Probing the physicochemical impact of musk melon seed oil on mayonnaise

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Abstract

Owing to high consumption and industrial preparation of musk melon products, most of its byproducts are wasted without effective utilization. Musk melon agro-based waste material (seeds and peels) is an excellent source of antioxidants and phytochemicals. The purpose of this study was to improve the oxidative stability of mayonnaise by addition of musk melon seed oil. The study was conducted to check the physiocochemical effect of musk melon seed oil in mayonnaise. Proximate analysis of seeds (i.e. moisture, crude fat, crude fiber, crude protein, ash, and carbohydrate content) was performed. Oil was extracted by using the cold press extraction method, and this oil was tested for different physiocochemical analyses (i.e., saponification value, iodine number, specific gravity, 2,2-diphenyl-1-picrylhydrazyl [DPPH] value, viscosity, free fatty acid, and color). Physicochemical analysis was done during the storage period of 0, 20, 40, and 60 days, prior to performing sensory evaluation of mayonnaise. Data obtained from this analysis were further analyzed using statistical tools. A decreasing trend was observed for DPPH and peroxide values of mayonnaise with progression of days, thus showing that addition of musk melon seed oil decreased the production of free radicals. Hence, adding 40% musk melon seed oil showed the best result for overcoming the oxidation of mayonnaise and minimizing the production of free radicals. The data obtained from the statistical analysis indicated that the aroma and texture values of treatment T₅ were maximum, and the color and flavor of treatments T₄ and T₅ were high. The overall acceptability of treatment T₅ was high in which 40% of musk melon seed oil was used to combat the production of free radicals. In brief, waste material could be used for producing different types of products in the industry, rather than discarding the same, as it lessened the cost and provide a good quantity of nutrients.

Keywords: DPPH; mayonnaise; muskmelon seeds; oil; use of wastage
Introduction

Mayonnaise is an oil-in-water emulsion having extensive global consumption. It is the most preferably consumed and liked sauce and condiment globally. Nowadays, people, especially the young generation, have increased its consumption and want to add it to maximum food items. Mayonnaise, one of the oldest and most commonly used sauces globally, is a mixture of egg, oil, spices, and vinegar and used as a sandwich spread. Mayonnaise is a stable emulsion formed from approximately 65% vegetable oil and egg yolk (Singla et al., 2013).

The food industry has some major tasks to produce low-cholesterol and low-fat mayonnaise and salad dressings having characteristics similar to that of full-fat products. Well-organized monitoring of products to evaluate suitable quality requires awareness of their physicochemical characteristics, such as emulsion stability, rheology, appearance, charge distribution, particle size, and flavor. The use of low-cholesterol egg yolk and plant-based ingredients in the preparation of such products may prove to be beneficial in reducing cholesterol (Ma and Boye, 2013). Phyto compounds that are natural and newly biosynthesized have achieved important nutritional, safety, and health benefits, compared to chemically synthesized antioxidants. However, natural and newly biosynthesized phytochemicals are rarely available in the commercial market and are used customarily during food processing and in food business (Hussain et al., 2018).

Furthermore, the use of natural antioxidants and bioactive ingredients help to produce a functional healthy mayonnaise sauce (Mirzanajafi-Zanjani et al., 2019). The apparent interaction of fats with several diseases, such as high blood pressure, obesity, and cardiovascular diseases, has shown the tendency toward low-fat-containing products. Food processors face some major challenges in manufacturing novel food products, such as mayonnaise and salad dressings (Mozafari et al., 2017). Rheological properties, texture profile, flavor, and viscoscity analysis indicate that mayonnaise is a semi-solid emulsion made with starch if fat is reduced. Fat plays an important role in providing color, texture, and viscosity, but also causes several disorders and diseases in humans. The rheological properties indicate its hardness is 10 to 3 nm, firmness, and viscosity (Gaikwad et al., 2019).

Mayonnaise has a different stability that can be estimated from some macroscopic defects, such as syneresis, and can be formulated through different formulations as well as under appropriate processing conditions, such as vegetable oil temperature, egg yolk weight, and homogenizer speed. Protein coverage at the interface and oil droplet distribution are some initial parameters to evaluate the long-term stability of mayonnaise (Ariizumi et al., 2017).

Melon (Cucumis melo L.) has desirable attributes as a liable cash crop cultivated globally. Various groups of vine plants, such as C. melo, which had its origin in Iran and Pakistan, are mostly grown in hot climacteric conditions (Mansouri et al., 2017). Cucurbita belongs to the family Cucurbitaceae, which consists of about 110 genera and 650–850 species and is distributed mainly in equatorial and semitropical regions of the world. Worldwide, the production of melon is approximately 3.1 billion tons, with a cultivated area of 1.2 million hectares. The yield of melon is about 0.2 million hectares (Food and Agriculture Organization of United Nations [FAO], 2019). In Pakistan, the total cultivated area of melon is approximately 37,000 hectares and the total melon production is 0.5 million tons; in Sindh (Pakistan), the total melon production is 41,000 tons (Government of Pakistan [GOP], 2016). In Pakistan, mainly in the Sindh region, Dharidar and Golden varieties are cultivated.

Musk melon seeds have a high content of protein and carbohydrates as well as 30%–40% of oil content, depending upon the varieties and regions in which it is cultivated (Rashid et al., 2011). Seeds of musk melon are generally disposed of as agro-waste but can be utilized economically to extract muskmelon seed oil (Maran and Priya, 2015). Musk melon seeds have anti-oxidant, analgesic, anti-microbial, and anti-fertility properties (Mehra et al., 2015). The plant seed oil has a large number of natural antioxidants and components. The musk melon seeds are consumed directly or after processing as well as in roasted form (Mallek-Ayadi et al., 2018). The chemical composition and comprehensive study of lipids in musk melon seeds indicate that oil content ranged from 41.1% to 44.3%, protein from 34.2% to 39.8%, carbohydrates from 8.2% to 12.7%, crude fiber from 4.4% to 8.4%, soluble sugars from 3.8% to 4.3%, and minerals from 4.6% to 5.1%. The basic component of musk melon seeds is γ-tocopherol, which varies from 71.5% to 91.4% (Petkova and Antova, 2015). The seeds also have linoleic acid (denoted by L; 69.1%), followed by palmitic acid (denoted by P; 8.5%) and oleic acid (denoted by O; 16.4%). OLL (21.5%), POL (12.4%), PLL (15.9%), and LLL (24.8%) are the major triacylglycerols discovered in musk melon seeds. Crystallization and melting temperatures of musk melon seeds are -59°C and -5.12°C, respectively. Electronic nose analysis pointed out that more volatile compounds, along with a high amount of linolenic acid, are present in musk melon seed oil, compared to purified sunflower oil (Yanty et al., 2008).

