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Evaluation of the Effects of Amylose-Stearic Acid-Whey Protein Isolate Ternary Complex on the Rheological, Sensory, and Stability Properties of Low-Fat Mayonnaise

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ABSTRACT

Given the high-calorie content of fat in mayonnaise, finding an effective fat replacer is crucial. In this study, amylose was extracted from raw corn starch and combined with whey protein isolate (3% w/w) and stearic acid (5% w/w) at 75°C for 60 min to form a ternary complex. This complex was incorporated into mayonnaise formulations at 4 different concentrations: 0, 3, 5, and 7 % (w/w). Rheological analysis revealed a shear-thinning behaviour in all samples, with viscosity decreasing as the complex concentration increased from 0 to 7%. The storage modulus (G') was consistently higher than the loss modulus (G"), categorizing the samples as solid viscoelastic materials. The sample without the complex exhibited the highest stability against phase separation (88.5 %) whereas sample c with 7 % of the ternary complex showed the lowest stability (78.75 %). Sensory evaluation indicated that the sample with 5 % (w/w) ternary complex achieved the highest acceptability. These findings suggest that incorporating 5 % w/w ternary complex is effective for producing low-fat mayonnaise with both desirable technological and sensory properties.

1. Introduction

The growing awareness of the health risks associated with excessive fat consumption has prompted the food industry to develop low-fat products. However, fat plays a crucial role in creating the unique texture, flavor, and aroma of foods, and replicating these sensory attributes in low-fat products presents a significant challenge. This often results in these products failing to meet consumer expectations. To address this issue, fat substitutes are used, which can maintain desirable sensory properties. These substitutes can enhance the acceptability of low-fat products and contribute to a more balanced diet and improved health [1, 2].

Mayonnaise is recognized as a semi-solid, high-fat oil-in-water emulsion that typically contains 70–80% fat. The production and quality characteristics of low-calorie mayonnaise emulsions at various levels of fat reduction have been extensively studied. However, the challenge of maintaining desirable sensory properties in this industry persists [2, 3]. In the formulation of low-fat emulsions, researchers use compounds such as starches, gums, and proteins to replace the attributes lost due to fat removal. Finding a substitute capable of mimicking the multifunctional role of fat in food emulsions remains a challenge for the food industry, and research in this field is ongoing. Modified starches, which are chemically altered to enhance their functionality, are among the most popular fat substitutes [4].

In related studies, low-fat mayonnaise has been formulated using whey protein isolate, low-methoxyl pectin, and modified starch. Additionally, partial substitution of oil with gelatinized rice starch and xanthan gum has proven effective in reducing fat content while evaluating rheological properties. Low-fat mayonnaise emulsions have been produced by replacing up to 50% of the fat, resulting in products with 23% lower energy content compared to full-fat mayonnaise and showing rheological properties similar to commercial low-fat mayonnaise [5-7].

The amount of fat replaced by fat substitutes is a critical quality attribute in low-fat mayonnaise. Products with up to 80% fat replacement using modified teff starch with 1.5% stearic acid have been studied. Results indicated that replacing sunflower oil with stearic acid-modified corn starch at 50% and 80% levels produced low-calorie mayonnaise emulsions with higher viscosity and smaller oil droplet sizes compared to full-fat mayonnaise [8]. In subsequent research, the sensory and rheological properties of two starch-based fat substitutes, including amylose-fat complexes (corn starch with 1.5% stearic acid and corn starch with 2% monoglycerides), were investigated. Fat-modified starches were found to be non-gelling and exhibited fat-like properties, such as glossiness, softness, and creaminess [9].

In this study, the amylose-stearic acid-whey protein isolate (WPI) ternary complex was used as a fat substitute in mayonnaise emulsions. Starch, protein, and lipids are the three main nutrients in the human diet, and during food processing, complex interactions occur among these macromolecules. These interactions can affect the flavor, texture, nutritional value, and other quality characteristics of food products [10]. Amylose in starch, with its helical structure, can form complexes with various types of lipids. Proteins can also interact with lipids through covalent bonds, hydrophobic interactions, electrostatic forces, and hydrogen bonds [11].

