applied sciences

MDPI

Article

Physico-Chemical Characteristics, Sensory Attributes and Oxidative Stability of Soy Milk Mayonnaise Enriched in Carotenoids from Tomato By-Products

Ana Maria Blejan [1,2] and Violeta Nour [2,*]

[1] Faculty of Food Science and Engineering, Dunărea de Jos University of Galati, Domnească Street 111, 800201 Galati, Romania; ana.blejan@ugal.ro
[2] Department of Horticulture and Food Science, University of Craiova, 13 AI Cuza Street, 200585 Craiova, Romania
* Correspondence: violeta.nour@edu.ucv.ro

Abstract: In the present study, sunflower oil was used as the extracting solvent for carotenoids and other lipophylic compounds from tomato by-products at 2.5% and 5.0% (*w*/*v*) and the carotenoid-enriched oils were further used in the manufacturing of soy milk mayonnaise. An addition of basil essential oil at 0.05% (*v*/*v*) in the carotenoid-enriched mayonnaise was also investigated. Color parameters, pH, acid, and peroxide values, as well as lipid oxidation as measured by TBARS values were monitored in control and in supplemented mayonnaise samples during refrigerated storage for up to 8 weeks. The effect of enrichment on the sensory attributes of mayonnaises was also studied. The extraction of dry tomato by-products resulted in a significant increase in the total carotenoid content and antioxidant activity of the oils while their color changed significantly by increasing the redness and decreasing the lightness and yellowness. The use of carotenoid-enriched oils in the mayonnaise manufacture increased the oxidative stability of soy milk mayonnaise during storage and improved the flavor and the chromatic characteristics of mayonnaise compared to the control sample without significantly affecting its consistency and overall acceptability. The addition of basil essential oil (0.05% *v*/*v*) enhanced the oxidative stability and improved the sensory profile of the mayonnaise.

Keywords: mayonnaise; tomato by-products; carotenoids; sunflower oil; extraction

Citation: Blejan, A.M.; Nour, V. Physico-Chemical Characteristics, Sensory Attributes and Oxidative Stability of Soy Milk Mayonnaise Enriched in Carotenoids from Tomato By-Products. *Appl. Sci.* **2023**, *13*, 7101. https://doi.org/10.3390/app13127101

Academic Editors: Alessandra Biancolillo and Anna Lante

Received: 28 May 2023
Revised: 5 June 2023
Accepted: 11 June 2023
Published: 14 June 2023

1. Introduction

Nowadays, consumers are increasingly aware of the connection between food and health, and they are therefore more and more attracted to foods that, in addition to having a high nutritional value and sensory satisfaction, exert beneficial biological and physiological activities. These potential health benefits may be attributed to their content of bioactive compounds, such as phenolic acids, flavonoids, vitamins, carotenoids, and vitamins, which are found mainly in fruits and vegetables.

Mayonnaise is one of the most widely consumed sauces in the world due to its creamy mouthfeel and special flavor [1]. Mayonnaise represents a cold oil-in-water emulsion prepared by mixing vegetable oils (70–80%), emulsifier (egg yolk), texture enhancers (gum and starch), lemon juice or vinegar, and flavoring agents (salt, sweetener, mustard, or garlic) [2,3].

Mayonnaise consumption has increased in recent decades as a result of the development of international food restaurant chains, including fast food and Japanese and Middle Eastern restaurants that use mayonnaise as a seasoning for many of their dishes [4]. The mayonnaise market is expected to rise in the years ahead due to the growing demand for convenience food and the changing eating habits of consumers [5]. However, the regular consumption of mayonnaise can induce health problems mainly related to the high cholesterol content of the egg yolks and the high energy value determined by the oil content.

The trend toward the adoption of vegetarian diets among consumers and the understanding of the need to adopt healthy diets has challenged the food industry to create egg-less, vegan, low-fat, and natural mayonnaise variants [6]. In recent years, numerous studies aimed to replace the egg yolk in the mayonnaise recipe with emulsifiers of plant origin, without affecting the mayonnaise's stability, consistency, taste, and color [6]. The emulsifying performances of canola, wheat germ, and white lupin proteins have been tested for the formulation of vegan mayonnaise, as well as soy milk, chia mucilage, and modified potato starch [7–11]. Soy milk has been used successfully as an egg yolk substitute in low-cholesterol mayonnaise formulations [8,12].

Mayonnaise is highly susceptible to lipid oxidation during storage due to the high oil content and the unsaturated character of the oil. This process reduces the shelf life of mayonnaise by the development of rancid flavors formed as secondary oxidation products through the decomposition of hydroperoxides and by discoloration determined by the reaction of pigments, especially carotenoids, with the free radicals formed during lipid oxidation [13]. In addition, lipid oxidation reduces the nutritional value of mayonnaise, by decreasing the concentration of bioactive compounds, especially antioxidants [14].

In a multiphase system, such as mayonnaise, the oxidative reactions are initiated mainly at the interface between the oily and the aqueous phase, and they are strongly influenced by the composition and physicochemical properties of these two phases and of the surfactants, and by the surface area of the oil droplets [15].

To delay lipid oxidation in mayonnaise, synthetic antioxidants, such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT), have been extensively used, but their long-term intake has been reported to have harmful effects on human health [16]. As a result, natural antioxidants from plant sources have gained attention as alternatives to enhance the stability of foods against oxidation, more so as they exhibit a wide spectrum of pharmacological activities, such as antioxidant, antimicrobial, anti-inflammatory, and antimutagenic activities [1,2,15].

Fruits, vegetables, seeds, herbs, and spices have been demonstrated to be excellent sources of natural antioxidant molecules. Moreover, by-products generated in the juice or pulp processing of fruits and vegetables can be a valuable source of functional compounds, considering that the peels, cores, and seeds have a higher antioxidant content than the pulp [16]. As a result, numerous studies have aimed to find technological solutions for obtaining food natural additives from these alternative raw materials [17]. Extracts from fruits and vegetables by-products have also been evaluated as alternative antioxidants for use in various oils [18,19].

Tomatoes are known as a rich source of carotenoids, mainly lycopene (70–80%) [20], which are very efficient scavengers of singlet oxygen and other reactive oxygen species [21,22]. Tomato processing generates about 3–7% of by-products consisting of skins, seeds, and residual pulp, which are typically used as livestock feed or often discarded, thereby leading to environmental pollution. However, the industrial tomato by-products represent one of the most promising sources of nutrients and bioactive compounds, including polyphenols, carotenoids, minerals, proteins, fibers, and minerals [23–25].

The extraction of carotenoids from tomato by-products is attracting worldwide interest with a view to their use as food colorants and functional food ingredients. However, the traditional use of organic solvents poses several drawbacks to both human health and environmental safety [25]. Given the lipophilic properties of carotenoids, several previous studies proposed the use of vegetable oils as the extracting solvents for carotenoids to increase the functionality and thermal stability of the oils and to use them in food applications [26,27].