The seed grains are used for dressing confectionary, cake, bread, custard, and snack foods, rather than pistachios and almonds. Musk melon seeds can be used as a substitute of soybeans for preparation of milk. These are also useful for removing freckles and tan. In recent years, the seed kernels have been used as the basis of several soups, custards, and stews, where they act as emulsifying,
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Proximate analysis of musk melon seeds

Proximate analysis of musk melon seeds, such as moisture, ash, fat, protein, and carbohydrates, was performed.

**Moisture**
The moisture content of musk melon seeds oil was determined using the methodology described by the American Association of Cereal Chemists (AACC; 2000).

\[
\text{Moisture} (\%) = \frac{\text{weight of original moisture of sample (g)} - \text{weight of dried sample (g)}}{\text{weight of the original sample (g)}} \times 100.
\]

**Ash**
The ash content of musk melon seeds was measured by using the methodology described by AACC (2000) and was calculated by the following formula:

\[
\text{Ash} (\%) = \frac{\text{weight of ash sample (g)}}{\text{weight of the sample (g)}} \times 100.
\]

**Crude Protein**
The crude protein content of musk melon seeds was determined by using the methodology described by AACC (2000):

\[
\text{Nitrogen} (%) = \frac{\text{Titer of } 0.1 \text{ N H}_2\text{SO}_4 \times \text{used} \times 0.0014 \times 250}{\text{Weight of the sample} \times \text{volume of the sample}} \times 100.
\]

\[
\text{Protein} (%) = \text{Nitrogen} (%) \times 6.25.
\]

**Crude Fat**
Fat content in musk melon seeds was determined by using the methodology described by AACC (2000). The weight of crude fat of musk melon seeds was determined by the following formula:

\[
\text{Crude fat} (\%) = \frac{\text{Weight of hexane extract / residue}}{\text{Weight of the sample}} \times 100.
\]

**Crude Fiber**
The fiber content of musk melon seeds was estimated by using the methodology described by AACC (2000). The fiber content was calculated using the following formula:

\[
\text{Crude fiber} (\%) = \frac{\text{Weight of the residue} - \text{weight after ashing}}{\text{Weight of the sample (g)}} \times 100.
\]

Hence, following were the objectives of the present study:

- To assess the physicochemical effect of musk melon seed oil.
- To check the oxidative stability of prepared mayonnaise.
- To check the consumer acceptability of mayonnaise (incorporated musk melon seed oil).

**Material and Methodology**

**Procurement of raw material**
Musk melon seeds were procured from a local market located in district Faisalabad, Pakistan. Raw material for mayonnaise preparation (eggs, vinegar, salt, sugar, and regular sunflower cooking oil) was also procured from the local market of Faisalabad. All other materials, such as reagents and chemicals, required for research work were purchased from Azeem Scientific Store, Faisalabad, Pakistan. The material required for packaging was also procured from the local market.

**Preparation of Sample**
First, the drying of musk melon seeds was performed in a hot air oven (GZX-9023MBE, Boxun, China). Second, impurities were removed, followed by the grinding of musk melon seeds by using a steel stainless grinder (SKU 131088839, Electronica, Germany). The seed powder was filled in a suitable glass jar.
Carbohydrates
The carbohydrate content of musk melon seeds was estimated by using the methodology described by AACC (2000) and calculated by the following formula:

\[ \text{Carbohydrates} \% = 100 - (\text{Moisture} \% + \text{ash} \% + \text{protein} \% + \text{fat} \%) \]

 Extraction of oil
The oil from the musk melon seeds was extracted by using the cold press extraction method. The extraction of oil depended upon the pressure directly applied on the seeds. Then, musk melon seed oil was filtered using filter paper to remove impurities.

Physicochemical analysis of musk melon seed oil
Saponification value
The saponification value of musk melon seed oil was determined using the methodology described by Association of Official Analytical Chemists (AOAC, 2006). The musk melon seed oil sample was taken and its impurities, such as scum, moisture, and trace elements, were removed using a filter paper. The oil was completely dried and weighed to have 2.0 g of oil sample. This oil sample was transferred into a 250-mL Erlenmeyer flask, and mixed slowly with 25-mL alcoholic potassium hydroxide (KOH) solution (Merck, India) using a pipette. Then, this sample was refluxed in a water bath for 30 min. The sample was shaken vigorously, followed by the addition of 2–3 drops of phenolphthalein indicator and treated with 0.5-N hydrochloric acid (HCL) (Merck, Germany) until the pink color changes into a clear solution; this clarity was achieved after 1 h of boiling. Blank determination was also done along with sample determination. The saponification value of musk melon seed oil was calculated using the following formula:

\[ \text{Saponification value (mg/g) = } \frac{56.1 \times (B - S)}{W} \times N \]

where:
- \( B \) = volume (mL) of typical hydrochloric acid (HCL) compulsory for blank.
- \( S \) = volume (mL) of average hydrochloric acid (HCL) essential for the sample.
- \( N \) = normality of the standard hydrochloric acid.
- \( W \) = weight (g) of oil sample taken for testing.