Fatty acids can form starch-lipid-protein complexes that exhibit higher relative crystallinity and greater molecular order compared to starch-lipid complexes [12, 13]. Furthermore, starch-lipid-protein complexes possess unique functional properties, such as higher viscosity, reduced gel strength, and lower in vitro digestibility, which distinguish them from starch-lipid complexes [14].

The use of the ternary complex (amylose, whey protein isolate, and stearic acid) in low-fat mayonnaise improves texture, emulsion stability, and flavor retention, similar to full-fat mayonnaise. Amylose contributes to increased viscosity and gel structure formation, while whey protein, as a natural emulsifier, prevents phase separation in the sauce. Stearic acid creates a fat-like mouthfeel, reducing the need for high-fat content. As a result, mayonnaise with lower fat content but similar quality to full-fat mayonnaise can be produced. Several studies have been conducted on low-fat mayonnaise production using different complexes, such as pectin-whey protein [15], egg yolk-alginate [16], egg yolk-chitosan [17], teff starch and stearic acid-modified corn starch (Teklehaimanot et al., 2013), amylose-corn starch and stearic acid [9], and chitosan-stearic acid [18].

Based on the existing literature, no study has explored fat replacement in mayonnaise using the amylose-stearic acid-whey protein isolate ternary complex, which is the focus of this research. The findings of this study could be utilized for the production of low-fat mayonnaise in sauce processing factories.

2. Materials and Methods

2.1.Materials

Corn starch (11.4% moisture and 24.8% amylose content) was obtained from Glucosan Company in Qazvin, Iran. Stearic acid and whey protein isolate (containing approximately 86% protein) were purchased from Pegah Company in Isfahan, Iran. Other ingredients, including eggs (Telavang, Tehran, Iran), sunflower oil (Oila, Tehran, Iran), distilled vinegar with 10.5% acidity (Khosh Khorrak, Hamedan, Iran), sugar, salt, and mustard powder (Golha, Tehran, Iran), were sourced from a hypermarket in Hamedan, Iran. All chemicals used were analytical grade and purchased from Merck (Germany).

2.2. Methods

2.2.1. Amylose Extraction

To extract amylose, 10 grams of corn starch were mixed with a small amount of absolute ethanol. Then, 0.5 M sodium hydroxide solution was added to the starch suspension to prevent particle aggregation. The suspension was maintained in a shaking water bath (SWB-35, HANYANG, Republic of Korea) for 20 min and then stirred at room temperature until cooled. Subsequently, the alkaline solution was centrifuged at 6000 rpm for 20 min (HB320, Behsan, Iran).

The supernatant was titrated with 2 M hydrochloric acid to adjust the pH to 7. To 100 mL of this solution, a mixture of n-butanol and isoamyl alcohol at a 1:3 v/v ratio was added and incubated in a shaking water bath for 20 min. The solution was then transferred to a plastic container and refrigerated for 24 h. The upper layer was discarded, and the remaining precipitate, which contained amylose, was centrifuged again, and the supernatant was removed. The precipitate was dried in an oven at 60°C for 24 h [19].

2.2.2. Preparation of Amylose–Stearic Acid–Whey Protein Complex

To prepare the amylose–stearic acid–whey protein complex, various concentrations of whey protein isolate and stearic acid were used. Initially, a 0.5% (w/v) amylose suspension was prepared in water. Then, whey protein isolate at 3% (w/w, based on amylose weight) and stearic acid at 5% (w/w, based on amylose weight) were added to the amylose suspension. The 0.5% (w/v) amylose suspension was heated to approximately 95°C for 20 min and then gradually cooled. During cooling, appropriate amounts of whey protein isolate and/or stearic acid were added to the suspension, and the mixture was stirred continuously at 75°C for 60 min [20]. After gradual cooling overnight at room temperature with continuous stirring, the triple complex was filtered through a 0.45 µm pore-size filter paper and dried in an oven at 60°C for 24 h [21].

