.83 ± 0.75^{a}
12:1	7.73 ± 0.45^{a}	7.83 ± 0.87^{a}	7.93 ± 0.69^{a}	7.60 ± 0.72^{a}	7.70 ± 0.70^{a}
11:2	7.70 ± 0.47^{ab}	7.63 ± 0.81^{a}	7.80 ± 0.66^{ab}	7.53 ± 0.68^{ab}	7.63 ± 0.67^{a}
10:3	7.67 ± 0.48^{ab}	7.60 ± 0.86^{a}	7.70 ± 0.60^{ab}	7.50 ± 0.68^{ab}	7.60 ± 0.67^{a}
9:4	7.40 ± 0.72^{b}	7.00 ± 0.69^{b}	7.47 ± 0.63^{b}	7.20 ± 0.61^{bc}	7.17 ± 0.70^{b}
8:5	6.67 ± 0.76^{c}	6.60 ± 0.56^{b}	6.87 ± 0.78^{c}	6.87 ± 0.63^{c}	6.60 ± 0.50^{c}

$^{a-c}$ Means±S.D with the different superscripts in each column indicate significant differences ($p \leq 0.05$).

10:3 had no statistically different mean scores for appearance, odor, taste, texture, and total likeness. Therefore, the maximum ratio of sunflower seed oil - Jerusalem artichoke extract powder of 10:3 was selected for flavor studies in the next step. As per the testers, salad dressing aroma needed to be adjusted. Adding a high quantity of Jerusalem artichoke extract powder resulted in the distinctive odor of the Jerusalem artichoke extract.

3.3 Effect of adding calamondin essence on salad dressing quality

Table 5 shows the results of the sensory acceptance test of the salad dressing products containing artificial calamondin fruit odor and the odor extracted from the fresh calamondin peel. The results indicate that the appearance, texture, and total likeness were not statistically different ($p \leq 0.05$). However, odor and taste were statistically different ($p \leq 0.05$). The formula with 0.1% of fresh calamondin peel extracts received the highest average scores for odor and taste. According to panelist's opinions, synthetic calamondin fruit odor was less aromatic than fresh calamondin peel extracts. Fresh, dried, or frozen calamondin peels produce calamond essential oil which is similar to the essential oil from citrus fruits (Rutaceae). The essential oil found in calamondin peels includes limonene, α- pinene, β- pinene, linalool, geraniol, and citral. Moreover, the peels contain flavonoids such as naringosi, hesperidin, diosim, diosmetin, and hesperitin, which helped to protect the walls of capillaries, reduce permeability, and increase their flexibility. Thus, broken capillaries can be prevented and blood pressure can be lower [33]. Calamondin peel oil, a clear liquid with a unique fragrance, contains approximately 25 ingredients. The main ingredient is D-limonene accounting for about 85% of the total ingredients. D-limomene, molecular formula $C_{10}H_{16}$, is a clear liquid hydrocarbon in terpenoid group that belongs to the Monoterpenes family. It is found in the skin of citrus fruits such as oranges and lemons. D-limonene is commonly used as a flavoring agent in the food industry or as a fragrance agent in cosmetic products [34].

Salad dressing with 0.1% of calamondin extract was selected for the preparation of a new healthy salad dressing. The chemical composition and microbial analyzes of the recipe were conducted to compare with the control formula (Table 6). The results showed that the dressing had lower energy and fat content. On the other hand, the protein content, total carbohydrates, total antioxidants, and lactic acid bacteria were higher than the control formula. The dressing and the control sample had microorganisms within the standard level of a salad dressing [35]. The salad dressing with Jerusalem artichoke extract powder was a healthy product as artichoke extracts were

Table 5. The liking score (n = 30) for salad dressing with synthetic (S) and natural of calamondin fruit odor (N)

Type and amount of calamondin essence	Appearance	Odor	Taste	Texture	Overall liking
0	7.67 ± 0.48^{ns}	7.60 ± 0.86^{bc}	7.70 ± 0.60^{ab}	7.50 ± 0.68^{ns}	7.60 ± 0.67^{ns}
S 0.1 %	7.70 ± 0.53^{ns}	7.67 ± 0.88^{abc}	7.77 ± 0.63^{ab}	7.53 ± 0.68^{ns}	7.67 ± 0.70^{ns}
S 0.2 %	7.77 ± 0.50^{ns}	7.90 ± 0.76^{ab}	7.83 ± 0.65^{ab}	7.57 ± 0.73^{ns}	7.73 ± 0.74^{ns}
S 0.3 %	7.73 ± 0.52^{ns}	7.33 ± 1.03^{c}	7.67 ± 0.66^{b}	7.53 ± 0.68^{ns}	7.63 ± 0.67^{ns}
N 0.1 %	7.80 ± 0.55^{ns}	8.13 ± 0.78^{a}	8.07 ± 0.69^{a}	7.70 ± 0.79^{ns}	7.90 ± 0.76^{ns}
N 0.2 %	7.70 ± 0.47^{ns}	7.70 ± 0.84^{abc}	7.80 ± 0.55^{ab}	7.57 ± 0.68^{ns}	7.73 ± 0.64^{ns}
N 0.3 %	7.73 ± 0.45^{ns}	7.93 ± 0.83^{ab}	7.97 ± 0.67^{ab}	7.63 ± 0.76^{ns}	7.87 ± 0.78^{ns}