Free fatty acids
The measurement of free fatty acids present in musk melon seed oil was estimated according to the standard method described by American Oil Chemist’s Society (AOCS; 2006). About 10-mL musk melon seed oil was taken in a conical flask; then, 25 mL 95% ethanol was poured into it and mixed until the oil sample turned miscible in ethanol. Then 2–3 drops of phenolphthalein indicator were added and shaken vigorously, and 0.1-N NaOH (Merck, Germany) was used to titrate the mixture with constant stirring until pink color was achieved. The free fatty acid (FFA) value of musk melon seed oil was calculated by using the following formula:

\[ \text{FFA (\%) = } \frac{\text{Alkali used (mL)} \times N \times 28.2 + \text{weight of the sample (g)}}{\text{weight of the sample (g)}} \]

Peroxide value
The peroxide value of musk melon seed oil was calculated according to the standard method described by AOCS (2006). First, 5 mL of musk melon seed oil sample was taken in a 250-mL conical flask. Then, 30-mL 3:2 ratio acetic acid–chloroform (Catalog# 160-1; Ricca, Germany) solvent mixture was added and whirled for approximately 1 min until dissolved. After that, about 0–5 mL of standard potassium iodide solution was slowly pipetted using a Mohr pipette. This mixture was kept in a cool and dark place. After that, the sample solution was titrated against 0.1-N sodium thiosulphate (Na\(_2\)S\(_2\)O\(_3\)) solution. The solution was stirred continuously until yellow color was obtained. Subsequently, starch solution was used as an indicator, and constant shaking was done until blue color vanished. The peroxide value (PV) was calculated by the following formula:

\[ \text{PV (meq/kg) = } \frac{(B - S) \times N \times 1,000}{\text{Weight of oil (g)}} \times 100 \]

where:
- \( N \) = normality of Na\(_2\)S\(_2\)O\(_3\) solution.
- \( B \) = volume of Na\(_2\)S\(_2\)O\(_3\) used for blank.
- \( S \) = volume of Na\(_2\)S\(_2\)O\(_3\) used for sample.

Specific Gravity
The iodine number of musk melon seed oil was estimated according to the procedure described by AOAC (2006). First, dry pycnometer was filled with oil sample in such a manner that enmeshed the air bubbles when removed the cap of the side arm was. Then stopper was inserted and pycnometer was placed in a water bath for 30 min. The oil that came out of the opening of capillary tube was cautiously wiped off. The pycnometer was cleaned and dried and the cap was removed from the side arm after removing it from water bath. It was weighed with the sample; at the time of weighing, it was ensured that the temperature must be 30°C. The specific gravity of musk melon seed oil was computed by the following formula:

\[ \text{Specific gravity} = \frac{\text{Weight of oil sample (g)}}{\text{Weight of water (g)}} = \frac{C - A}{B - A} \]
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Seed oil was swirled with 5 mL of heptane and 250-µL sodium methoxide. The mixture was swirled until three layers were formed. The epical layer consisted of methyl esters and the second and third layers consisted of impurities and foam, respectively. The upper layer was collected in a vial with the help of a micro-syringe and used for Gas chromatography (GC) analysis.

Antioxidant activity
The antioxidant value was measured with 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging capacity estimation by the methodology described by Sun and Ho (2005). First, completely mix the 1 mL of methanol (MeOH) of DPPH with approximately 1 mL of musk melon seed oil sample. After mixing, the oil sample was allowed to stand in a dark place at an ambient temperature for almost 30 min. Absorbance of the solution was estimated against 517-nm blank reagent. The antioxidant value was calculated as the percentage of inhibition of DPPH radical.

Preparation of mayonnaise
Mayonnaise was prepared in laboratory with regular sunflower oil and musk melon seed oil blended in different concentrations as described in the treatment plan. A variety of blended mixtures of musk melon seed oil and sunflower oil were created for producing mayonnaise. The treatment plan is discussed in Table 1.

Product analysis during storage
The prepared mayonnaise samples were packed in plastic cups and stored at 25°C for investigation of quality

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Regular sunflower oil content (%)</th>
<th>Musk melon oil content (%)</th>
<th>Butylated hydroxy toluene (BHT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₀ (control)</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>T₁</td>
<td>99.99</td>
<td>–</td>
<td>0.01</td>
</tr>
<tr>
<td>T₂</td>
<td>90</td>
<td>10</td>
<td>–</td>
</tr>
<tr>
<td>T₃</td>
<td>80</td>
<td>20</td>
<td>–</td>
</tr>
<tr>
<td>T₄</td>
<td>70</td>
<td>30</td>
<td>–</td>
</tr>
<tr>
<td>T₅</td>
<td>60</td>
<td>40</td>
<td>–</td>
</tr>
</tbody>
</table>

T₀ = control.
T₁ = mayonnaise containing 0.01% BHT.
T₂ = mayonnaise containing 10% musk melon seed oil.
T₃ = mayonnaise containing 20% musk melon seed oil.
T₄ = mayonnaise containing 30% musk melon seed oil.
T₅ = mayonnaise containing 40% musk melon seed oil.

Iodine value
The iodine number of musk melon seed oil was estimated according to the procedure described by AOAC (2006). About 5 mL of oil sample was taken in an Erlenmeyer flask. About 25 mL of carbon tetrachloride (CCL₄) solution was added with continuous stirring, followed by the addition of Wij’s solution. All the contents were mixed thoroughly. The solution was allowed to stand for approximately 30 min in a dark place. The distillation was performed using 10% potassium iodide solution with 20 mL of distilled solution. The contents of the flask were titrated against 0.1-N Na₂S₂O₃ solution, and starch solution was used as an indicator. A blank reading was also conducted, and the given formula was used to calculate the iodine value of musk melon seed oil:

\[
\text{Iodine value} = \frac{(B-S) \times N \times 12.69}{\text{Weight of the sample}}
\]

where:
- B = volume of Na₂S₂O₃ solution used to run blank sample.
- N = volume of Na₂S₂O₃ solution consumed by the sample.
- S = normality of Na₂S₂O₃ solution.

Color
Color variations in musk melon seed oil were estimated with a colorimeter according to method described by Abdulkarim et al. (2005). To determine the color of musk melon seed oil, Lovibond tintometer was used having L’ a’ b’ color scales, and each scale elaborated different adjustments of red, green, and yellow colors consequently. The change in color or hue was noticed and the given formula was used to determine or adjust musk melon seed oil’s final color.