2.2.3. Preparation of Low-Fat Mayonnaise

To prepare low-fat mayonnaise, vinegar, eggs, and powdered ingredients (as listed in Table 1) were homogenized using a homogenizer (10 basic, IKA, Germany) at 4500 rpm for 1 min. Sunflower oil was then gradually added to the mixture over 2 min, during which the homogenizer speed was increased to 8000 rpm. Finally, the resulting emulsion was further homogenized at 8000 rpm for another 2 min. For the low-fat mayonnaise formulation, part of the oil was replaced with a stable amylose–stearic acid–whey protein complex. The complex was incorporated at three different levels (3%, 5%, and 7% of the total formulation) before the oil addition, mixed with the other ingredients, and added to the mixture. The mayonnaise emulsions were poured into glass containers and stored at 4°C for three months for subsequent testing.

Table 1. Composition of ingredients used in the formulation of various mayonnaise samples (% w/w)

Ingredients	Substitute with oil (%)			
	T0 (0)	T25 (25)	T50 (50)	T80 (80)
Sunflower oil	75	56.25	37.5	15
Egg	8	8	8	8
Ternary complex	-	3	5	7
Vinegar	12	12	12	12
Mustard powder	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5
Sugar	4	4	4	4
Water	-	15.75	32.5	53
Total	100	100	100	100

T0, T1, T2, and T3 presented the sample containing 0, 3, 5, and 7 %ternary complex, respectively.

2.2.4. Measurement of Flow Properties

The steady shear flow properties were measured using a rheometer (MCR 301, Anton Paar, The Netherlands) with a vane-in-cup configuration (vane diameter: 22 mm; cup diameter: 28.9 mm). Mayonnaise samples were equilibrated at 25°C for 30 min, and measurements were conducted at the same temperature. The shear rate was increased from 0.01 to 1000 s^{-1} and then decreased back from 1000 to 0.01 s^{-1}. The experimental data were analyzed using the Herschel-Bulkley model ($\sigma=\sigma_s+K(\dot{\gamma})^n$), where σ_s is the yield stress (Pa), σ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), KK is the consistency index (Pa/s^n, indicating viscosity), and n is the flow behavior index. In this model, n=1 indicates a Newtonian fluid, n<1 represents shear-thinning behavior, and n>1 represents shear-thickening behavior [1].

2.2.5. Stability of Mayonnaise at High Temperature

Two grams of each mayonnaise sample were weighed into six Eppendorf tubes and stored at 50°C for 24 h. The samples were then centrifuged at 3000 rpm for 10 min, and the separated liquid was weighed. The stability of the samples was calculated using the formula

Stability (%)=(1−Weight of separated liquid/Initial sample weight)×100 [8].

2.2.6. Sensory Evaluation

Mayonnaise samples were evaluated for color and appearance, aroma, taste, texture, and overall acceptance by 10 trained panelists (5 men and 5 women) aged between 20 and 50 years. Sensory evaluation was conducted 24 h after sample preparation in a controlled room with fluorescent lighting and regulated temperature. Samples were presented to the panelists in plastic containers labeled with random codes, and the panelists assessed the samples randomly. Water was provided for palate cleansing between tests. The panelists were asked to rate the sensory attributes on a 9-point hedonic scale (1 = extremely undesirable, 5 = neither desirable nor undesirable, 9 = extremely desirable) [22].

2.3. Statistical Analysis

The experimental design of this study was completely randomized with a 95% confidence level. Mean comparisons of the data obtained from three repetitions were conducted using Duncan's multiple range test and one-way ANOVA. All statistical analyses were performed using SAS software, and charts were created using Excel software (version 2013).