The present study aimed to investigate the physicochemical and sensory properties, as well as the oxidative stability of soy milk mayonnaise enriched with carotenoids and other lipophilic bioactive compounds from dried tomato by-products directly extracted in the vegetable oil used in mayonnaise preparation.

2. Materials and Methods

2.1. Materials and Reagents

Samples of industrial tomato by-products, containing peels, seeds, and residual pulp, were obtained from Elio Monte Verde, a tomato processing factory from Caracal, Olt county, South-West Romania. A total of 20 kg of tomato by-products were collected, air-dried in a cabinet-type laboratory dryer (Deca +SS Design, Profimatic, Romania) at 57 °C, mixed well, and then ground to a powder to pass through a 0.70 mm sieve. The powders were packed in aluminum-coated polyethylene bags and stored in ambient conditions for further analysis and use.

The ingredients for preparing mayonnaise, including refined sunflower oil, soy milk, lemon juice, salt, and mustard, were procured from a local market located in Craiova, South-West Romania. Butylated hydroxytoluene (BHT), potassium persulfate, thiobarbituric acid, trichloracetic acid, 2,2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), malondialdehyde, and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) were supplied from Sigma-Aldrich (St. Louis, MO, USA). All other reagents used were of analytical grade and procured from Merck (Darmstadt, Germany).

2.2. Extraction of Dried Tomato By-Products in Oil

Triplicate samples of dried tomato by-products (DTB) were macerated at 20 °C in refined sunflower oil at 2.5% (*w*/*w*) (DTB2.5) and 5.0% (*w*/*w*) (DTB5) concentration at 20 °C for 10 days. The extraction was followed by filtration through Whatman No.1 filter paper (Whatman International Ltd., Maidstone, UK), and the resulting oils were collected in screw-capped dark plastic containers filled with oil and stored at 4 °C until they were used. The commercial sunflower oil was also stored under the same conditions as the extracted oils to be used as control (C). Acid value, peroxide value, total carotenoid content, ABTS antioxidant activity, and CIELab color values were investigated in the oil samples.

2.3. Total Carotenoid Content

The total carotenoid content of the oils was determined using the spectrophotometric method previously described by Szydłowska-Czerniak et al. [28]. Briefly, the oil samples (1 g) were solubilized in 50 mL of n-hexane and the absorbance was read against n-hexane at 450 nm using a Varian Cary 50 UV spectrophotometer (Varian, Palo Alto, CA, USA). Standard solutions of β-carotene in n-hexane (10–70 mg/L) were used to obtain a calibration curve. Analysis was conducted in triplicate for each oil. The results were reported as mg of β-carotene per kg of oil.

2.4. ABTS Antoxidant Activity

Antioxidant activity of the oils was evaluated using the ABTS assay according to Re et al. [29]. The ABTS cation radical solution ($ABTS^+$) was prepared by reacting 5 mL ABTS stock solution (7 mM) with 88 µL of potassium persulfate solution (145 mM). After incubation in the dark at room temperature for 16 h, the $ABTS^+$ solution was diluted with 80% ethanol to a final absorbance of 0.70 ± 0.02 at 734 nm. The samples (120 µL) were added to the $ABTS^+$ solution (12 mL) and mixed vigorously. The absorbance was recorded after 6 min against 80% ethanol as a blank. Trolox was used as a standard and results were expressed in mmol Trolox equivalents (TE) per kg of oil.

2.5. Preparation of Mayonnaise

Mayonnaise samples were prepared according to a reference recipe with the following formulation: sunflower oil (61.5%), soy milk (30.8%), mustard (3.1%), lemon juice (3.1%), and salt (1.5%). The preparation was carried out in a one-step procedure by homogenizing together all ingredients for 2 min using a household mixer (Bosch MFQ3540, BSH

GmbH Germany). A mayonnaise with good emulsion stability and without syneresis was produced through this formulation. Five different mayonnaises were prepared in this experiment: MC (control mayonnaise, made using sunflower oil), MBHT (made using sunflower oil + 0.1% BHT addition), MDTB2.5 (made using sunflower oil macerated with 2.5% DTB), MDTB5 (made with sunflower oil macerated with 5% DTB), and MDTB5B (made using sunflower oil macerated with 5% DTB + 0.05% basil essential oil addition). Samples of 500 g of mayonnaise were prepared for each batch and four batches were prepared for each type of mayonnaise. Mayonnaise samples were packaged in disposable plastic containers of 500 mL capacity, covered externally with aluminum foil to avoid photodegradation, and kept under refrigeration (4 °C) for up to eight weeks. Samples were taken immediately after preparation and at two week intervals to investigate CIELab color values, pH, peroxide values, titratable acidity, thiobarbituric acid reactive substances (TBARS) values, and sensory attributes.

2.6. pH Measurement

The pH of mayonnaise samples was measured in triplicate at room temperature (20 °C) using a Hanna pH meter HI255 (Hanna Instruments, Padova, Italy).

2.7. Acid Value

The acid value of mayonnaise samples was determined using the AOAC 940.28 method [30]. The results were expressed as g of KOH per kg of sample.

2.8. Color Measurement

The color of the oils and mayonnaise samples was evaluated by directly reading the color coordinates of the CIEL *a *b * system (L*—lightness, a*—redness/greenness, and b*—yellowness/blueness) using a Thermo Scientific Evolution 600 UV/VIS spectrophotometer (Thermo Scientific, Waltham, MA, USA) calibrated against a white standard. Readings at five different points were taken for each sample. The total color change (ΔE) was calculated for each mayonnaise sample using the equation below:

$\Delta E = \sqrt{(L1 - L0)^2 + (a1 - a0)^2 + (b1 - b0)^2}$, where L1, a1, b1 represent color values of mayonnaise samples after 8 weeks of storage, while L0, a0, b0 are color values of fresh mayonnaise samples.

2.9. Peroxide Value

Peroxide value was determined according to the AOAC 965.33 method [30] in the oils and in the oil phase of the mayonnaises. The oil phase was separated from the mayonnaise according to the procedure of Park et al. [31]. Portions of 20 g of mayonnaise were frozen at −18 °C for 24 h in 50 mL centrifuge tubes and then thawed at room temperature to break the emulsion. The thawed sample was then centrifuged at 6000× *g* rpm for 10 min and the separated oil phase was used directly for peroxide value analysis. For peroxide value, the extracted oil (5 g) dissolved in 25 mL chloroform: acetic acid (2:3, *v*/*v*) was vigorously shaken with 1 mL of saturated potassium iodide. After 5 min of standing in the dark, 75 mL of double distilled water and 1 mL of 1% starch solution were added and the liberated iodine was titrated with 0.01 N sodium thiosulfate solution until colorless. A blank sample was prepared following the same procedure without the addition of the oil sample. Peroxide value was expressed as milliequivalents (mEq) of active oxygen per kg of sample.