Viscosity
The viscosity of musk melon seed oil was analyzed according to the methods described by Lalas and Tsaknins (2002). The Brook-field DV111 digital model of rheometer was used at a constant temperature of 30°C LV₂ spindle at 10, 20, and 30 revolution per minute (rpm) respectively.

Fatty acid profile
Chromatography technique was used to determine the composition of fatty acids according to the method reported by Kaphueakngam et al. (2009). First, the fatty acid methyl esters (FAME) were prepared through the transesterification of oil. Then, 100 μL of musk melon seed oil was swirled with 5 mL of heptane and 250-µL sodium methoxide. The mixture was swirled until three layers were formed. The epical layer consisted of methyl esters and the second and third layers consisted of impurities and foam, respectively. The upper layer was collected in a vial with the help of a micro-syringe and used for Gas chromatography (GC) analysis.
characteristics and oxidation stability at 0, 20, 40, and 60 days of storage.

Oxidative stability tests

Peroxide value

Peroxide value was calculated by measuring iodine, formed from the reaction between hydrogen peroxide and iodine in the process described in AOCS (2006). The prepared 250-mL mayonnaise samples were taken in an Erlenmeyer flask. Then about 30 mL of mixture of glacial acetic acid and chloroform was added. The sample solution was titrated against 0.1-N Na$_2$S$_2$O$_3$ solution prepared by adding freshly prepared potassium iodide (KI) solution. The mixture was shaken continuously till the disappearance of yellow color. After that, 0.5 mL of starch solution, an indicator, was added to the mixture with continuous shaking until the disappearance of yellow color. A blank sample was also run separately and the peroxide value was calculated by the following formula:

\[
PV \text{ (meq/kg)} = \frac{(B - S) \times N \times 1,000}{\text{Weight of oil (g)}} \times 100
\]

where:
- \(N\) = normality of Na$_2$S$_2$O$_3$ solution.
- \(B\) = volume of the Na$_2$S$_2$O$_3$ used for blank sample.
- \(S\) = volume of Na$_2$S$_2$O$_3$ used for mixture sample.

\(p\)-Anisidine value

The standard method of IUPAC (1987) was followed for the estimation of \(p\)-anisidine value of mayonnaise. The test was conducted after some simple tasks, such as melting at 60–70°C temperature, filtering of samples using filter paper, then complete mixing of samples. The samples were homogenized, and 0.3 g of the same was taken in a volumetric flask of 25 mL capacity to 0.1 mg closest. Then iso-octane, about 5–10 mL, was taken and dissolved completely in the sample to make the final volume with the same solution. The measurement of test sample was done by calculating absorbance after applying 350-nm wavelength. For reference, iso-octane cells were filled as blank. After that, 5 mL of iso-octane was taken in a second test tube. Then anisidine reagent was added to the test tube using an automatic pipette. Wavelength of 350 nm was used to run the sample, and absorbance was estimated after 10 min in the sample cells of the first test tube and the result was taken as vacant in the suggestion cell for the second test tube.

Antioxidant potential test

DPPH radical scavenging assay

DPPH radical scavenging assay was conducted according to the procedure described by Sun and Ho (2005). Mayonnaise samples, 3 mL, were taken and diluted with methanol. Then these samples were mixed with DPPH (3 mL) in methanol \((2.0 \times 10^{-4})\) to obtain the final concentration of DPPH. All the samples were shaken vigorously before incubation performed for approximately 30 min. A wavelength of 517 nm was used to calculate the absorbance value of all the samples.

Sensory analysis

A hedonic scale having 9 points ranging from extreme liking (value of 9) to extreme disliking (value of 1) was used for sensory analysis of all mayonnaise samples (Meilgaard et al., 2007). The sensory parameters of mayonnaise samples evaluated were flavor, color, appearance, mouth feel, and overall acceptability for 0, 20, 40, and 60 days. The sensory evaluation laboratory of NIFSAT, University of Agriculture, Faisalabad, was used to conduct sensory analysis. A very comfortable environment with separate white fluorescent lights was available for panelists. The unsalted crackers and distilled water were also provided to neutralize the mouth feel when panelists were testing different mayonnaise samples. Samples were presented in random to PhD faculty members and scholars to prevent bias. Samples were scored according to the suitability of each characteristic.

Storage stability

The storage stability study was performed at different storage intervals. Mayonnaise samples were filled in separate plastic cups and stored at a temperature of approximately 25 ± 5°C for investigation of quality attributes and antioxidative stability at 0, 20, 40, and 60 days of time intervals.

Statistical analysis

Data were subjected to analysis to find the level of significance as described by Montgomery (2008). Statistical analysis was done to determine comparison between mean values and to find out the level of significance for each parameter.

Results and Discussion

The present study was designed to examine the physicochemical impact of musk melon seed oil on mayonnaise. The stability of oil keeps in view relevant to the antioxidant stability of artificial antioxidants in all tested samples of mayonnaise and it is crucial to replace artificial antioxidants with some secure natural antioxidants.
The observed results were organized, statistically investigated, and discussed below:

**Approximate analysis of musk melon seeds**

**Moisture test**

Moisture content (%) of musk melon seeds as shown in Table 2 was 3.23 ± 0.16%. Mehra et al. (2015) observed that the moisture content of musk melon seeds was 2.358%, and demonstrated that the moisture content of musk melon seeds was 3.5 ± 0.12%.

**Ash test**

Ash content (%) of musk melon seeds as shown in Table 2 was 4.86 ± 0.24%. Mehra et al. (2015) demonstrated that the ash content of musk melon seeds was 4.8%, and Amin et al. (2018) described the ash content of musk melon seed as 5.10 ± 0.05%.

**Crude protein test**

The content of protein in musk melon seeds was 31.37 ± 0.45%, as shown in Table 2. Mehra et al. (2015) demonstrated that the content of crude protein in musk melon seeds was 32.80%, and Amin et al. (2018) described that the crude protein content in these seeds was 30.0 ± 0.00%.