3. Results and Discussion

3.1. Measurement of Flow Properties

3.1.1. Apparent Viscosity

The viscosity of mayonnaise is a critical factor influencing consumer acceptance. The analysis of viscosity changes with increasing shear rate demonstrated a reduction in viscosity in all samples, indicating their pseudoplastic behavior. As shown in Figure 1, the highest viscosity was observed in the control sample, while the lowest viscosity was recorded in the sample containing 7% of the triple complex. The reduction in viscosity at varying levels of replacement can be interpreted as a consequence of the reduced oil requirement for forming a stable emulsion, thereby decreasing the viscosity. Additionally, in mayonnaise, the increased surface contact between oil droplets enhances the frictional force between particles, significantly affecting the viscosity. The presence of the triple complex prevents the formation of continuous gel networks by amylose, increases the mobility of fat particles, and decreases the density of the continuous phase, improving the flowability of the mayonnaise. Whey protein, acting as an emulsifier, reduces the attractive force between fat particles, while stearic acid, with its long chains, decreases the resistance of the continuous phase, ultimately leading to lower viscosity [23]. In a related study, researchers investigated the effects of teff and stearic acid-modified corn starches on the rheological, microstructural, freeze-thaw, and thermal stability characteristics of low-fat mayonnaise (LCMTE). The use of modified starches led to reduced stress and viscosity, as well as improved stability against freeze-thaw cycles and high temperatures. With 80% oil replacement using modified starches, the low-fat mayonnaise exhibited similar properties to full-fat mayonnaise [8]. These findings are consistent with the results obtained in the present study.

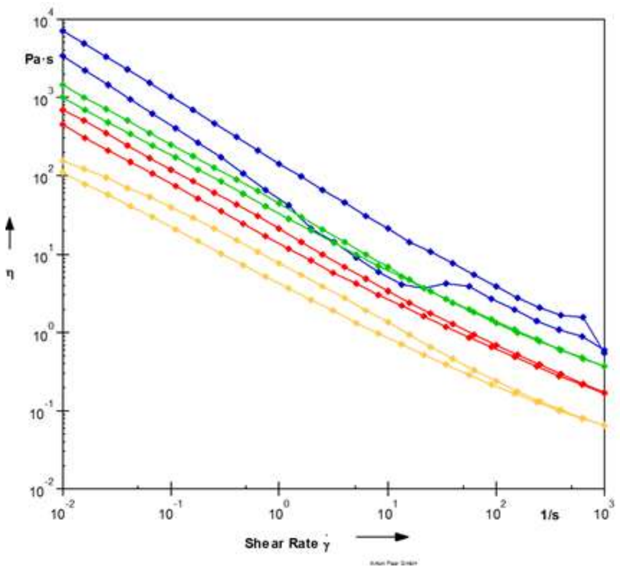

Fig. 1. The apparent viscosity of various mayonnaise samples. The blue, green, red, and yellow lines are related to mayonnaise containing 0, 3, 5, and 7 % of the ternary complex, respectively.

3.1.2. Frequency Sweep Test

To determine the viscoelastic properties of the mayonnaise samples produced in this study, a frequency sweep oscillatory test was performed. The variable frequency test can identify four types of systems: dilute solutions, concentrated solutions, weak gels, and strong gels. In this test, the loss modulus (G″, viscous) and storage modulus (G′, elastic) were analyzed over a frequency range of 0.1–100 Hz. As shown in Table 2, in all samples, G′ was greater than G″, classifying the samples as viscoelastic solids. For weak gels, the elastic modulus (G′) is always greater than the viscous modulus (G″) across the applied frequency range, and both moduli are frequency-dependent. The difference between strong and weak gels lies in the frequency dependency of the moduli, where the moduli in strong gels are independent of frequency. In dilute solutions, G″ is greater than G′ within the studied frequency range, and the moduli converge at higher frequencies. However, in concentrated solutions, G′ is initially lower than G″ at low frequencies and intersects with G″ at intermediate frequencies. The crossover point of the two moduli depends on molecular structure, molecular weight, and concentration [24]. In this study, despite the substantial reduction in oil content compared to full-fat mayonnaise (control), the storage modulus (G′) was greater than the loss modulus (G″), indicating the suitability of the amylose–stearic acid–whey protein triple complex as a fat replacer in mayonnaise formulation. Emulsions with higher oil content are expected to exhibit higher storage moduli. The mayonnaise samples containing the triple complex exhibited lower G′ compared to the control sample, which is attributed to the varying amounts of the triple complex, reducing the elastic properties of the product. This reduction in G′ suggests an increase in viscous behavior relative to viscoelastic behavior.

