Optimization of Aquafaba Production by Response Surface Methodology and Application in Plant-Based Mayonnaise

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Abstract: Aquafaba is the liquid left over after the chickpeas are boiled and canned. Aquafaba, which is used as an egg replacer in vegan products, is a valuable by-product that has become popular in recent years. The components that are transferred from chickpea into water during the boiling process provide foaming and emulsion-forming capabilities. The composition and functionality of aquafaba are affected by parameters such as boiling time, pH, and solid-liquid ratio. The purpose of this study was to investigate the effects of pH, time and solid-liquid ratio on various characteristics of aquafaba and to optimize aquafaba production using Response Surface Methodology. The °Brix, pH, foaming capacity, stability and emulsion activity index values were measured in 15 aquafaba samples produced according to the experimental design. The °Brix values of the samples ranged from 1.12 to 2.22. The foaming properties of the samples at pH 4.0 yielded significantly higher foam value and stability compared to the other samples. While the foam volume varied between 58.5 and 74.5%, the foam stability varied between 4.6-83.8%. The emulsion activity index was affected by the solid-liquid ratio and varied between 96.8 and 99.1%. In conclusion, aquafaba characteristics changed depending on pH, time, and solid-liquid ratio. The optimization was performed according to the Box-Behnken design and the optimum parameters were identified as pH: 3.58, time: 80 min and solid-liquid ratio: 0.25. Characteristics of plant-based mayonnaise prepared with optimized aquafaba was compared with commercial regular and vegan mayonnaise samples. The quality characteristics of the product can be improved by making further formulation revisions. Within the scope of this study, aquafaba was successfully used in the formulation of plant-based mayonnaise.

Keywords: Aquafaba, response surface methodology, plant-based mayonnaise.

Aquafabanın Yanıt-Yüzey Metodolojisi ile Optimizasyonu ve Bitkisel Bazlı Mayonez Üretiminde Kullanımı

Özet: Aquafaba, nohutun haşlama ve konserveleme işleminden sonra kalan sıvı kısmı ifade etmektedir. Vegan ürünlerde yumurta ikamesi olarak kullanılan aquafaba son yıllarda popülerliği artan değerli bir yan üründür. Haşlama işlemi sırasında suya geçen bileşenler köpük ve emülsiyon oluşturma ve stabilize etme özelliği sağlamaktadır. Aquafabanın bileşimi ve fonksiyonel özellikleri haşlama süresi, pH, katı-sıvı oranı gibi değişkenlerden etkilenmektedir. Bu araştırmanın amacı pH, süre ve katı-sıvı oranının aquafabanın karakteristik özellikleri üzerindeki etkilerini araştırmak ve aquafaba üretimini Yanıt-Yüzey Metodolojisi kullanarak optimize etmektir. Deney tasarımına göre üretilen 15 aquafaba örneğinde °Brix, pH, köpük oluşturma kapasitesi, köpük stabilitesi ve emülsiyon aktivite indeksi değerleri ölçülmüştür. Elde edilen numunelerin °Brix değerleri 1,12 ila 2,22 arasında ölçülmüştür. pH 4,0'da numunelerde köpürme özellikleri diğer numunelere kıyasla önemli düzeyde yüksek ölçülmüş olup; köpük hacmi %58,5 ile %74,5 arasında değişirken, köpük stabilitesi %4,6-83,8 arasında değişmiştir. Emülsiyon aktivite indeksi katı-sıvı oranından önemli düzeyde etkilenmiş ve %96,8–99,1 arasında değişmiştir. Sonuç olarak aquafabanın karakteristik özellikleri pH, süre ve katı-sıvı oranına bağlı olarak değişmiştir. Box-Behnken tasarımına göre optimizasyon yapılmış ve optimum koşullar pH 3,58, süre 80 dk ve katı-sıvı oranı 0,25 olarak üretildiğinde sağlanmıştır. Optimum koşullarda üretilen aquafaba ile hazırlanan bitki bazlı mayonez piyasadan temin edilen standart mayonez ve vegan mayonez ile karşılaştırılmıştır. Mayonez örneklerinin pH, °Brix, asitlik ve kıvam analizleri yapılmıştır. Gerekli iyileştirmeler yapılarak istenilen özelliklerde ürün elde edilmesi mümkündür. Bu çalışma kapsamında aquafaba bitkisel bazlı mayonez formülasyonunda başarılı şekilde kullanılmıştır.