**Crude fat test**

The content of crude fat in musk melon seeds was 35.70 ± 0.63%, as shown in Table 2. Mehra et al. (2015) reported that the crude fat content of musk melon seeds was 37.167%, and Amin et al. (2018) investigated that the crude fat content in these seeds was 38.25 ± 0.31%.

**Crude fiber test**

The estimated crude fiber content in the selected sample was 6.67 ± 0.47%, as tabulated in Table 2. It was compared with 4.5 ± 0.1% of the dietary fiber present in musk melon seeds described by Petkova and Antova (2015), and according to Amin et al. (2018), the content of dietary fiber in musk melon seeds was 9.53 ± 0.47%.

**Carbohydrates**

Carbohydrates are starch and sugar that are mainly composed of carbon, hydrogen, and nitrogen and used as a source of energy. The estimated carbohydrate content of the sample was 24.40 ± 0.70%, as mentioned in Table 2. This value was compared with the carbohydrate content of 17.08 ± 0.03%, as described by Amin et al. (2018) and 8.2 to 12.7% described by Petkova and Antova (2015).

**Physicochemical analysis of musk melon seed oil**

**Saponification value**

The saponification value of oil is described as a measurement used to describe the functionality of oil, and is also used to compare molecular mass. Fundamentally, it is the amount of alkali KOH (mg/g) required to break free fatty acids to saponify eaters that are shown in definite amount of substances (1 g of fat or oil). The estimated value of musk melon seed oil was 138.58 ± 1.09 mg KOH/g (Table 3), compared with the saponification value of 131.95 ± 0.06 mg KOH/g. The estimated value of musk melon seed oil was also compared with 197.17 mg KOH/g saponification value described by Mehra et al. (2015).

**Free fatty acid value**

The free fatty acid content is defined as the degree of strength where glyceride compounds present in oil are impaired through the activity of lipase. Free fatty acids are responsible for purity as well as freshness of oil. The estimated free fatty acid value of musk melon seed oil was 0.33 ± 0.05% (Table 3). A low free fatty acid value indicates that musk melon seed oil has a good nutritional value. This value was also compared with 0.31% as estimated by Mallek-Ayadi et al. (2018) and 2.13 ± 0.02% as estimated by Shafi et al. (2019).

**Peroxide value**

The peroxide value (PV) is usually considered as the rancidity of oil caused by oxidation. It is defined as the content of peroxide oxygen present in 1 L of oil or fat. The estimated peroxide value of musk melon seed oil was 7.02 ± 0.49%, as mentioned in Table 2. This peroxide value was compared with the peroxide value described by Shafi et al. (2019).

**Specific gravity**

Specific gravity is used to estimate the purity of fats and oils. The specific gravity may also be considered as the ratio of the density of oil to the density of the reference compound (water). Specific gravity is always <1 and the normal value for fats and oils is 0.85–0.959 g/cm³. The estimated specific gravity in the study was 0.86 ± 0.04 g/cm³ (Table 3). This value was compared with the specific gravity value of 0.91 ± 0.00 g/cm³ described by Mallek-Ayadi et al. (2018).

**Table 2. Proximate analysis of musk melon seeds.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>3.23 ± 0.16</td>
</tr>
<tr>
<td>Ash</td>
<td>4.86 ± 0.24</td>
</tr>
<tr>
<td>Crude protein</td>
<td>31.37 ± 0.45</td>
</tr>
<tr>
<td>Crude fat</td>
<td>35.70 ± 0.63</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>6.67 ± 0.47</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>24.40 ± 0.70</td>
</tr>
</tbody>
</table>

N = 2; data are shown as mean value ± standard deviation (SD).
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Table 3. Physiochemical analysis of musk melon seed oil.

<table>
<thead>
<tr>
<th>Physiochemical analysis</th>
<th>Mean value ± standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saponification value (mg/KOH)</td>
<td>138.58 ± 1.09</td>
</tr>
<tr>
<td>Free fatty acids (%)</td>
<td>0.33 ± 0.05</td>
</tr>
<tr>
<td>Peroxide value (meq/kg)</td>
<td>7.02 ± 0.49</td>
</tr>
<tr>
<td>Specific gravity (kg/m³)</td>
<td>0.86 ± 0.04</td>
</tr>
<tr>
<td>Iodine value (gl₂/100 g)</td>
<td>135.85 ± 6.7</td>
</tr>
<tr>
<td>Color L'</td>
<td>47.90 ± 0.28</td>
</tr>
<tr>
<td>Color a'</td>
<td>-4.67 ± 0.12</td>
</tr>
<tr>
<td>Color b'</td>
<td>13.34 ± 0.60</td>
</tr>
<tr>
<td>Viscosity (MPa.s)</td>
<td>90.07 ± 0.57</td>
</tr>
<tr>
<td>DPPH</td>
<td>32.63 ± 0.93</td>
</tr>
</tbody>
</table>

N = 2; data are shown as mean value ± standard deviation (SD)

DPPH: 2,2-diphenyl-1-picrylhydrazyl.

Table 4. Free fatty acids profile of musk melon seed oil.

<table>
<thead>
<tr>
<th>Free fatty acids profile</th>
<th>Mean value ± standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myristic acid (C14:0)</td>
<td>0.24 ± 0.01</td>
</tr>
<tr>
<td>Palmitic acid (C16:0)</td>
<td>11.27 ± 0.50</td>
</tr>
<tr>
<td>Palmitoleic acid (C16:1)</td>
<td>1.73 ± 0.08</td>
</tr>
<tr>
<td>Stearic acid (C18:0)</td>
<td>5.67 ± 0.28</td>
</tr>
<tr>
<td>Oleic (C18:1)</td>
<td>14.63 ± 0.06</td>
</tr>
<tr>
<td>Linoleic (C18:2)</td>
<td>66.63 ± 0.72</td>
</tr>
<tr>
<td>Linolenic (C18:3)</td>
<td>0.25 ± 0.02</td>
</tr>
</tbody>
</table>

N = 2; data are shown as mean value ± standard deviation (SD).