In a related study, the physicochemical, textural, sensory, and rheological properties of low-calorie mayonnaise were investigated using yogurt at replacement levels of 25%, 50%, and 75%. Results indicated that the viscosity of low-fat mayonnaise samples was also lower compared to the control. Regarding rheological properties, in all samples, the storage modulus (G′) was greater than the loss modulus (G″), classifying them as viscoelastic solids. Furthermore, the loss tangent of low-fat mayonnaise samples was higher than that of the control, indicating a greater tendency toward semi-liquid behavior [25]. The ratio of viscous modulus to elastic modulus, known as the loss tangent or damping factor (tanδ), is a method for evaluating the viscoelastic behavior of an emulsion. When the loss tangent is less than 1, elastic behavior dominates, while values greater than 1 indicate viscous behavior. Loss tangent values between 0.1 and 1 imply that the samples are not true gels but exhibit a structure between a high-concentration biopolymer and a real gel. As shown in Table 2, the loss tangent values for the mayonnaise samples are less than 1 and greater than 0.1, indicating that these samples exhibit elastic behavior. Another parameter assessed during the frequency sweep test is the complex modulus (G*), which is derived from the ratio of maximum stress to maximum strain during oscillatory testing. The complex modulus represents overall stiffness, which includes both elastic and viscous stiffness. From the ratio of complex modulus (G*) to frequency, the complex viscosity (η*) is calculated, which serves as a measure of the overall stiffness of the material. As shown in Table 2, the complex viscosity values of the samples containing the triple complex decrease with increasing frequency, indicating the non-Newtonian, shear-thinning behavior of the emulsions [26]. Additionally, as the proportion of the triple complex increases and oil content decreases in the mayonnaise formulation, the complex viscosity decreases. The highest complex viscosity value was observed in the control sample, while the lowest value corresponded to the mayonnaise sample containing 7% of the triple complex.

Table. 2. Parameters of frequency sweep test for mayonnaise samples

Sample	tanδ	Loss modulus (Pa)	Storage modulus (Pa)	η*
T0	0.139±0.00[b]	54.0 ±0.78[a]	386.0±0.42[a]	62.0±0.14[a]
T1	0.168±0.00[ab]	25.9 ±0.28[a]	154.0±0.28[b]	24.9±0.14[a]
T2	0.237±0.00[a]	15.7 ±0.14[b]	66.1±0.28a[c]	10.8±0.28[a]
T3	0.347±0.00[a]	5.80 ±0.19[c]	14.6±0.42[d]	2.47±0.07[b]

Different letters indicate statistical significance between samples in each column at $p<0.05$. T0, T1, T2, and T3 presented the sample containing 0, 3, 5, and 7 %ternary complex, respectively.

3.1.3. Strain Sweep Test

The value and interpretability of viscoelastic tests rely on their execution within the linear viscoelastic region (LVR). Thus, identifying the strain or stress limit below which the material's behavior remains linear is crucial. To determine the LVR of mayonnaise samples, curves of storage modulus (G′) and loss modulus (G″) as a function of strain amplitude (0.1% to 10%) were plotted at specific low frequencies. The strain at which G′ and G″ start to decline is considered the upper limit of the LVR. A larger LVR in emulsions indicates greater stability under strain sweep tests. As shown in Figure 2, the strain sweep test identifies two regions: the linear viscoelastic region and the non-linear viscoelastic region. In the non-linear viscoelastic region, increasing strain leads to a reduction in G′ and G″ values. The LVR and its endpoint are defined by the critical strain (γL). Within this range, the mayonnaise emulsion structure remains relatively unchanged. Table 2 reveals that the storage modulus (G′) values of the samples are higher than the loss modulus (G″) within the strain range examined. This dominance of elastic modulus over viscous modulus indicates a solid-like behavior in the mayonnaise samples containing the triple complex. In other words, samples with higher storage modulus values exhibit stronger interactions and greater stability within the LVR, along with a broader LVR. With increased strain percentages, G′ and G″ values decrease, leading to the breakdown of solid-like interactions in the mayonnaise emulsion structure (Table 2). In another study, low-calorie mayonnaise was formulated by replacing part of the oil with gelatinized rice starch and xanthan gum, and the effects on its rheological properties were examined [6]. The results showed that mayonnaise with up to 30% fat replacement had 23% lower energy content compared to full-fat mayonnaise. Moreover, the low-calorie mayonnaise exhibited rheological properties similar to those of commercially available low-fat mayonnaise.