Anahtar kelimeler: Aquafaba, yanıt-yüzey metodolojisi, bitki bazlı mayonez.

Article

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1. Introduction

Chickpea is an important legume that is grown and consumed widely in Türkiye. Chickpea is a good source of protein, carbohydrates and essential micronutrients. It is commercially processed in the form of canned chickpeas, chickpea flour and roasted chickpeas. During all these processes, several by-products are formed. The most important by-product during the processing of chickpeas is aquafaba. Aquafaba is the liquid part that remains after the chickpeas are boiled and separated from the grains. Aquafaba has functional properties such as foaming, emulsifying and gelling. However, these functional properties vary according to the processing conditions of chickpeas as well as chickpea cultivar, grain-water ratio, pH, boiling time, temperature etc. In recent studies, aquafaba is frequently encountered as an egg alternative in various products, especially for the vegan consumers. In a study conducted by Buhl et al. (2019), aquafaba samples were collected from different brands of canned products and compared with egg white (Buhl et al., 2019). In another recent study, aquafaba was obtained from a company in powder form and was used as a gelling agent in plant-based yoghurt samples (Raikos et al., 2020).

Mayonnaise is a product that aquafaba can be applied easily. It is an emulsified viscous sauce. Egg yolk provides the emulsion in the structure. Due to the proteins in its composition, it can form and stabilize an emulsion. In a study by Raikos, Hayes, and coworkers (2020), aquafaba was collected from canned chickpeas and a vegan mayonnaise recipe was optimized using aquafaba. The stability of the obtained samples was investigated. The aquafaba/oil ratio had a minor impact on colour properties and no significant effect was observed on the physicochemical stability of the mayonnaise during cold storage (Raikos, Hayes, et al., 2020). In another recent study, the temperature of soaking water, the soaking time and the boiling time were optimized and the produced aquafaba was used in mayonnaise. Aquafaba prepared by soaking chickpeas in 4 °C water for 16 h and boiling for 30 min achieved the highest emulsion capacity and stability (He et al., 2021). Since it is not possible to obtain exactly same composition in every batch, various gums and starches can be used to provide consistency to support the structure.

In majority of the studies from the current literature, aquafaba is collected from the canned products. There are a few studies focusing on the optimization of aquafaba processing parameters. The main goal of this study was to investigate the effects of processing conditions on aquafaba characteristics using Response Surface Methodology and to optimize aquafaba production on a lab scale. The application of aquafaba in mayonnaise formulation can enable development of plant-based products that can be consumed by vegan individuals.

2. Materials and Methods

2.1 Materials

The chickpeas used in the production of aquafaba were supplied from a market and the same brand product was used throughout the experiments. The ingredients used in mayonnaise production were also obtained from the market.

2.2 Processing techniques

An experimental design was created using the Response Surface Methodology, Box-Behnken design to observe the effects of pH, solid-liquid ratio and boiling time on aquafaba characteristics.

Parameter levels were determined based on preliminary experiments. The experimental design is presented in Table 1.

Table 1. The experimental design created by the response-surface methodology.

Tablo 1. Yüzey-yanıt metodolojisi ile oluşturulan deney tasarımı.