Tsaknins (2002) and mentioned in Table 4. This value of viscosity was compared to 90.75 ± 0.25 MPa.s described by Mallek-Ayadi et al. (2018).

Fatty acids profile

A fatty acid is a carboxylic acid with a long aliphatic chain that could be unsaturated or saturated. The nutritional value of vegetable fats and oils can be estimated based on composition of fatty acids. The musk melon seed oil was infused into a chromatographic apparatus and the temperature was maintained at 220°C. The temperature of the broiler was maintained at 175°C and changed by an increment of about 3°C step by step up to a level of 220°C. The fatty acid results of musk melon seed oil sample are presented in Table 4, which demonstrates that the oil had major unsaturated fatty acids, such as oleic acid (C18:1) 14.63 ± 0.06%, linoleic acid (C18:2) 66.63 ± 0.72%, and linolenic acid (C18:3) 0.25 ± 0.02%.

Antioxidant activity

The antioxidant value is measured through DPPH radical scavenging capacity estimation by the methodology described by Sun and Ho (2005). DPPH is an organic compound of dark green color and found in crystalline powder form consisting of some stable molecules or free radicals. The DPPH value of musk melon seed oil was 32.63 ± 0.93% (Table 4). This value was compared to the DPPH value described by Mallek-Ayadi et al. (2018).

Preparation of mayonnaise samples

Salt, sugar, and white pepper were first mixed with egg and vinegar in an electric pan mixer at a liquefying velocity for 5 s. To begin with, the mixture of sunflower oil and musk melon seed oil in different proportions was added slowly to the system, and more rapidly after the mass began to thicken. Then, butylated hydroxy toluene (BHT) was added. All ingredients were mixed in a blender for 5 min. Mayonnaise samples were packed into clean glass.
bottles with screw caps and stored at room temperature (20°C ± 2°C). The samples were used on next day for organoleptic evaluation.

**Product analysis during storage study**

All samples of mayonnaise were packed in a plastic container and stored at a temperature of 25–28°C. The stored samples were used for antioxidative stability and all quality characteristics at time intervals of 0, 20, 40, and 60 days of storage.

**Oxidative stability test**

**Peroxide value**

The results showed that there was a significant interaction between all treatments. The interaction effect of days and treatments was significant. This study showed that the peroxide value was maximum for the control treatment. At the end of 60 days of storage time, the lowest peroxide value was observed for treatment T7 (Table 5). These results further showed that peroxide value could be reduced by increasing musk melon oil seed value. These findings were similar to the results of Zeb (2016), who studied the phenolic content and antioxidant activity of melon seeds and concluded that the seeds could be used as an excellent and natural antioxidant and for fortification of different food products. According to Landrault et al. (2001), all antioxidants remain effective for a specific time and lose their activity after specified period. Natural oxidants should be used to prevent loss of activity so that oxidation could be reduced in mayonnaise and other oil-containing products (Anwar et al., 2003).

**Para-anisidine VALUE (p-AV)**

Table 6 shows that slight increase in p-AV was observed up to 20 days of storage; then, a considerable increase in p-AV was recorded up to the end of the storage period (60 days). The highest value of p-AV was recorded for the control treatment. Treatment T5 showed the lowest p-AV value. A significant effect was observed for different treatments. The interaction effect of treatments and days was also significant. These findings showed that muskmelon seed oil contains high levels of phenolic compounds; these compounds have antioxidant effects and show anti-hydrolytic effects during storage. The phenolic and antioxidant activity of Cucumis melo var. cantalupensis showed that high antioxidant activity was in parallel with their higher phenolic contents. Hence, these results were similar to those of Ibrahim and El-Masry (2016). The finding results are in agreement with these findings (peanut skins) ethanol 80% extracts (200 ppm) showed the lowest increase in p-AV compared with other extracts and BHA at the same ratio (200 ppm) (Ismail et al., 2010). The resulting p-AV value was compared to seed butter oil obtained by using pumpkin seeds, sunflower seeds, and sesame seeds; a significant increase in the p-AV value of seed butter oil was observed due to temperature (Chien, 2015).

**Antioxidant potential test**

**DPPH radical scavenging assay**

The antioxidant potential of musk melon seed oil increases with increase in its concentration. Results in Table 7 demonstrate that there is significant interaction between all the treatments. The interaction effect of days and treatments is also significant. Treatment T5 showed a high antioxidant potential throughout the storage time of 60 days. These findings are similar to those of Ibrahim and El-Masry (2016), who studied the phenolic content and antioxidant activity of Cantaloupe (Cucumis melo var. cantalupensis). The results of DPPH test indicated that extract components could scavenge free radicals because they had a hydrogen-donating mechanism. They

---

**Table 5. Mean treatment for peroxide value of mayonnaise during 60 days of storage.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Storage (days)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>0</td>
<td>0.727 ± 0.045</td>
</tr>
<tr>
<td>T1</td>
<td>0</td>
<td>0.643 ± 0.047</td>
</tr>
<tr>
<td>T2</td>
<td>0</td>
<td>0.743 ± 0.025</td>
</tr>
<tr>
<td>T3</td>
<td>0</td>
<td>0.733 ± 0.045</td>
</tr>
<tr>
<td>T4</td>
<td>0</td>
<td>0.837 ± 0.020</td>
</tr>
<tr>
<td>T5</td>
<td>0</td>
<td>0.541 ± 0.031</td>
</tr>
<tr>
<td>Mean</td>
<td>0.8448</td>
<td>2.6452</td>
</tr>
</tbody>
</table>

T0 = control; T1 = mayonnaise containing 0.01% butylated hydroxy toluene (BHT); T2 = mayonnaise containing 10% musk melon seed oil; T3 = mayonnaise containing 20% musk melon seed oil; T4 = mayonnaise containing 30% musk melon seed oil; T5 = mayonnaise containing 40% musk melon seed oil; N = 2; data are shown as mean value ± standard deviation (SD).
could also stop the initiation of free radical-mediated chain reactions. Moreover, this also showed that due to extract scavenging ability, they could be used as therapeutic agents. The impact of antioxidants on DPPH radical scavenging is due to their hydrogen-donating ability and DPPH is a stable free radical and accepts an electron or hydrogen radical to become a stable molecule.