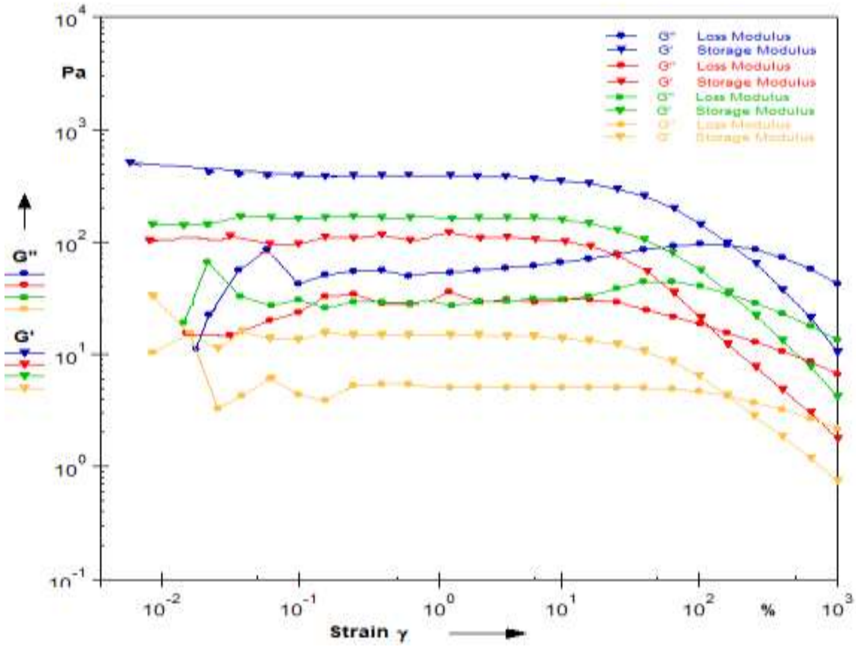

Fig. 2. The storage modulus (G’) and loss modulus (G”) of various mayonnaise samples in strain sweep test. The blue, green, red, and yellow lines are related to mayonnaise containing 0, 3, 5, and 7 % of the ternary complex, respectively.

3.2. High-Temperature Stability of Mayonnaise

The results of the high-temperature stability test for low-fat mayonnaise samples containing the triple complex are illustrated in Figure 3. Reducing oil content in the mayonnaise formulation to 25%, 50%, and 80%, alongside incorporating the triple complex at levels of 3%, 5%, and 7%, significantly impacted thermal stability ($p < 0.05$). Additionally, an increase in the proportion of the triple complex resulted in reduced high-temperature stability of the mayonnaise samples. In a separate study, three levels of cellulose nanofiber–soy protein isolate complex gel (5%, 15%, and 25%) and three ratios of cellulose nanofiber to soy protein isolate (5%, 10%, and 15%) were used as fat substitutes in low-fat mayonnaise. The results demonstrated that increasing the substitution of oil with the complex gel significantly enhanced the physical and thermal stability of mayonnaise ($p < 0.05$). A stable emulsion is characterized by the absence of coalescence, creaming, and sedimentation. Creaming is less frequent in high-fat mayonnaise samples (80% oil), as oil droplets are closely packed, leading to increased friction between them, which prevents creaming. Conversely, this phenomenon is more common in low-fat samples. In low-fat products, adding thickening agents such as gums or proteins to the aqueous phase reduces droplet mobility and inhibits creaming [27]. In oil-in-water emulsions, proteins stabilize emulsions by adsorbing onto the oil droplet surfaces due to their inherent surface activity and forming a thick, viscous interfacial film. Polysaccharides, on the other hand, contribute to stability by increasing the viscosity of the continuous phase and forming a gel-like network [28]. In some emulsions, an increased concentration of particles in the continuous phase, not adsorbed onto oil droplets, can cause instability through the depletion flocculation mechanism. In this study, whey protein appeared to adsorb onto oil droplet surfaces in low-fat mayonnaise. However, the excess protein concentration in the continuous phase (due to surface saturation) likely led to the instability of the emulsified system. These findings align with prior reports, such as those by Shirmohammadi et al. (2015), which noted reduced physical and thermal stability in low-fat mayonnaise compared to full-fat samples [29].