Sample	pH	Time (min)	Solid-liquid ratio
1	2.0	80	0.225
2	4.0	70	0.225
3	4.0	60	0.250
4	4.0	60	0.200
5	2.0	70	0.200
6	4.0	80	0.200
7	2.0	70	0.250
8	2.0	60	0.225
9	6.0	80	0.225
10	4.0	80	0.250
11	4.0	70	0.225
12	6.0	70	0.200
13	6.0	60	0.225
14	4.0	70	0.225
15	6.0	70	0.250

2.3 Preparation of the samples

Chickpeas were soaked in tap water for 24 h at a chickpea: water ratio of 1:3 (w/v). With this process, chickpea grains were softened by absorbing water and increased in volume. At the end of 24 h, chickpeas were washed several times with water and cleaned, then weighed and placed in a pot. For each treatment, 400 g of chickpeas were used and water was added according to the determined solid- liquid ratio. After the solid-liquid ratio was adjusted, the pot was placed on the induction cooker and the boiling process was carried out according to the time determined in the experimental design at a temperature of 100 °C under constant heating. After the boiling process, chickpeas and aquafaba were separated from each other by a strainer. Aquafaba was transferred into a glass beaker and cooled in a water bath.

The pH value of the samples was adjusted with citric acid and trisodium citrate according to the experimental design at 20°C. Aquafaba samples were analyzed the same day after preparation.

2.4 pH analysis

pH values were measured when the temperature of the aquafaba samples was dropped to around 20°C. Three replicate measurements were made for each sample. The pH value was measured with a pH meter (Mettler Toledo, USA).

2.5 Analysis of Soluble Solid Matter (°Brix)

The total soluble solids content was measured with a digital refractometer (ATAGO 5000a, Japan). Results were expressed in °Brix at 20°C (Tüfekci & Fenercioğlu, 2010).

2.6 Foaming Capacity and Stability

Foam volume and foam stability were measured according to method of Makri et al. (2005), with slight modifications (Makri et al. 2005). Approximately 30 mL of aquafaba sample was transferred into a beaker. Afterwards, it was whipped for 2 min with a hand mixer (Bosch, Germany) at 1400 rpm. The foam was transferred into a measuring cylinder. The first reading on the scale was recorded as the foaming capacity. After waiting for 30 min, the amount of foam was read again and % foam stability and % foam volume were calculated using equation 1 and 2, respectively (Lafarga et al., 2019). Analysis was repeated three times for each sample.

$Foaming\ capacity\ (\%): ((VF - Vo)\ /Vf)\ * 100$ (Equation 1)
Vo: volume before homogenization
VF: volume after homogenization

$Foaming\ stability\ (\%): ((V30/Vf)\ * 100$ (Equation 2)
Vf: Initial foam
V30: Foam volume after 30 min

2.7 Emulsion Activity Index

A measuring cylinder was used to measure 40 mL of aquafaba and 60 mL of sunflower oil. The ingredients were transferred into a plastic beaker and homogenized (Silverson L5M-A, England) for 1 min. The obtained emulsion was transferred into a measuring cylinder and kept at room temperature. The emulsion volume was recorded at time 0 and 1 h. Emulsion activity index was calculated according to the equation 3 (Meurer et al., 2020). The analysis was performed in three replicates for each sample.

$EAI\ (\%): (V60/Vi)\ * 100$ (Equation 3)
Vi: Initial emulsion volume
V60: emulsion volume after 60 min

2.8 Optimization and Validation

It is indicated that the foam and emulsion properties of aquafaba also change depending on the processing conditions. The results of the measurements made on the foam and emulsion properties were used to reach the optimum conditions. With the optimization, the foam and emulsion properties of aquafaba were maximized. Optimum levels of this study were determined as: pH 3.58, time 80 min, and the solid-liquid ratio 0.25. For validation, the analyzes were repeated under these conditions.

2.9 Production of Plant-Based Mayonnaise

Plant-based mayonnaise was produced with the optimized aquafaba. The mayonnaise formulation is presented in Table 2. Mayonnaise was produced in 500 g with using Thermomix (Thermomix Vorwerk, Germany) without applying heat treatment. First, salt, sugar and aquafaba were mixed at a speed of 2.5 and 350 rpm for 2 min. Starch, xanthan gum and 75 g of sunflower oil were mixed in a separate bowl and added to the aquafaba mixture in the Thermomix. After mixing, the speed was increased to 3.5 and 450 rpm. The remaining 175 g of sunflower oil was added slowly. The subsequently added oil was introduced slowly over approximately 4 min. After adding the oil, apple vinegar was added and mixed for 3 min. After the mayonnaise production was completed, it was stored at +4 °C.