2.10. Thiobarbituric Acid Reactive Substances Values

TBARS values were determined according to the spectrophotometric method described by Witte et al. [32] with slight modifications. Briefly, 5 g of mayonnaise sample was taken and TBARS were extracted with 12.5 mL of 20% trichloroacetic acid. The extract was collected and made up to 25 mL with cold distilled water. After filtration, 5 mL of extract was mixed with 5 mL of 0.02 M 2-thiobarbituric acid and placed in a water bath at 100 °C for 35 min. After cooling in tap water, the absorbance was read at 532 nm with a Cary 50 UV spectrophotometer (Varian, Palo Alto, CA, USA). The results were calculated from a standard curve of 1,1,3,3-tetraethoxypropane and expressed as mg of malondialdehyde (MDA) per kg of sample.

2.11. Sensory Evaluation

The sensory evaluation was carried out to determine consumer preference for the studied mayonnaise samples. A panel of twelve tasters consisting of Master's students and staff members of the Department of Food Science and Technology (University of Craiova, Romania) scored the mayonnaise samples for color, flavor, taste, consistency, and overall acceptability. A brief training scale and sensory attributes were carried out to the panelists before sensory analysis. The test was performed on a nine-point hedonic scale, with 1 = extremely dislike and 9 = extremely like. The samples were randomly served at room temperature in transparent plastic cups of about 10 g each with teaspoons. Water and crispy bread were served between samples for panelists to cleanse the palate.

2.12. Statistical Analysis

The mayonnaise samples were prepared in three batches for each formula and the determinations were run in triplicate. Results were reported as means ± standard deviations. Analyses of variance (ANOVA) and mean comparison tests were performed using Statgraphics Centurion XVI software (version 16.2.04) (StatPoint Technologies, VA, USA), and significant differences between the mean values ($p < 0.05$) were determined by least significant difference (LSD) multiple range test.

3. Results and Discussion

3.1. Physico-Chemical Properties of Oils

The total carotenoid content of the control oil and of the oils macerated with dried tomato by-products is presented in Table 1. No carotenoids were detected in the refined sunflower oil, but maceration of the oil with tomato by-products determined the enrichment of the oil in carotenoids. Moreover, a linear dependency was found between the content of carotenoids in the enriched oils and the amount of extracted by-products (r = 0.996).

Table 1. Acid values, peroxide values, total carotenoid content, and antioxidant activity of control and experimental oils.

	C	DTB2.5	DTB5
Total carotenoid content (mg/kg)	nd ^{a}	19.48 ± 0.68 ^{b}	34.86 ± 0.85 ^{c}
Acid value (g/kg)	0.56 ± 0.03 ^{a}	0.84 ± 0.05 ^{b}	0.98 ± 0.04 ^{c}
Peroxide value (meq/kg)	2.10 ± 0.10 ^{c}	1.88 ± 0.09 ^{b}	1.42 ± 0.06 ^{a}
Antioxidant activity (mmol/kg)	2.78 ± 0.13 ^{a}	3.34 ± 0.17 ^{b}	4.01 ± 0.18 ^{c}
L*	78.85 ± 0.25 ^{c}	76.92 ± 0.28 ^{b}	75.7 ± 0.32 ^{a}
a*	0.12 ± 0.03 ^{a}	0.65 ± 0.03 ^{b}	0.95 ± 0.04 ^{c}
b*	6.37 ± 0.21 ^{a}	4.69 ± 0.28 ^{b}	3.61 ± 0.46 ^{c}

C—control refined sunflower oil, DTB2.5—refined sunflower oil macerated with 2.5% DTB, DTB5—refined sunflower oil macerated with 5% DTB, L*—lightness, a*—redness/greenness, b*—yellowness/blueness. Different superscript letters indicate significant ($p < 0.05$) differences between oils. Data are expressed as mean ± standard deviation.

Generally, sunflower oil shows a lower oxidation resistance compared to other edible oils due to the higher unsaturation degree and the lower antioxidant protection conferred by alpha-tocopherol as compared with other tocopherols (gamma- and delta-tocopherols) with higher antioxidant potency that are found in other edible oils (i.e., soybean oil) [33]. Significant decreases in the peroxide value were recorded in the oils after the extraction of 2.5% and 5% dried tomato by-products compared with the control oil, which could be ascribed to the antioxidant action of the carotenoids and of the other antioxidant compounds extracted from dried tomato by-products.

The extraction of dry tomato by-products resulted in a significant increase ($p < 0.05$) of the radical scavenger activity as a result of the extraction of carotenoids and other antioxidant compounds. The antioxidant activity was linearly correlated with the carotenoid content of the oils (r = 0.992). DTB extraction determined a slight but significant ($p < 0.05$) increase in the acid value of the oils. This may be assigned to the hydrolysis of triglycerides as a result of the action of lipolytic enzymes originating from the tomato by-product.

The level of the CIELab parameters of the control and extracted oils are shown in Table 1. The extraction of dry tomato by-products significantly influenced the color values of the oils ($p < 0.05$). Redness (a* values) increased while lightness (L* values) and yellowness (b* values) decreased, changes that could be assigned to the extraction of carotenoids, especially the red lycopene, in the oil. A similar evolution of color parameters has been previously reported by Nour et al. [27] in different oils enriched with carotenoids from dried tomato waste. However, Corbu et al. [34] reported an increase in all color values, including b* values in the oils enriched with carotenoids extracted from by-products of sea buckthorn. The differences may be due to the predominance of the red lycopene in the carotenoid profile of tomato waste [24], as compared with sea buckthorn by-products whose carotenoid profile is dominated by the yellow zeaxanthin and the orange β-carotene pigments [35,36].

3.2. Physico-Chemical Properties of Mayonnaises

The pH value of mayonnaise is very important for its shelf life by reducing the risk from microorganisms, and for its structure by influencing the viscosity and elasticity of mayonnaise [4,37].

The pH of the control sample (3.6) was slightly higher than the recommended range of 3.0 to 3.5 [38] mainly due to the lack of acetic acid in the present mayonnaise recipe. Acetic acid is currently used to acidify and to ensure the microbiological control of mayonnaise [39], but it is usually missing from artisanal recipes. The use of carotenoid-enriched oil after extraction from tomato by-products in mayonnaise manufacture determined a slight increase in pH, while no significant influence on mayonnaise pH was found by the addition of basil essential oil.

The pH slightly increased during storage, remaining, however, between 3.5 and 4.0, which is still considered a safe pH range for mayonnaise [40]. Previously, Naznin et al. [41] reported a significant increase in the pH values after 30 days of storage both in the control and ajoene-added homemade mayonnaise, while Tavakoli et al. [42] found also that pH increased from the first day until the 60th of storage in low-fat mayonnaise without preservatives. However, other researchers found that pH values declined continuously in mayonnaise samples during the storage period [15].

Acid value provides information on the extent of lipid hydrolysis in the oil phase resulting in the formation of free fatty acids [15]. The results indicated that acid values continuously increased during 8 weeks of storage in all samples, but the control sample showed acid values significantly higher than other samples throughout the storage period. The increase in acid value could be attributed to the action of hydrolytic and oxidative enzymes and lactic acid bacteria from the aqueous phase of mayonnaise [43,44]. The addition of BHT or basil essential oil as well as the extraction of carotenoids from tomato by-products, reduced the growth of acid values probably as a result of the inhibition of oxidative processes. At the end of the storage period, the lowest acid values were found in MDSB5 and MDSB5B samples.