Furthermore, according to Stokes' law, the greater the viscosity of the continuous phase, the slower the phase separation and the more stable the emulsion. Conversely, reduced viscosity increases droplet mobility, leading to higher syneresis (water expulsion). The reduced stability of samples in this study can be attributed to an increased aqueous phase, lower concentration, and consequently, decreased viscosity. Additionally, the application of heat during the thermal stability test likely contributed to destabilization. Thermal shock increases molecular disintegration, freedom, and mobility, resulting in droplet flow, reduced viscosity, and consequently, decreased emulsion stability [30].

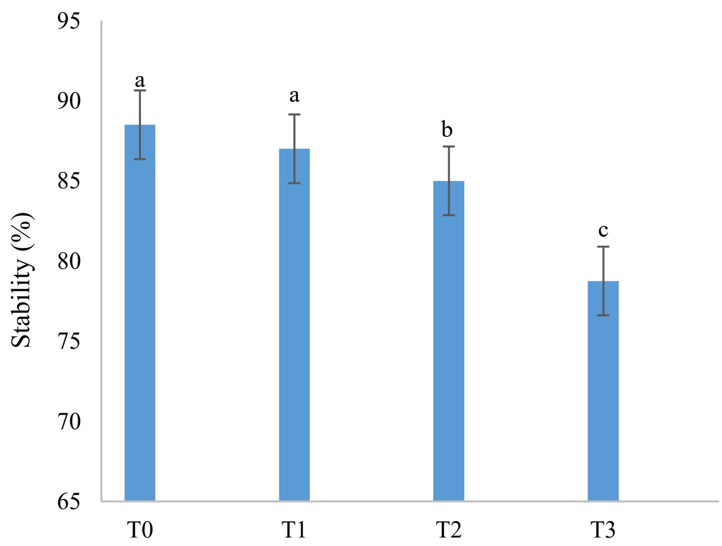

Fig. 3. Stability of mayonnaise sample. Different letters indicate statistical significance between samples at $p<0.05$. T0, T1, T2, and T3 presented the sample containing 0, 3, 5, and 7 %ternary complex, respectively.

3.3.Sensory Evaluation

The results of the sensory evaluation, including color and appearance, texture, aroma, flavor, mouthfeel, and overall acceptability of low-fat mayonnaise samples containing the triple complex, are presented in Table 3. Regarding color and appearance, the highest score was attributed to mayonnaise with a 50% reduction in oil content. For texture, the highest score was given to the control sample, while the lowest score was assigned to the mayonnaise sample with an 80% oil reduction. These results align with the instrumental texture analysis findings. For flavor, there was no significant difference among the T0, T1, and T2 samples ($p > 0.05$). However, the mayonnaise with an 80% oil reduction received the lowest score for flavor. The mouthfeel of the T2 sample also received the lowest score. In terms of overall acceptability, the control sample received the highest score, followed by T1 and T2, while T3 had the lowest acceptability. Overall, the mayonnaise with a 50% oil reduction and 5% triple complex scored highest in terms of color and appearance. This formulation demonstrated appropriate consistency and texture, making it suitable for use in formulations requiring lower viscosity, such as salad dressings. The sample with a 25% oil reduction, which showed no significant difference from the control in terms of texture and overall acceptability, was better suited for formulations requiring higher viscosity, such as spoonable mayonnaise. In a separate study, fat substitutes including lipid-modified corn starch, corn starch with 1.5% stearic acid, and corn starch with 2% monoglyceride were used in reduced-fat mayonnaise formulations with oil replacement levels of 0% (control), 50%, 80%, and 98%. The findings revealed that reduced-fat mayonnaise containing the starch-monoglyceride complex exhibited similar texture uniformity, creaminess, and mouthfeel to full-fat mayonnaise across all oil replacement levels. Moreover, it had comparable thickness and sensory attributes to full-fat mayonnaise up to a 50% oil replacement. For the starch-stearic acid complex, evaluations of texture uniformity, thickness, creaminess, and mouthfeel were lower compared to the starch-monoglyceride complex. However, the starch-stearic acid complex performed better in terms of melting properties and ease of swallowing. Overall, all reduced-fat emulsions exhibited good lubricating properties [1].