Mayonnaise produced with aquafaba was compared with commercial products which is the regular mayonnaise and vegan mayonnaise. All analyses applied to mayonnaise were performed for these three products.

Table 2. Formulation of the plant-based mayonnaise.
Tablo 2. Bitkisel bazı mayonez formülasyonu.

Ingredient	Amount (g)
Salt	5.00
Sugar	10.00
Aquafaba	207.10
Potato starch	12.00
Xanthan gum	0.90
Sunflower oil	250.00
Apple vinegar	15.00

2.10 Characterization of plant-based mayonnaise

Analysis of Soluble Solid Matter (°Brix)

°Brix measurement of the mayonnaise sample was performed using a refractometer (Atago 5000a, Japan) at 20°C.

pH and Acidity Analyses

The pH values of the mayonnaise samples were measured using a pH meter (Mettler Toledo, USA), and the acidity values were measured using a titrator (Metrohm, Switzerland).

Consistency analysis

Bostwick consistometer was used to determine the consistency of mayonnaise samples at 20°C. Sample was placed in the reservoir of the consistometer and the cover was released. Bostwick values of the sample at the end of 30 and 60 secs were determined (Rüzgar & Yazıcı, 2022).

Heat Stability of Mayonnaise Samples

Heat stability of mayonnaise samples was determined according to the method used by Huang et al. (2016) with slight modifications (Huang et al., 2016). Approximately 10 g of mayonnaise was weighed and transferred into a 250 mL glass beaker. The water bath was pre-set to 80°C (Nüve BM 30, Türkiye). The beakers were placed in a hot water bath for 1 h. Afterwards, oil release from the samples was observed.

Sensory analyses

In total, 21 panelists between the ages of 23–36 participated in the sensory analyses. Panelists were requested to evaluate the products in terms of color, taste, mouthfeel, sourness, viscosity, spreadability, odor, taste and general acceptability. During the taste session, the panelists were requested to taste mayonnaise with fries and alone. The panelists were requested to answer the demographic questions and to give a score from 1 to 5 for each parameter. The significance level of the difference between samples was examined statistically by ANOVA test.

2.11 Statistical analysis

All analyses were performed in three replicates. Statistical analyses were performed using Minitab (Minitab Inc., USA). ANOVA test was applied and the difference between the results was determined at 95% confidence level using the Tukey test ($p < 0.05$).

3. Results and Discussion

3.1 pH and soluble solid content of the aquafaba

The pH values of the produced aquafaba samples varied between 5.96-6.14 and the °Brix values ranged between 1.12-2.22. Since the pH values specified in the experimental design were adjusted after the measurements, the possible reason for the variance observed was the changing solid-liquid ratio and time parameters. To examine the effect of solid-liquid ratio on initial pH and °Brix, comparisons were made between samples with the same duration. The change in the solid-liquid ratio in the samples with the same duration caused a statistically significant difference on the pH and °Brix value. As the solid-liquid ratio changed, the °Brix value of aquafaba changed. The dissolved solids content was measured higher in the samples with high this ratio. Accordingly, the pH value also changed due to the components that pass from chickpea to boiling water.
When the solid-liquid ratio was kept constant and the effect of the time on the initial pH and °Brix value was examined, no significant difference was observed. Presumably, the components that passed from chickpea to water did not change after a certain period of time and did not cause a significant difference between 60-70 and 70-80 min.