**Sensory analysis**

Hedonic scale with 9 points, ranging from extreme liking (point 9) to extreme dislike (point 1) was used for sensory analysis (Meilgaard et al., 2007).

**Aroma of mayonnaise**

The results are shown in Table 8. There was a significant interaction between different treatments and days. The results showed that on the first day of storage, all treatments had the best score, but with the passage of time, their aroma changed. Storage time had a negative effect on treatments. Treatment \( T_0 \) (control) had less score because there was no antioxidant and seed oil. Treatment \( T_5 \) showed the best result because it had 40% seed oil that acted as a natural antioxidant. The addition of seed oil changes aroma but not to a great level.

**Flavor of mayonnaise**

The results regarding flavor are shown in Table 9. On the first day of storage, all samples gave the best results for flavor, but with the passage of storage time, the flavor also tended to reduce. The reason was the production of some volatile compounds due to oxidation that occurred during storage. Treatment \( T_5 \) showed the best results after 60 days of storage because the oxidation was low, compared to other treatments. Treatment \( T_1 \) showed minimum result because there was a minimum addition of musk melon seed oil and antioxidants.

**Color of mayonnaise**

The results for color are shown in Table 10. There was significant interaction between all treatments. There...
Table 8. Mean of treatments for the aroma of mayonnaise during 60 days of storage.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Storage (days)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>T₀</td>
<td>7.1 ± 0.1</td>
<td>6.9 ± 0.1</td>
</tr>
<tr>
<td>T₁</td>
<td>7.4 ± 0.1</td>
<td>7.3 ± 0.1</td>
</tr>
<tr>
<td>T₂</td>
<td>7.6 ± 0.1</td>
<td>7.2 ± 0.1</td>
</tr>
<tr>
<td>T₃</td>
<td>7.7 ± 0.1</td>
<td>7.3 ± 0.1</td>
</tr>
<tr>
<td>T₄</td>
<td>7.8 ± 0.1</td>
<td>7.4 ± 0.1</td>
</tr>
<tr>
<td>T₅</td>
<td>7.9 ± 0.2</td>
<td>7.6 ± 0.1</td>
</tr>
<tr>
<td>Mean</td>
<td>9.10^a</td>
<td>8.74^b</td>
</tr>
</tbody>
</table>

T₀ = control; T₁ = mayonnaise containing 0.01% butylated hydroxy toluene (BHT); T₂ = mayonnaise containing 10% musk melon seed oil; T₃ = mayonnaise containing 20% musk melon seed oil; T₄ = mayonnaise containing 30% musk melon seed oil; T₅ = mayonnaise containing 40% musk melon seed oil; N = 2; data are shown as mean value ± standard deviation (SD).

Table 9. Mean of treatments for flavor of mayonnaise during 60 days of storage.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Storage (days)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>T₀</td>
<td>7.3 ± 0.1</td>
<td>7.1 ± 0.1</td>
</tr>
<tr>
<td>T₁</td>
<td>6.8 ± 0.1</td>
<td>6.7 ± 0.1</td>
</tr>
<tr>
<td>T₂</td>
<td>7.5 ± 0.3</td>
<td>6.9 ± 0.1</td>
</tr>
<tr>
<td>T₃</td>
<td>7.6 ± 0.2</td>
<td>7.2 ± 0.1</td>
</tr>
<tr>
<td>T₄</td>
<td>7.7 ± 0.1</td>
<td>7.6 ± 0.1</td>
</tr>
<tr>
<td>T₅</td>
<td>7.8 ± 0.1</td>
<td>7.7 ± 0.0</td>
</tr>
<tr>
<td>Mean</td>
<td>8.94^a</td>
<td>10.8^a</td>
</tr>
</tbody>
</table>

T₀ = control; T₁ = mayonnaise containing 0.01% butylated hydroxy toluene (BHT); T₂ = mayonnaise containing 10% musk melon seed oil; T₃ = mayonnaise containing 20% musk melon seed oil; T₄ = mayonnaise containing 30% musk melon seed oil; T₅ = mayonnaise containing 40% musk melon seed oil; N = 2; data are shown as mean value ± standard deviation (SD).

Table 10. Mean of treatments for the color of mayonnaise during 60 days of storage.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Storage (days)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>T₀</td>
<td>7.2 ± 0.1</td>
<td>6.9 ± 0.1</td>
</tr>
<tr>
<td>T₁</td>
<td>7.3 ± 0.1</td>
<td>7.0 ± 0.1</td>
</tr>
<tr>
<td>T₂</td>
<td>7.5 ± 0.1</td>
<td>7.2 ± 0.1</td>
</tr>
<tr>
<td>T₃</td>
<td>7.6 ± 0.1</td>
<td>7.3 ± 0.1</td>
</tr>
<tr>
<td>T₄</td>
<td>7.7 ± 0.1</td>
<td>7.3 ± 0.1</td>
</tr>
<tr>
<td>T₅</td>
<td>7.8 ± 0.1</td>
<td>7.4 ± 0.1</td>
</tr>
<tr>
<td>Mean</td>
<td>9.02^a</td>
<td>8.62^c</td>
</tr>
</tbody>
</table>

T₀ = control; T₁ = mayonnaise containing 0.01% butylated hydroxy toluene (BHT); T₂ = mayonnaise containing 10% musk melon seed oil; T₃ = mayonnaise containing 20% musk melon seed oil; T₄ = mayonnaise containing 30% musk melon seed oil; T₅ = mayonnaise containing 40% musk melon seed oil; N = 2; data are shown as mean value ± standard deviation (SD).
was a noticeable effect of storage on the color and appearance of mayonnaise. The color of mayonnaise tended to become descend with time. The control treatment showed the lowest score because there was no addition of musk melon seed oil and antioxidants. Treatments T\(_4\) and T\(_5\) showed the best results for color and appearance, compared to other treatments because the increased concentration of musk melon seed oil had a negative impact on the color and appearance of mayonnaise.