Table. 3. Sensory quality of various mayonnaise samples. T0, T1, T2, and T3 presented the sample containing 0, 3, 5, and 7 % ternary complex, respectively.

	Color and appearance	Texture	Aroma	Taste	Mouth feel	Overall acceptance
T0	5.6±1.4b	7.2±0.7a	7.0±1.0a	6.7±1.4a	5.9±1.1a	6.3±1.2a
T1	5.8±1.1b	7.1±1.3a	6.4±1.6ab	6.6±1.9a	5.9±1.1a	6.1±1.8a
T2	7.6±0.9a	5.8±1.3b	5.5±1.5b	6.0±1.3a	5.8±1.2a	6.0±1.0a
T3	4.7±1.1b	3.8±1.2c	5.3±1.3b	4.1±0.9b	3.7±0.9b	3.6±1.0b

Different letters indicate statistical significance between samples in each column at $p<0.05$. T0, T1, T2, and T3 presented the sample containing 0, 3, 5, and 7 % ternary complex, respectively.

4. Conclusion

In this study, the impact of using the triple complex of amylose-stearic acid-whey protein isolate as a fat replacer on the rheological, sensory, and stability properties of mayonnaise was investigated. All the mayonnaise samples exhibited shear-thinning behavior. The results showed that with an increase in the amount of complex from 0% to 7%, viscosity and, consequently, stability decreased. In all the samples, the storage modulus (G') was higher than the loss modulus (G"), thus classifying the samples as solid-like viscoelastic materials. The storage modulus (G') was higher than the viscous modulus (G") within the strain range studied. Regarding sensory properties, the mayonnaise sample with a 50% reduction in oil and containing 5% of the triple complex received the highest sensory evaluation score. Based on the results of this study, the use of 5% amylose-stearic acid-whey protein triple complex is recommended for the production of low-fat mayonnaise.

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بررسی تأثیر کمپلکس سه‌گانه آمیلوز-اسید استئاریک-ایزوله پروتئین آب‌پنیر بر خصوصیات رئولوژیکی، حسی و پایداری سس مایونز کم‌چرب

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چکیده

به دلیل کالری بالای چربی در سس مایونز، یافتن جایگزین برای این چربی اهمیت ویژه‌ای دارد. در این پژوهش آمیلوز از نشاسته ذرت خام استخراج و با ایزوله پروتئین آب پنیر (۳ ٪ وزنی/وزنی) و اسید استئاریک (۵ ٪ وزنی/وزنی) در دمای ۷۵ درجه سانتی‌گراد به مدت ٦۰ دقیقه کمپلکس سه‌تایی تشکیل شد. این کمپلکس در چهار غلظت مختلف ۰، ۳، ۵ و ۷ درصد (وزنی/وزنی) به فرمولاسیون سس مایونز اضافه شد. نتایج آزمون‌های رئولوژیکی نشان دهنده رفتار رقیق شونده با برش در تمامی نمونه‌ها بود. با افزایش میزان کمپلکس از ۰ به ۷ درصد ویسکوزیته کاهش یافت. در تمام نمونه‌ها مدول ذخیره (G') بیشتر از مدول ویسکوز (G") بود و نمونه‌ها به‌عنوان مواد ویسکوالاستیک جامد طبقه‌بندی شدند. بیشترین پایداری در برابر دوفاز شدن (۸۸ ٪) به نمونه فاقد کمپلکس و کمترین پایداری (۷۸/۷۵ ٪) به نمونه به نمونه حاوی ۷ ٪ کمپلکس سه‌گانه اختصاص داشت. از نظر خصوصیات حسی نمونه حاوی ۵ ٪ وزنی/وزنی کمپلکس سه‌گانه بالاترین مطلوبیت را داشت. نتایج این تحقیق نشان می‌دهد که استفاده از ۵۰ ٪ وزنی/وزنی کمپلکس سه‌گانه برای تولید سس مایونز کم‌چرب با ویژگی‌های تکنولوژیکی و حسی مطلوب پیشنهاد می‌شود.