3.2 Foaming Capacity and Stability

When the parameters affecting the foaming capacity were examined, the interaction of pH2 and pH*time significantly affected the foaming capacity of the samples. The created regression model was meaningful. In the study, where the foam and emulsion properties of aquafaba were tried to be improved, the solid-liquid ratio and pH significantly affected the foam capacity (Lafarga et al., 2019).
The graphs of the foam capacity obtained from the, Response-Surface Method were shown in Fig. 1-3. The foam volume of aquafaba reached maximum levels when the pH was around 4, the solid/liquid ratio was around 0.25 and the time was between 70-75 min. Samples in which the pH were adjusted to 4 during the foam volume analysis were visibly higher than the other pH levels. While the proteins in aquafaba were best around pH 4, the foaming capacity reaches maximum levels.

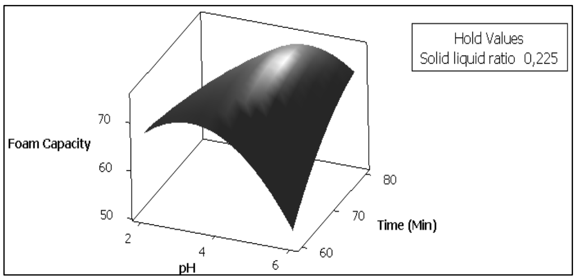

Figure 1. The effect of pH and time on foam capacity of aquafaba.
Şekil 1. pH ve sürenin aquafaba köpük kapasitesine etkisi.

The foam stability of aquafaba was significantly affected by pH2. As with the foam capacity, pH significantly affected the foam stability. The conditions between pH 4-5, solid/liquid ratio around 0.25 and duration longer than 70 min provide the best conditions for foam stability. Foam was produced at points where was around the pH 2 had the lowest stability. The higher the solid/liquid ratio was caused the higher protein and carbohydrate content in the water. Accordingly, the stability of the foam was at higher levels with a high solid/liquid ratio.

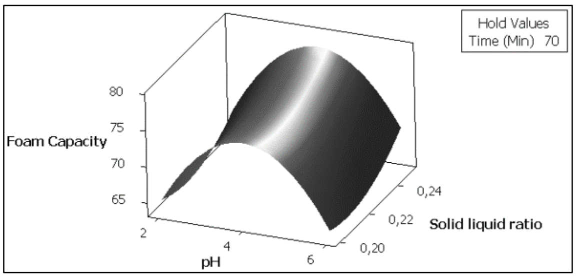

Figure 2. The effect of pH and solid/liquid ratio on foam capacity of aquafaba.
Şekil 2. pH ve katı/sıvı oranının aquafaba köpük kapasitesine etkisi.

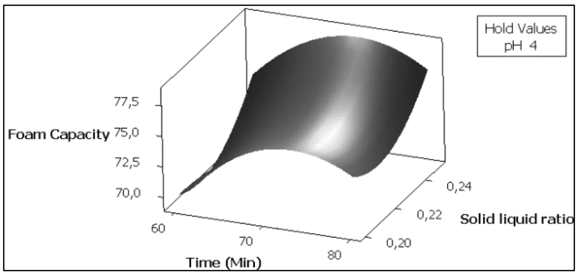

Figure 3. The effect of time and solid/liquid ratio on foam capacity of aquafaba.
Şekil 3. Süre ve katı/sıvı oranının aquafaba köpük kapasitesine etkisi.

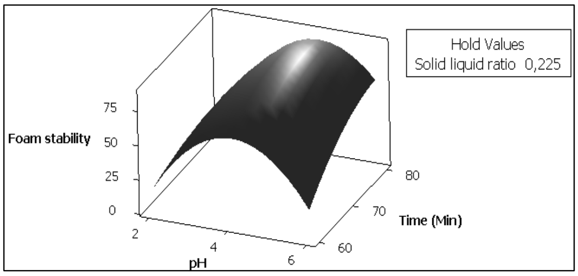

Figure 4. The effect of pH and time on foam stability of aquafaba sample.
Şekil 4. pH ve sürenin aquafaba köpük stabilitesine etkisi.