The evolution of peroxide values of mayonnaise samples during 8 weeks of storage is presented in Table 2. Peroxide value is used as a measure of the primary oxidation compounds (hydroperoxides) in lipid products. The results showed that the extraction of carotenoids from tomato by-products in oil retarded significantly the oxidation process.

Table 2. Effect of storage on pH, acid values, peroxide values, and TBARS values of mayonnaise samples.

Time (Weeks)	MC	MBHT	MDSB2.5	MDSB5	MDSB5B
			pH		
0	3.60 ± 0.02 ^{aA}	3.62 ± 0.03 ^{abA}	3.65 ± 0.02 ^{bA}	3.66 ± 0.03 ^{bA}	3.66 ± 0.02 ^{bA}
2	3.65 ± 0.03 ^{aAB}	3.68 ± 0.02 ^{aB}	3.66 ± 0.03 ^{aA}	3.67 ± 0.02 ^{aAB}	3.67 ± 0.02 ^{aA}
4	3.65 ± 0.03 ^{aAB}	3.73 ± 0.02 ^{bC}	3.66 ± 0.03 ^{aA}	3.67 ± 0.02 ^{aAB}	3.69 ± 0.02 ^{abA}
6	3.68 ± 0.03 ^{aBC}	3.78 ± 0.02 ^{bD}	3.66 ± 0.03 ^{aA}	3.69 ± 0.02 ^{aAB}	3.78 ± 0.02 ^{bB}
8	3.72 ± 0.03 ^{bC}	3.85 ± 0.02 ^{cE}	3.67 ± 0.03 ^{aA}	3.71 ± 0.02 ^{abB}	3.98 ± 0.02 ^{dC}
			Acid values (g/kg)		
0	0.90 ± 0.03 ^{c}	0.90 ± 0.03 ^{c}	0.84 ± 0.04 ^{b}	0.79 ± 0.03 ^{a}	0.87 ± 0.03 ^{b}
2	1.23 ± 0.04 ^{d}	1.01 ± 0.04 ^{b}	1.12 ± 0.04 ^{c}	1.01 ± 0.05 ^{b}	0.90 ± 0.03 ^{a}
4	1.68 ± 0.05 ^{e}	1.29 ± 0.04 ^{c}	1.40 ± 0.04 ^{d}	1.18 ± 0.05 ^{b}	1.27 ± 0.05 ^{a}
6	2.24 ± 0.11 ^{d}	1.74 ± 0.08 ^{bc}	1.85 ± 0.10 ^{c}	1.63 ± 0.09 ^{b}	1.46 ± 0.08 ^{a}
8	3.14 ± 0.16 ^{d}	2.47 ± 0.10 ^{bc}	2.64 ± 0.14 ^{c}	2.36 ± 0.14 ^{ab}	2.13 ± 0.12 ^{a}
			Peroxide values (meq/kg)		
0	2.20 ± 0.12 ^{dA}	1.80 ± 0.08 ^{cA}	1.20 ± 0.14 ^{bA}	0.60 ± 0.10 ^{aA}	0.60 ± 0.10 ^{aA}
2	2.50 ± 0.23 ^{cAB}	1.90 ± 0.17 ^{bA}	1.60 ± 0.21 ^{abB}	1.50 ± 0.24 ^{aB}	1.40 ± 0.24 ^{aB}
4	2.90 ± 0.32 ^{bBC}	1.90 ± 0.34 ^{aA}	2.00 ± 0.28 ^{aC}	1.90 ± 0.24 ^{aC}	1.90 ± 0.24 ^{aC}
6	3.20 ± 0.30 ^{bC}	2.00 ± 0.24 ^{aA}	2.90 ± 0.16 ^{bE}	2.10 ± 0.20 ^{aC}	2.30 ± 0.18 ^{aD}
8	3.00 ± 0.22 ^{bC}	2.00 ± 0.26 ^{aA}	2.40 ± 0.18 ^{aD}	2.00 ± 0.24 ^{aC}	2.10 ± 0.20 ^{aCD}
			TBARS values (mg/kg)		
0	0.22 ± 0.02 ^{abA}	0.20 ± 0.02 ^{abA}	0.24 ± 0.02 ^{bA}	0.18 ± 0.03 ^{aA}	0.18 ± 0.03 ^{aA}
2	0.33 ± 0.04 ^{dB}	0.26 ± 0.02 ^{abB}	0.32 ± 0.02 ^{cdB}	0.28 ± 0.02 ^{bcB}	0.22 ± 0.02 ^{aB}
4	0.57 ± 0.04 ^{dC}	0.34 ± 0.03 ^{abC}	0.45 ± 0.02 ^{cC}	0.37 ± 0.02 ^{bC}	0.32 ± 0.02 ^{aC}
6	0.96 ± 0.05 ^{dD}	0.63 ± 0.04 ^{abD}	0.75 ± 0.04 ^{cD}	0.69 ± 0.03 ^{bcD}	0.56 ± 0.03 ^{aD}
8	1.46 ± 0.08 ^{dE}	0.88 ± 0.05 ^{bE}	1.04 ± 0.04 ^{cE}	0.94 ± 0.04 ^{bE}	0.68 ± 0.03 ^{aE}

MC—control mayonnaise, MBHT—mayonnaise made with 1% BHT addition, MDTB2.5—mayonnaise made with sunflower oil macerated with 2.5% DTB, MDTB5—mayonnaise made with sunflower oil macerated with 5% DTB, MDSB5B–mayonnaise made with sunflower oil macerated with 5% DTB + 0.05% basil essential oil addition. Different lowercase letters indicate significant ($p < 0.05$) difference between different formulations, while different uppercase letters are indicative of the same between different sampling times. Data are expressed as mean ± standard deviation.

Peroxide values gradually increased in all mayonnaise samples during storage, reaching their highest values after 6 weeks, and decreased after that. This evolution could be due to the degradation of peroxides formed in the first stages of oxidation into secondary oxidation products [45]. At the end of the storage period, the highest peroxide value was found in the control samples, followed by the MDSB2.5 sample. Significantly lower peroxide values were found in BHT-added samples during the storage, as well as in MDSB5 and MDSB5B samples, with no significant differences ($p < 0.05$) between the peroxide values of these samples. In other words, the carotenoids extracted in oil from 5% tomato by-products lowered the peroxide value of mayonnaise compared to the control sample to an extent equivalent to the addition of 0.1% BHT. Other studies reported also an increase in the oxidation stability of mayonnaise as a result of the addition of natural plant extracts and powders, such as grape seed extract [46], purple maize extract [47], tartary buckwheat hull extract [31], or black glutinous rice extract [48]. In these studies, phenolics were the main compounds responsible for this behavior. In the present study, carotenoids are extracted in the oil from tomato by-products and reach the oily phase of the mayonnaise. Carotenoids are hydrophobic antioxidants that have the ability to quench various radical species [49] and are most likely responsible for increasing the oxidation stability of mayonnaise.