$^{a-c}$ Means$\pm$S.D with the different superscripts in each column indicates significant differences ($p \leq 0.05$).
^{ns} Means$\pm$S.D in each column is not significantly different ($p>0.05$).

Table 6. Chemical composition and microbiological content of salad dressing

Chemical Composition and Microbiological Content	Standard	Commercial Formula (Control)	Healthy Salad Dressing Formula
Ash	-	0.67 g/100g	1.29 g/100g
Energy	-	621.88 Kcal/100g	506.21 Kcal/100g
Fat	-	58.52 g/100g	41.41 g/100g
Moisture	-	17.01 g/100g	23.92 g/100g
Protein	-	2.96 g/100g	4.74 g/100g
Total antioxidant	-	115.74 mg eq Trolox/100g	256.05 mg eq Trolox/100g
Total carbohydrate	-	20.84 g/100g	28.64 g/100g
Inulin	-	0 g .100 g^{-1} of sample	1.91 g .100 g^{-1} of sample
Lactic acid bacteria	-	3.8×10^2 cfu/g	1.1×10^3 cfu/g
Aerobic plate count	$<1 \times 10^4$ cfu/g	7.1×10^2 cfu/g	3.9×10^3 cfu/g
Escherichia coli	< 3.0 MPN/g	< 3.0 MPN/g	< 3.0 MPN/g
Salmonells spp.	Not detected (in 25 g)	Not detected (in 25 g)	Not detected (in 25 g)
Staphylococcus aureus	Not detected (in 1 g)	Not detected (in 1 g)	Not detected (in 1 g)
Yeasts and molds	< 100 cfu/g	< 100 cfu/g	< 100 cfu/g

high in antioxidants and inulin, a dietary fiber. As it does not provide energy, it is not classified as a nutrient. Instead, it is considered a functional food due to its benefits to the consumer's body [36]. Lactic acid bacteria, a group of gram-positive bacteria, ferment glucose and lactose to produce lactic acid. The bacteria also produce other organic acids such as acetic acid, propionic acid, and other substances such as hydrogen peroxide and diacetyl which give rise to smell and taste of fermented food. Lactic bacteria also produced bacteriocin which inhibits the growth of other microorganisms [37, 38]. Lactic acid bacteria are generally recognized as safe bacteria, and some of them are classified as probiotics, the beneficial bacteria in the human intestine. Probiotics produce bacteriocin which inhibits the growth of pathogens in the large intestine, aid in digestion of foods that human intestine cannot digest, increase absorption of nutrients and cholesterol, and produce vitamins that are beneficial to the body. Food sources for probiotic bacteria are called prebiotics which can be soluble fibers like pectin and gum, or oligosaccharides such as fructo-oligosaccharide [39].

4. Conclusions

Preparation of healthy salad dressing recipes by partial replacing oil with inulin from Jerusalem artichoke powder and flavoring essential oil from calamondin peel resulted in a suitable alternative recipe. The developed salad dressing consisted of sunflower seed oil 37.4%, egg yolk 15.0%, Jerusalem artichoke extract powder 11.2%, calamondin peel oil 0.1% and the remaining agents at 36.3% which include vinegar, sweetened condensed milk, sugar, mustard, salt, and pepper. Partial replacement of oil with Jerusalem artichoke powder in salad dressing products provided a healthy salad dressing that was low in fat content (41.41 g/100 g), and was rich in antioxidants (256.05 mg eq Trolox/100 g) and lactic bacteria (1.1 x 10^3 cfu/g). The microbial count complied with Thai Community Product Standards (TCPS.672/2547) for salad dressings. The healthy salad dressing product not only had a lower oil content but it also had high antioxidant content and a rich prebiotic from inulin and was thus an option for health-conscious consumers. Furthermore, development of prebiotics for lactic acid bacteria in healthy salad dressings should further be studies.

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