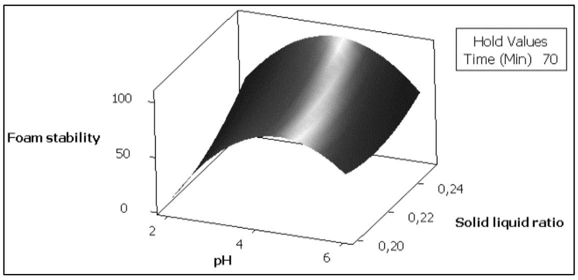

Figure 5. The effect of pH and solid/ liquid ratio on foam stability of aquafaba samples.
Şekil 5. pH ve katı/sıvı oranının aquafaba köpük stabilitesine etkisi.

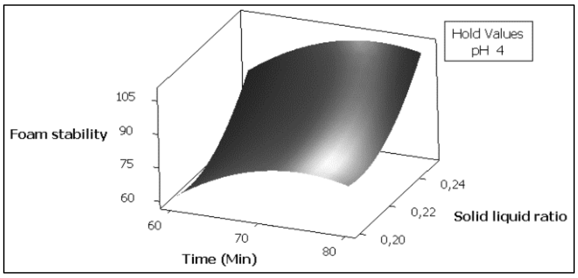

Figure 6. The effect of time and solid/ liquid ratio on foam stability of aquafaba samples.
Şekil 6. Süre ve katı/sıvı oranının aquafaba köpük stabilitesine etkisi.

3.3. Emulsion activity index

Solid/liquid ratio, pH2 and pH*time interaction significantly affected the emulsion activity index.
The effect of the parameters was presented in the Fig. 7-9 on the emulsion activity index. In contrast to the foam properties, the emulsion activity index was calculated higher when value was close to the pH 2. In cases where the time and solid/liquid ratio were high, the emulsion activity index was at higher levels.

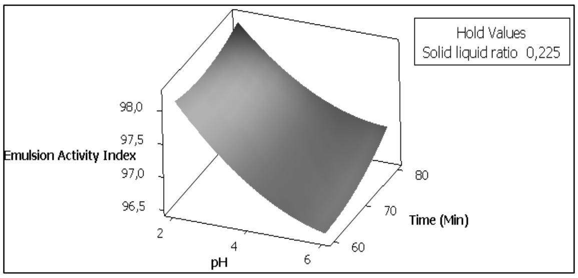

Figure 7. The effect of the pH and time on the emulsion activity index.
Şekil 7. pH ve sürenin emülsiyon aktivite indeksine etkisi.

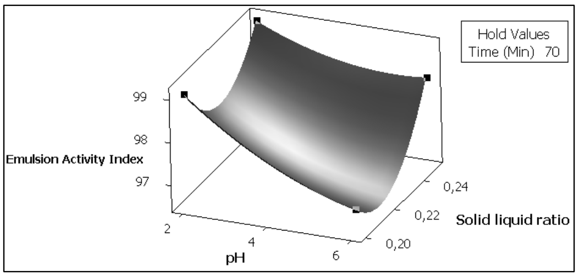

Figure 8. The effect of pH and solid/ liquid ratio on the emulsion activity index.
Şekil 8. pH ve katı/sıvı oranının emülsiyon aktivite indeksine etkisi.

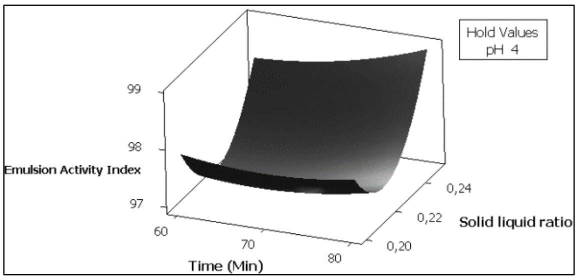

Figure 9. The effect of time and solid/ liquid ratio on the emulsion activity index.
Şekil 9. Süre ve katı/sıvı oranının emülsiyon aktivite indeksine etkisi.