No significant differences ($p < 0.05$) were found between MDSB5 and MDSB5B samples in terms of peroxide values throughout storage, and, therefore, the basil essential oil did not influence the susceptibility to oxidation of the mayonnaise. However, other studies have reported on the effectiveness of some essential oils in delaying the increase in the peroxide index in mayonnaise [13,39].

The lipid oxidation of mayonnaise samples was estimated by the TBARS assay, and the results, expressed in mg MDA per kg sample, are presented in Table 2.

The TBARS values continuously increased in all samples during the storage period, and the storage time had a significant effect on mayonnaise oxidation, considering that TBARS values significantly increased ($p < 0.05$) from one time of sampling to another. However, a faster increase in the TBARS values was observed in the control samples as compared with the other samples. After 8 weeks of storage, TBARS values were significantly lower ($p < 0.05$) in the MDSB2.5 sample compared with the control samples. The level of secondary oxidation products, as determined by TBARS values, decreased significantly with increasing enrichment with carotenoids ($p < 0.05$) through extraction in oils from tomato by-products, while no significant differences were found between MDSB5 and MBHT regarding the TBARS values reached at the end of the storage period.

The strongest antioxidant effect was observed in the samples containing basil essential oil (MDSB5B), proving that the basil essential oil increased the resistance of mayonnaise against oxidation, mostly against the formation of secondary oxidation products. Similar protection effects of the essential oils against mayonnaise oxidation have been previously reported [13,39], and they have been attributed to the antioxidant activity of the terpenes and phenolic compounds contained by the essential oils.

3.3. Color of Mayonnaises

The enrichment with carotenoids extracted in oil from dried tomato by-products led to significant ($p < 0.05$) color changes in the mayonnaise, which was expected considering that after extraction the oils had an orange color with increasing intensity depending on the extracted amount of dried tomato by-products. At the time of production, the lightness of the mayonnaise (L* values) dropped significantly ($p < 0.05$) with the percentage of dried tomato by-products extracted in the oil, yellowness (b* values) increased, and a* values changed from the green (a* = -1.92) to the red domains (a* = 9.91 for MDTB2.5 and a* = 13.43 for MDTB5). These values of the color parameters may be attributed to the carotenoids extracted in the oils from dried tomato by-products. A significant lightness decrease and yellowness increase was also reported by Roman et al. [3] after the incorporation of encapsulated sea buckthorn extract in the composition of mayonnaise. However, they found a decrease in redness after the enrichment of mayonnaise with carotenoids from sea buckthorn. The increase in redness (a* value) after the extraction of dried tomato by-products may be due to the red lycopene, which is reported as the dominant pigment in tomato peel [50].

After processing, BHT addition determined the significant increase in L* and b* values as compared with the control, while a* values did not undergo significant changes. Higher a* and b* values were observed for the MDTB5B sample as compared with the similar sample without basil oil (MDTB5).

The yellow color of traditional mayonnaise originates from the egg yolk and may be further influenced by the oil and by the addition of other ingredients with coloring effects, such as mustard or spices [1]. The vegan mayonnaise made with soy milk as an emulsifier had, generally, a paler color than the traditional mayonnaise due to the lower carotenoid pigments content of the soy milk compared with the egg yolk. As a result, the increment of yellowness of the soy milk mayonnaise makes it look more like the traditional egg yolk mayonnaise, and this may increase the consumers' willingness to purchase or taste it.

L* and a* values were quite stable in the control mayonnaise during storage and only b* values decreased. The redness and yellowness (a* and b* values) significantly ($p < 0.05$) decreased during storage in the mayonnaise samples enriched with carotenoids, which was previously related to the isomerization and to the oxidative degradation of carotenoids [51]. On the contrary, a* values increased and the b* values remained relatively constant in the samples with BHT addition.

3.4. Sensory Evaluation

The results of the sensory evaluation of mayonnaise samples are presented in the spider plot shown in Figure 1.

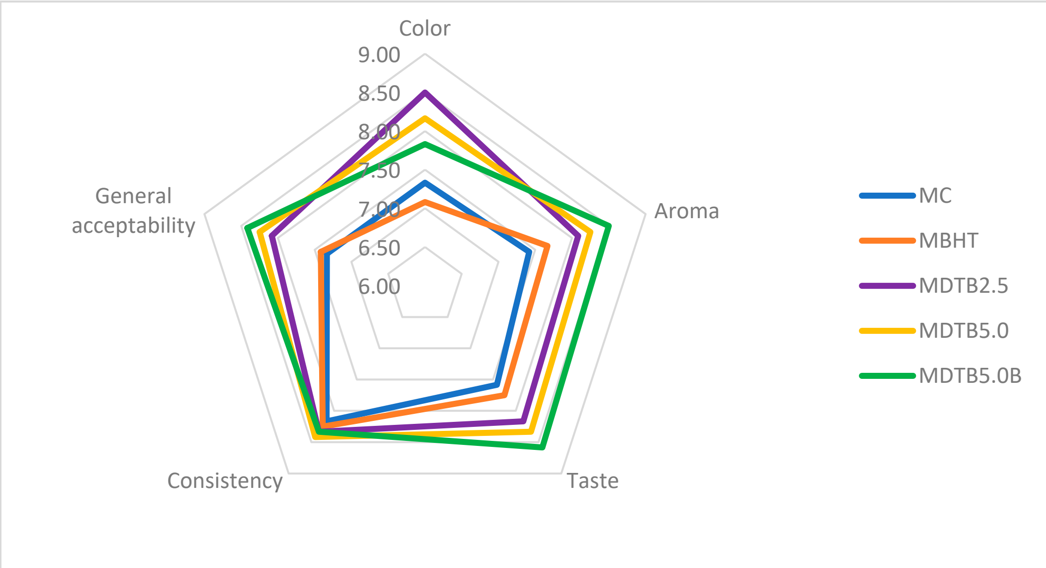

Figure 1. Sensory analysis of the mayonnaise samples. MC—control mayonnaise, MBHT—mayonnaise made with 1% BHT addition, MDTB2.5—mayonnaise made with sunflower oil macerated with 2.5% DTB, MDTB5—mayonnaise made with sunflower oil macerated with 5% DTB, MDSB5B—mayonnaise made with sunflower oil macerated with 5% DTB + 0.05% basil essential oil addition.

The mayonnaise made from oil enriched in carotenoids from tomato by-products had an orange-yellowish color, the more intense the higher the concentration of extracted by-product. The lack of egg yolk in vegan mayonnaise made from soy milk determines a whitish, pale color of the mayonnaise, and, therefore, the yellow-orange color obtained by the enrichment with carotenoids made it look like the classic mayonnaise from egg yolk and was appreciated by the panelists. Sample MSTB2.5 was best scored by the panelists in terms of color, as the color of samples MDSB5 and MDSB5B were considered to be too dark. The lightness values of the mayonnaise samples (Table 3) supported this result.