**Texture of mayonnaise**

Texture is also considered one of the most important features to check the quality of any food product. The results for texture are shown in Table 11. There was a significant interaction between treatments and day of storage. The results showed that on the first day of storage, all treatments had the best score, but with time, their texture changed. Storage time had a negative effect on treatments. Treatment T\(_0\) (control) had minus score because there was no antioxidant and seed oil. Treatments T\(_4\) and T\(_5\) showed the best result because they had 40% seed oil that acted as a natural antioxidant. The addition of seed oil changes the texture but not to a greater level.

**Overall acceptability**

The results for overall acceptability are shown in Table 12. There was a significant interaction between all treatments. The interaction effect of treatments and storage days was also significant. After 60 days of storage, treatment T\(_0\) (control) with no seed oil and BHT showed the maximum value for overall acceptability, while the treatment with 60% saponification (SOF) and 40% musk melon seed oil showed the highest value. These findings also demonstrated that storage time had a negative effect on product quality. This was because the antioxidant activity decreased with time; therefore, after a long storage period, the noticeable effect of storage on the color and appearance of mayonnaise.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Storage (days)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>T(_0)</td>
<td>6.9 ± 0.1</td>
<td>6.7 ± 0.1</td>
</tr>
<tr>
<td>T(_1)</td>
<td>6.8 ± 0.1</td>
<td>6.4 ± 0.1</td>
</tr>
<tr>
<td>T(_2)</td>
<td>7.3 ± 0.1</td>
<td>7.2 ± 0.1</td>
</tr>
<tr>
<td>T(_3)</td>
<td>7.4 ± 0.1</td>
<td>7.3 ± 0.1</td>
</tr>
<tr>
<td>T(_4)</td>
<td>7.5 ± 0.1</td>
<td>7.4 ± 0.1</td>
</tr>
<tr>
<td>T(_5)</td>
<td>8.1 ± 0.1</td>
<td>7.2 ± 0.1</td>
</tr>
<tr>
<td>Mean</td>
<td>8.8^a</td>
<td>8.4^b</td>
</tr>
</tbody>
</table>

T\(_0\) = control; T\(_1\) = mayonnaise containing 0.01% butylated hydroxy toluene (BHT); T\(_2\) = mayonnaise containing 10% musk melon seed oil; T\(_3\) = mayonnaise containing 20% musk melon seed oil; T\(_4\) = mayonnaise containing 30% musk melon seed oil; T\(_5\) = mayonnaise containing 40% musk melon seed oil; N = 2; data are shown as mean value ± standard deviation (SD).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Storage (days)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>T(_0)</td>
<td>8.1 ± 0.2</td>
<td>8.0 ± 0.1</td>
</tr>
<tr>
<td>T(_1)</td>
<td>6.4 ± 0.4</td>
<td>6.5 ± 0.2</td>
</tr>
<tr>
<td>T(_2)</td>
<td>7.5 ± 0.1</td>
<td>7.4 ± 0.1</td>
</tr>
<tr>
<td>T(_3)</td>
<td>7.6 ± 0.2</td>
<td>7.4 ± 0.1</td>
</tr>
<tr>
<td>T(_4)</td>
<td>8.0 ± 0.1</td>
<td>7.8 ± 0.1</td>
</tr>
<tr>
<td>T(_5)</td>
<td>8.3 ± 0.1</td>
<td>8.4 ± 0.1</td>
</tr>
<tr>
<td>Mean</td>
<td>9.18^v</td>
<td>9.10^w</td>
</tr>
</tbody>
</table>

T\(_0\) = control; T\(_1\) = mayonnaise containing 0.01% butylated hydroxy toluene (BHT); T\(_2\) = mayonnaise containing 10% musk melon seed oil; T\(_3\) = mayonnaise containing 20% musk melon seed oil; T\(_4\) = mayonnaise containing 30% musk melon seed oil; T\(_5\) = mayonnaise containing 40% musk melon seed oil; N = 2; data are shown as mean value ± standard deviation (SD).
period, oxidation started and minimized the quality and overall acceptability of the product. The overall acceptability changed due to changes in taste, color, appearance, and flavor. Extract of musk melon seeds added in mayonnaise showed considerable lowering of oxidation. Hence, the natural antioxidant plays an important role in controlling the oxidation process (Altunkaya et al., 2013).

Conclusions

By comparing the effect of these antioxidants on the shelf life of the mayonnaise enhanced sensory quality and with 10, 20, 30, and 40% musk melon seed oil were stored at 25°C temperature for 10, 20, 40, and 60 days and evaluated by using different activity test viz. Results indicated that seed oil was more significant for antioxidant and antimicrobial activities, and lower the rate of free radicals, compared to the control synthetic sample. This recommends that musk melon seed oil must be used in a variety of economical food products, rather than discarded it as a waste. This would significantly lower the waste, with positive effects on economy of the country. This would also result in improved shelf life of food commodities and good health of consumers.

Availability of Data and Materials

Data can be provided on demand.

Conflict of Interest

The authors declared no conflict of interest and gave their consent for publishing of the article.

Author Contributions

Conceptualization (Zahra Nishat); Data curation (Syyada Sana Mahmood); Formal analysis and Methodology (Zahra Nishat); Project Administration (Muhammad Yousaf Quddoos, Kashif Ameer, Isam A. Mohamed Ahmed, Moneera O. Aljobair); Journal Format Setting and Uploading to Journal (Muhammad Yousaf Quddoos and Ayesha Rafique); Resources (Shanza Mukhtar, Kashif Ameer, Isam A. Mohamed Ahmed, Moneera O. Aljobair); Software (Muhammad Siddique Raza, Aymen Shahzad); Supervision (Muhammad Yousaf Quddoos, Shahid Mahmood, Kashif Ameer); Validation (Kashif Ameer, Isam A. Mohamed Ahmed, Moneera O. Aljobair); Visualization (Bushra Umar Hayat, Neelum Shahzadi); Writing original draft (Zahra Nishat); Review & editing (Kashif Ameer, Muhammad Yousaf Quddoos).

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