3.4 Optimization and validation

The results of aquafaba produced with optimized conditions are given in Table 3. The sample produced under optimized conditions for foam volume and foam stability was measured at the highest levels. As a result, the foam properties reached maximum levels when the pH was around 3.5. Considering the emulsion activity index, the measured value was like the samples. In a study in which the solid/liquid ratio and the time were tried to be optimized, the optimum conditions were calculated as the situation where the solid/liquid ratio was 1.5/3.5 and the duration was 60 min. Optimum foam volume was measured as 88.3 ± 2.36 and foam stability as 55 ± 2.45 (Alsalman et al., 2020).

Table 3. Characteristics of the optimized sample.
Tablo 3. Optimize örneğin karakteristikleri.

	Optimized sample
pH	6.10 ± 0.03
°Brix	2.000 ± 0.006
% Foam capacity	76.0 ± 1.1
% Foam stability	85.6 ± 1.8
Emulsion activity index	97.9 ± 0.9

3.5 Characteristics of plant-based mayonnaise

pH and acidity

Characteristics of the mayonnaise samples are presented in Table 4. The lowest pH was measured in commercial vegan mayonnaise. While there was no significant difference in pH values of mayonnaise which is produced with aquafaba and regular mayonnaise from the market; the pH of commercial vegan mayonnaise is significantly different from the others. In a study by Karas and coworkers, commercially produced mayonnaise samples with different fat contents were taken and physicochemical analyzes were applied. The pH value of aquafaba was measured 3.74 and 4.66, in another study, the lowest pH value was measured as 3.27 (Karas et al., 2002). The values measured in this study were lower than the values in other studies. The reason for the difference between the pH values of the samples was the amount of acid added and formulation differences.

Table 4. Characteristics of mayonnaise samples.
Tablo 4. Mayonez numunelerinin özellikleri.

	pH	**°Brix**	**Acidity (%)**	**Bostwick value (cm)**
Mayonnaise with aquafaba	3.40±0.02^{A}	11.2±0.3^{C}	0.40±0.03^{A}	1.1-1.4^{A}
Regular commercial mayonnaise control	3.40±0.02^{A}	25.8±0.8^{A}	0.40±0.006^{A}	0^{B}
Commercial vegan mayonnaise	2.90±0.02^{B}	21.9±0.6^{B}	0.40±0.02^{A}	0^{B}

* There is a statistically significant difference between the values shown with capital letters within the same column (p<0.05).

No significant difference was observed in the acidity values of the samples (p>0.05). In the study conducted by Hakimian et al., the pH value of the control samples was measured as

0.61% (Hakimian et al., 2022). In another study, acidity was measured as 0.50% (Pradhananga et al, 2016). The acidity value of mayonnaise used in this study was observed to be relatively lower compared to the studies in the literature.

Soluble Solid Content

°Brix is an important parameter for sauce type products. It provides an idea about mouthfeel and consistency. When two mayonnaise samples with different °Brix values are compared, it will be observed that the sample which has higher °Brix value has more intense consistency and more mouth-satisfying taste. In the present study, significant differences were observed between the °Brix values of the mayonnaise samples. The °Brix value of the mayonnaise produced with aquafaba was approximately half of the °Brix value of other products. Significantly lower °Brix values observed in the newly developed mayonnaise formulation can result in negative effects on the consistency and stability of the products. Generally, increases in soluble solid content contribute to higher viscosity of the sauces (Gamonpilas et al., 2011). This can be accomplished via using various stabilizers such as hydrocolloids in the product formulation. Increasing the soluble solid content in the formulation can also have a significant effect on both the consistency and mouthfeel of the product. In a study aiming to reduce the amount of oil in mayonnaise formulation, various stabilizers including xanthan gum and sodium carboxymethyl cellulose were used. The °Brix value of mayonnaise produced using xanthan gum was measured as 23 (Than & Win, 2020).

Consistency

It was observed that the commercial products did not move in 60 sec, while the mayonnaise sample produced with aquafaba moved 1.1 cm in 30 sec and 1.37 cm in 60 sec. In terms of consistency and viscosity of the product produced with aquafaba was lower than commercial product. In a study focusing on fat reduction in mayonnaise, modified starch was added, and the control sample (80% fat content) moved 0.2 cm in 30 sec (Carcelli et al., 2020). The mayonnaise produced for this study moved more in 30 sec, and therefore its consistency was found to be lower.