While no statistical difference ($p < 0.05$) was found in the consistency properties of the enriched mayonnaise samples comparative to the control sample, the aroma and the taste were significantly influenced by the enrichment. The enriched samples scored higher in aroma and taste with respect to the control due to the characteristic tomato flavor that was perceived in these mayonnaises. The tomato flavor is a result of the interaction of taste components and aromatic volatiles [52]. However, the best-rated sample was the one with the addition of basil essential oil, which was to be expected considering that basil aroma notes are widely used in Italian cuisine and are often paired with tomatoes [53].

The overall acceptability score values showed a preference of panelists for samples made with oil enriched in carotenoids extracted from dried tomato by-products compared to the control sample with significant differences ($p < 0.05$). In terms of overall acceptability, the panelists did not find significant differences ($p > 0.05$) between the enriched samples, although the sample supplemented with basil essential oil displayed the highest overall acceptability score from the panel.

Table 3. Effect of storage on color parameters of mayonnaise samples.

Time (Weeks)	MC	MBHT	MDSB2.5	MDSB5	MDSB5B
			L*		
0	93.39 ± 0.32 ^{cA}	94.29 ± 0.47 ^{dD}	86.42 ± 0.66 ^{bB}	84.84 ± 0.77 ^{aBC}	84.23 ± 0.87 ^{aC}
2	93.84 ± 0.75 ^{cA}	94.48 ± 0.44 ^{cD}	85.79 ± 0.52 ^{bB}	84.45 ± 0.63 ^{aAB}	84.47 ± 0.39 ^{aCD}
4	93.51 ± 0.40 ^{dA}	93.45 ± 0.20 ^{dC}	83.61 ± 0.82 ^{bA}	85.40 ± 0.42 ^{cC}	81.13 ± 0.66 ^{aA}
6	93.77 ± 0.51 ^{dA}	92.09 ± 0.49 ^{cB}	84.28 ± 0.47 ^{bA}	83.89 ± 0.47 ^{abA}	83.33 ± 0.48 ^{aB}
8	94.08 ± 0.66 ^{eA}	89.36 ± 0.74 ^{dA}	86.21 ± 0.72 ^{cB}	84.23 ± 0.67 ^{aAB}	85.21 ± 0.44 ^{bD}
			a*		
0	−1.92 ± 0.04 ^{aA}	−1.74 ± 0.10 ^{aA}	9.91 ± 0.41 ^{bC}	13.43 ± 0.54 ^{cC}	13.97 ± 0.45 ^{dC}
2	−1.89 ± 0.30 ^{aA}	−1.43 ± 0.10 ^{aB}	9.80 ± 0.53 ^{bC}	13.32 ± 0.25 ^{cC}	13.89 ± 0.65 ^{dC}
4	−1.76 ± 0.43 ^{aA}	−1.24 ± 0.40 ^{bBC}	9.58 ± 0.17 ^{cC}	13.11 ± 0.46 ^{dC}	13.69 ± 0.08 ^{eC}
6	−1.73 ± 0.17 ^{aA}	−1.19 ± 0.06 ^{bBC}	8.88 ± 0.35 ^{cB}	12.56 ± 0.21 ^{dB}	12.89 ± 0.16 ^{dB}
8	−1.70 ± 0.18 ^{aA}	−1.15 ± 0.11 ^{bC}	8.32 ± 0.28 ^{cA}	11.81 ± 0.45 ^{dA}	12.04 ± 0.19 ^{dA}
			b*		
0	9.46 ± 0.20 ^{aC}	10.00 ± 0.48 ^{bB}	29.70 ± 0.23 ^{cB}	39.68 ± 0.39 ^{dD}	40.75 ± 0.48 ^{eB}
2	9.01 ± 0.31 ^{aB}	9.65 ± 0.54 ^{aA}	29.09 ± 0.56 ^{bA}	38.85 ± 0.19 ^{cC}	39.81 ± 0.66 ^{dA}
4	8.80 ± 0.26 ^{aAB}	9.38 ± 0.12 ^{aA}	28.96 ± 0.70 ^{bA}	38.48 ± 0.33 ^{cC}	39.55 ± 0.57 ^{dA}
6	8.68 ± 0.22 ^{aAB}	9.23 ± 0.23 ^{bA}	28.88 ± 0.31 ^{cA}	37.73 ± 0.25 ^{dB}	39.69 ± 0.30 ^{eA}
8	8.56 ± 0.24 ^{aA}	9.18 ± 0.33 ^{bA}	29.06 ± 0.20 ^{cA}	35.80 ± 0.25 ^{dA}	39.63 ± 0.85 ^{eA}

MC—control mayonnaise, MBHT–mayonnaise made with 1% BHT addition, MDTB2.5—mayonnaise made with sunflower oil macerated with 2.5% DTB, MDTB5—mayonnaise made with sunflower oil macerated with 5% DTB, MDSB5B–mayonnaise made with sunflower oil macerated with 5% DTB + 0.05% basil essential oil addition. Different lowercase letters indicate significant ($p < 0.05$) difference between different formulations, while different uppercase letters are indicative of the same between different sampling times. Data are expressed as mean ± standard deviation.

4. Conclusions

The results have shown that the maceration of dried tomato by-products in sunflower oil determined a prominent enrichment of the oil in carotenoids accompanied by significant changes in the color parameters and by the increase in antioxidant activity of the oil. The sensory evaluation revealed that using the carotenoid-enriched oils in the mayonnaise manufacture improved the flavor and the chromatic characteristics of mayonnaise with respect to the control sample, without significantly affecting its consistency and overall acceptability.

A significant increase ($p < 0.05$) in oxidative stability during 8 weeks of storage was found in the mayonnaises enriched in carotenoids as compared with the controls. The addition of the basil essential oil at 0.05% level had notable favorable effects on the aroma and taste as well as on the oxidative stability of the mayonnaise made from oils macerated with dried tomato by-products.

Author Contributions: Conceptualization, V.N.; methodology, V.N.; software, V.N.; validation, V.N. and A.M.B.; formal analysis, A.M.B.; investigation, V.N. and A.M.B.; resources, V.N. and A.M.B.; data curation, V.N.; writing—original draft preparation, V.N. and A.M.B.; writing—review and editing, V.N.; visualization, V.N. and A.M.B.; supervision, V.N.; project administration, V.N.; funding acquisition, V.N. and A.M.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All of the data is contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Flamminii, F.; Di Mattia, C.D.; Sacchetti, G.; Neri, L.; Mastrocola, D.; Pittia, P. Physical and Sensory Properties of Mayonnaise Enriched with Encapsulated Olive Leaf Phenolic Extracts. *Foods* **2020**, *9*, 997. [CrossRef]
2. Mirzanajafi-Zanjani, M.; Yousefi, M.; Ehsani, A. Challenges and approaches for production of a healthy and functional mayonnaise sauce. *Food Sci. Nutr.* **2019**, *7*, 2471–2484. [CrossRef] [PubMed]
3. Roman, D.; Condurache (Lazăr), N.N.; Stănciuc, N.; Andronoiu, D.G.; Aprodu, I.; Enachi, E.; Barbu, V.; Bahrim, G.E.; Stanciu, S.; Râpeanu, G. Advanced Composites Based on Sea Buckthorn Carotenoids for Mayonnaise Enrichment. *Polymers* **2022**, *14*, 548. [CrossRef] [PubMed]
4. Muhialdin, B.J.; Ying, L.L.; Farouk, A.-E.; Meor Hussin, A.S. Valorisation of Virgin Coconut Oil Application in Mayonnaise Production as Functional Ingredient. *J. Food Nutr. Res.* **2019**, *7*, 65–70. [CrossRef]
5. Wang, W.; Hu, C.; Sun, H.; Zhao, J.; Xu, C.; Ma, Y.; Jiang, Z. Low-cholesterol-low-fat mayonnaise prepared from soybean oil body as a substitute for egg yolk: The effect of substitution ratio on physicochemical properties and sensory evaluation. *LWT-Food Sci. Technol.* **2022**, *167*, 113867. [CrossRef]
6. Raikos, V.; Hayes, H.; Ni, H. Aquafaba from commercially canned chickpeas as potential egg replacer for the development of vegan mayonnaise: Recipe optimisation and storage stability. *Int. J. Food Sci. Technol.* **2020**, *55*, 1935–1942. [CrossRef]
7. Raymundo, A.; Franco, J.M.; Empis, J.; Sousa, I. Optimization of the composition of low-fat oil-in-water emulsions stabilized by white lupin protein. *J. Am. Oil Chem. Soc.* **2002**, *79*, 783–790. [CrossRef]
8. Rahmati, K.; Mazaheri Tehrani, M.; Daneshvar, K. Soy milk as an emulsifier in mayonnaise: Physico-chemical, stability and sensory evaluation. *J. Food Sci. Technol.* **2014**, *51*, 3341–3347. [CrossRef]
9. Ghazaei, S.; Mizani, M.; Piravi-Vanak, Z.; Alimi, M. Particle size and cholesterol content of a mayonnaise formulated by OSA-modified potato starch. *Food Sci. Technol.* **2015**, *35*, 150–156. [CrossRef]
10. Fernandes, S.S.; Salas-Mellado, M.D.L.M. Development of mayonnaise with substitution of oil or egg yolk by the addition of chia (*Salvia hispanica* L.) mucilage. *J. Food Sci.* **2018**, *83*, 74–83. [CrossRef]
11. Rahbari, M.; Aalami, M.; Kashaninejad, M.; Maghsoudlou, Y.; Aghdaei, S.S.A. A mixture design approach to optimizing low cholesterol mayonnaise formulation prepared with wheat germ protein isolate. *J. Food Sci. Technol.* **2015**, *52*, 3383–3393. [CrossRef]
12. Nikzade, V.; Tehrani, M.M.; Saadatmand-Tarzjan, M. Optimization of Low-Cholesterol–Low-Fat Mayonnaise Formulation: Effect of Using Soy Milk and Some Stabilizer by a Mixture Design Approach. *Food Hydrocoll.* **2012**, *28*, 344–352. [CrossRef]
13. Ahmadi-Dastgerdi, A.; Ezzatpanah, H.; Asgary, S.; Dokhani, S.H.; Rahimi, E.; GholamiAhangaran, M. Oxidative stability of mayonnaise supplemented with essential oil of Achillea millefolium ssp millefolium during storage. *Food Sci. Technol.* **2019**, *13*, 34–42. [CrossRef]
14. Ozdemir, N.; Kantekin-Erdogan, M.N.; Tat, T.; Tekin, A. Effect of black cumin oil on the oxidative stability and sensory characteristics of mayonnaise. *J. Food Sci. Technol.* **2018**, *55*, 1562–1568. [CrossRef]
15. Kishk, Y.F.M.; Elsheshetawy, H.E. Effect of Ginger Powder on the Mayonnaise Oxidative Stability, Rheological Measurements, and Sensory Characteristics. *Ann. Agric. Sci.* **2013**, *58*, 213–220. [CrossRef]
16. Lourenço, S.C.; Moldão-Martins, M.; Alves, V.D. Antioxidants of Natural Plant Origins: From Sources to Food Industry Applications. *Molecules* **2019**, *24*, 4132. [CrossRef]
17. Ueda, J.M.; Pedrosa, M.C.; Heleno, S.A.; Carocho, M.; Ferreira, I.C.F.R.; Barros, L. Food Additives from Fruit and Vegetable By-Products and Bio-Residues: A Comprehensive Review Focused on Sustainability. *Sustainability* **2022**, *14*, 5212. [CrossRef]
18. Saeed, A.; Shabbir, A.; Khan, A. Stabilization of sunflower oil by using potato peel extract as a natural antioxidant. *Biomass Convers. Biorefin.* **2022**, 1–10. [CrossRef]
19. Kariminejad, M.; Naimabadi, A.; Morshedi, A.; Mohammadi-Moghaddam, T.; Shokuhi, A.; Bordbar, M. Oxidative stability of sunflower and soybean oils enriched with black plum peel extract in comparison with synthetic antioxidants. *PLoS ONE* **2023**, *18*, e0279735. [CrossRef]
20. Vági, E.; Simándi, B.; Vásárhelyiné, K.P.; Daood, H.; Kéry, Á.; Doleschall, F.; Nagy, B. Supercritical carbon dioxide extraction of carotenoids, tocopherols and sitosterols from industrial tomato by-products. *J. Supercrit. Fluids* **2007**, *40*, 218–226. [CrossRef]
21. Fiedor, J.; Burda, K. Potential role of carotenoids as antioxidants in human health and disease. *Nutrients* **2014**, *6*, 466–488. [CrossRef] [PubMed]
22. Edge, R.; Truscott, T.G. Singlet Oxygen and Free Radical Reactions of Retinoids and Carotenoids—A Review. *Antioxidants* **2018**, *7*, 5. [CrossRef] [PubMed]
23. Gharbi, S.; Renda, G.; La Barbera, L.; Amri, M.; Messina, C.M.; Santulli, A. Tunisian tomato by-products, as a potential source of natural bioactive compounds. *Nat. Prod. Res.* **2017**, *31*, 626–631. [CrossRef] [PubMed]
24. Nour, V.; Panaite, T.D.; Ropota, M.; Turcu, R.; Trandafir, I.; Corbu, A.R. Nutritional and bioactive compounds in dried tomato processing waste. *CyTA—J. Food* **2018**, *16*, 222–229. [CrossRef]