Heat Stability

At the end of 60 min, while water started to accumulate on the surface of the vegan mayonnaise and aquafaba mayonnaise, it was clearly observed that the amount of separated oil was higher in the regular mayonnaise control. As a result, the thermal stability of regular mayonnaise was found to be lower than plant-based mayonnaise samples.

Figure 10. Heat stability of mayonnaise samples.
Şekil 10. Mayonez örneklerinin ısı stabilitesi.

Sensory Characteristics

Sensory scores of the mayonnaise sample are presented in Table 5. Mayonnaise produced with aquafaba was whitish in color, while vegan mayonnaise was brighter yellow than regular mayonnaise. According to the taste parameter, vegan mayonnaise received the lowest ratings from the panelists since it was indicated to leave an artificial and oily taste in the mouth.

In terms of sourness, the formulation of the product with aquafaba needs to be improved. When the odor was examined in all 3 products, no significant difference was detected in terms of odor. When considering the overall acceptability, vegan mayonnaise received the lowest score.

The general comments about the product with aquafaba were additionally provided by the panelists which included that it did not leave an aftertaste and that it was perceived to be significantly better than expected.

Table 5. Sensory properties of mayonnaise samples.
Tablo 5. Mayonez örneklerinin duyusal özellikleri.

	Color	**Taste**	**Mouthfeel**	**Sourness**	**Viscosity**	**Spreadability**	**Odor**	**Aftertaste**	**Overall Acceptability**
Mayonnaise with aquafaba	3.3 ± 1.0^{B}	4.0 ± 0.7^{A}	3.9 ± 0.6^{AB}	3.9 ± 1.1^{A}	4.6 ± 0.5^{A}	4.3 ± 0.9^{A}	4.2 ± 0.9^{A}	3.9 ± 1.1^{A}	4.1 ± 0.5^{AB}
Regular commercial mayonnaise	4.7 ± 0.6^{A}	4.0 ± 1.1^{A}	4.3 ± 0.7^{A}	4.0 ± 0.9^{A}	4.7 ± 0.6^{A}	4.7 ± 0.5^{A}	4.5 ± 0.7^{A}	3.9 ± 1.2^{A}	4.4 ± 0.7^{A}
Vegan mayonnaise	3.8 ± 1.2^{B}	3.5 ± 1.1^{A}	3.4 ± 1.2^{B}	3.7 ± 11^{A}	4.2 ± 1.2^{A}	4.2 ± 1.0^{A}	4.1 ± 1.2^{A}	3.9 ± 1.2^{A}	3.7 ± 1.3^{B}

* There is a statistically significant difference between the values shown with capital letters within the same column ($p<0.05$).

4. Conclusion

The effects of processing parameters such as boiling time, pH and solid-liquid ratio on aquafaba properties were investigated. According to the results obtained from Response Surface Methodology, maximum values for foaming capacity, foam stability and emulsion activity index were obtained when the solid-liquid ratio was approximately 0.25 and time over 70 min. Maximum levels for foaming capacity and stability were obtained at pH 4, whereas pH 2 resulted in maximum emulsion activity index, and optimized samples were validated.

Plant-based mayonnaise was prepared with the optimized aquafaba and compared with commercial samples. The °Brix value and consistency of the sample produced with aquafaba were significantly lower than the commercial products. These differences can be eliminated with revisions on the formulation of mayonnaise produced with aquafaba.

By including thickeners such as starches and gums in the formulation, it is possible to match the consistency and °Brix values of commercial samples. On the other hand, the desired yellowish color can be obtained by the addition of natural colorants. While improving the taste of mayonnaise by adding lactic acid to the formulation; at the same time, the shelf life of the product can be extended.

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6. Conflicts of interest

The authors declare no conflict of interest.

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