25. Madia, V.N.; De Vita, D.; Ialongo, D.; Tudino, V.; De Leo, A.; Scipione, L.; Di Santo, R.; Costi, R.; Messore, A. Recent Advances in Recovery of Lycopene from Tomato Waste: A Potent Antioxidant with Endless Benefits. *Molecules* **2021**, *26*, 4495. [CrossRef] [PubMed]
26. Benakmoum, A.; Abbeddou, S.; Ammouche, A.; Kefalas, P.; Gerasopoulos, D. Valorisation of low quality edible oil with tomato peel waste. *Food Chem.* **2008**, *110*, 684–690. [CrossRef]
27. Nour, V.; Corbu, A.R.; Rotaru, P.; Karageorgou, I.; Lalas, S. Effect of carotenoids, extracted from dry tomato waste, on the stability and characteristics of various vegetable oils. *Grasas Aceites* **2018**, *69*, e238. [CrossRef]
28. Szydłowska-Czerniak, A.; Trokowski, K.; Karlovits, G.; Szłyk, E. Effect of refining processes on antioxidant capacity, total contents of phenolics and carotenoids in palm oils. *Food Chem.* **2011**, *129*, 1187–1192. [CrossRef]
29. Re, R.; Pellegrini, N.; Proteggente, A.; Pannala, A.; Yang, M.; Rice-Evans, C. Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radic. Biol. Med.* **1999**, *26*, 1231–1237. [CrossRef]
30. AOAC International. *Official Methods of Analysis of AOAC International*, 17th ed.; AOAC International: Gaithersburg, MD, USA, 2000.
31. Park, B.I.; Kim, J.; Lee, K.; Lim, T.; Hwang, K.T. Flavonoids in Common and Tartary Buckwheat Hull Extracts and Antioxidant Activity of the Extracts against Lipids in Mayonnaise. *J. Food Sci. Technol.* **2019**, *56*, 2712–2720. [CrossRef]
32. Witte, V.C.; Krause, G.F.; Bailey, M.F. A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. *J. Food Sci.* **1970**, *35*, 582–585. [CrossRef]
33. Hassanein, M.M.; El-Shami, S.M.; El-Mallah, M.H. Changes occurring in vegetable oils composition due to microwave heating. *Grasas Aceites* **2003**, *54*, 343–349. [CrossRef]
34. Corbu, A.R.; Rotaru, A.; Nour, V. Edible vegetable oils enriched with carotenoids extracted from by-products of sea buckthorn (*Hippophae rhamnoides* ssp. *sinensis*): The investigation of some characteristic properties, oxidative stability and the effect on thermal behaviour. *J. Therm. Anal. Calorim.* **2020**, *142*, 735–747. [CrossRef]
35. Tudor, C.; Bohn, T.; Iddir, M.; Dulf, F.V.; Focșan, M.; Rugină, D.O.; Pintea, A. Sea Buckthorn Oil as a Valuable Source of Bioaccessible Xanthophylls. *Nutrients* **2020**, *12*, 76. [CrossRef]
36. Nour, V.; Panaite, T.D.; Corbu, A.R.; Ropota, M.; Turcu, R.P. Nutritional and bioactive compounds in dried sea-buckthorn pomace. *Erwerbs-Obstbau* **2021**, *63*, 91–98. [CrossRef]
37. Depree, J.A.; Savage, G.P. Physical and flavour stability of mayonnaise. *Trends Food Sci. Technol.* **2001**, *12*, 157–163. [CrossRef]
38. Herald, T.J.; Abugoush, M.; Aramouni, F. Physical and sensory properties of egg yolk and egg yolk substitutes in a model mayonnaise system. *J. Texture Stud.* **2009**, *40*, 692–709. [CrossRef]
39. Gomes, S.; Freitas-Silva, O.; Lima, J.P. Effect of oregano essential oil on oxidative stability of low- acid mayonnaise. *J. Pharm.* **2016**, *6*, 45–52.
40. Xiong, R.; Xie, G.; Edmondson, A. Modelling the pH of mayonnaise by the ratio of egg to vinegar. *Food Control* **2000**, *11*, 49–56. [CrossRef]
41. Naznin, M.T.; Maeda, T.; Morita, N. Stability of E and Z-ajoene in home-made mayonnaise. *Int. J. Food Prop.* **2010**, *13*, 317–327. [CrossRef]
42. Tavakoli, R.; Karami, M.; Bahramian, S.; Emamifar, A. Production of Low-fat mayonnaise without preservatives: Using the ultrasonic process and investigating of microbial and physicochemical properties of the resultant product. *Food Sci. Nutr.* **2021**, *9*, 2676–2685. [CrossRef] [PubMed]
43. Karas, R.; Skvarča, M.; Žlender, B. Sensory quality of standard and light mayonnaise during storage. *Food Technol. Biotechnol.* **2002**, *40*, 119–127.
44. Pradhananga, M.; Adhikari, B. Sensory and Quality Evaluation of Mayonnaise and Its Effect on Storage Stability. *Update Dent. Coll. J.* **2016**, *2*, 48–53. [CrossRef]
45. Ghorbani Gorji, S.; Smyth, H.E.; Sharma, M.; Fitzgerald, M. Lipid oxidation in mayonnaise and the role of natural antioxidants: A review. *Trends Food Sci. Technol.* **2016**, *56*, 88–102. [CrossRef]
46. Altunkaya, A.; Hedegaard, R.S.V.; Harholt, J.; Brimer, L.; Gökmen, V.; Skibsted, L.H. Oxidative Stability and Chemical Safety of Mayonnaise Enriched with Grape Seed Extract. *Food Funct.* **2013**, *4*, 1647–1653. [CrossRef]
47. Li, C.; Kim, H.-W.; Li, H.; Lee, D.-C.; Rhee, H. Antioxidative Effect of Purple Corn Extracts during Storage of Mayonnaise. *Food Chem.* **2014**, *152*, 592–596. [CrossRef]
48. Tananuwong, K.; Tewaruth, W. Extraction and application of antioxidants from black glutinous rice. *LWT-Food Sci. Technol.* **2010**, *43*, 476–481. [CrossRef]
49. Rodriguez-Amaya, D.B. Quantitative analysis, in vitro assessment of bioavailability and antioxidant activity of food carotenoids—A review. *J. Food Compos. Anal.* **2010**, *23*, 726–740. [CrossRef]
50. Rizk, E.M.; Bedier, S.H.; Elgendy, M.A. Utilization of carotenoid pigments extracted from tomato peel as natural antioxidants and colorants in sunflower oil and spaghetti. *Egypt. J. Agric. Res.* **2014**, *92*, 309–321. [CrossRef]
51. Khoo, H.E.; Prasad, K.N.; Kong, K.W.; Jiang, Y.; Ismail, A. Carotenoids and their isomers: Color pigments in fruits and vegetables. *Molecules* **2011**, *16*, 1710–1738. [CrossRef]

52. Yilmaz, E. The Chemistry of Fresh Tomato Flavor. *Turk. J. Agric. For.* **2001**, *25*, 149–155.
53. Ayala-Zavala, J.F.; González-Aguilar, G.A.; Del-Toro-Sánchez, L. Enhancing Safety and Aroma Appealing of Fresh-Cut Fruits and Vegetables Using the Antimicrobial and Aromatic Power of Essential Oils. *J. Food Sci.* **2009**, *74*, R84–R91. [CrossRef]