Effect of Using Raw and Treated Quinoa Seeds (Chenopodium Quinoa) in the Diets on Oxidation Indicators of Broiler Carcass

Noufal H.J. Alsafi¹*, Bushra S.R. Zangana²

Abstract

The experiment aimed to study the use of different proportions of raw and treated Chenopodium quinoa seeds by soaking in the diet to identify the effect on the oxidation indicators of the meat stored for 2, 4, and 6 weeks. In the experiment, 336 sexed broilers (Ross308) were used at the age of one day, with an average initial weight of 39 g/chick. The chicks were fed on a starter diet (1-14 days) and the finisher diet including the initial grower diet (15-28 days) and second grower diet (29-42 days). Chicks were randomly distributed to seven treatments (8 males + 8 females/replicate), while the raw quinoa seeds were added at 0, 0.5, 1, and 1.5% for treatments T₁, T₂, T₃, and T₄, and the treated by soaked in water for 48 hours for treatments T₅, T₆ and T₇ % feed, respectively. The results showed a significant decrease (P<0.05) in the values of Thiobarbituric Acid (TBA), Peroxide Value (PV), and Free Fatty Acids (FFA) for the meat of all treatments using raw and treated quinoa seeds compared to the control treatment and for all storage periods of 2, 4 and 6 weeks. The current study results showed that all concentrations of raw and treated quinoa seeds contributed to reducing the exposure of meat to rancidity and preserving it from oxidation during different storage periods. Besides, enhancing the possibility of storing it for long periods.

Key Words: Quinoa Seeds, Raw, Treatment, Oxidation Indicators, Broiler Carcass.

Introduction

Studies interested in the poultry industry have found alternatives to the rejected industrial antioxidant because of its negative effects on consumer health. In addition to meeting their demand for meat products with special qualities and functions that enhance their health. Furthermore, preserve the quality of meat from fat oxidation and damage that it is exposed to during storage operations due to its high content of polyunsaturated fatty acids and low content of natural antioxidants (Aziza et al., 2010). Because the presence of these natural antioxidants will protect biological cells from oxidative reactions due to reactive oxygen species, which delays or prevents the oxidation of other substances by inhibiting the initiation of oxidative chain reactions (Velasco and Williams, 2011). For these reasons research has recently increased interest in the use of broad-range natural antioxidants derived from medicinal plants in broiler diets to prevent fat oxidation in meat and its products (Avila-Ramos et al., 2013). Therefore, oxidative stress is a major factor for concern in broilers, which negatively affected the body tissues, leading to their damage and destruction, which is due to the lack of balance between the production and disposal of free radicals. However, it can be reduced by adding antioxidants to the diet of broilers, either individually or in combination that works on excluding and inhibiting

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them and thus mitigating the negative effects caused by those pathogens (Panda and Cherian, 2014). Generally, natural antioxidants contain many biologically active compounds with potential and health benefits that have proven effective compared to industrial antioxidants (Surface et al., 2014). Chenopodium quinoa wild seeds are a traditional food with medicinal and functional properties with high efficacy and antioxidant activity (Nowak et al., 2016). They are starchy seeds belonging to the family Chenopodiaceae of the genus Chenopodium is of interest to poultry diets, as they are a food source rich in vitamins, and minerals. Besides, fatty compounds rich in unsaturated fatty acids are represented by omega-6 linoleic acid, omega-9 oleic acid, omega-3 linolenic acid, and active biological materials such as phytosterols, squalene, and polyphenols (Vilacundo and Hernandez-Ledesma, 2017; Pereira et al., 2019). Thus, it has a high antioxidant activity, especially associated with phenolic compounds (Contreras-Jiménez et al., 2019; Repo-Carrasco-Valencia, 2020). The anti-oxidant activity of quinoa seeds is also related to its content of vitamin E and the phenolic compounds it contains, which worked synergistically to capture free radicals, reduce their work, and get rid of their harmful products. These vital components also contributed to possessing a wide range of these necessary elements with the possibility of using them in the field of manufacturing food, health products, and pharmaceutical treatments, as well as other uses due to their most important and necessary antioxidant activity (Pour销售hi et al., 2021). Therefore, quinoa seeds are considered a meal that protects animals from oxidative stress, raises their antioxidant capacity and inhibits lipid peroxidation in plasma and different body tissues (Navruz-Varli and Sanlier, 2016). Moreover (Shokry 2016) showed that quinoa flour added by 15% to beef burgers will inhibit fat oxidation in both fresh and cooked Burger during freezing storage for 7 days. (Hes et al., 2017) also noted a significant decrease in peroxide values when adding ground buckwheat seeds to minced beef balls stored in freezing. This antioxidant activity is due to the ability of phenolic and flavonoid compounds that are distinguished to search for free radicals and give them electrons or hydrogen atoms and thus inhibit or prevent the oxidation of fats and this is one of their functional properties (Rajani et al., 2011). However, (Easssawy et al., 2016) indicated a significant decrease in TBA values for meat each of the chest and thigh of broiler that eats a diet with quinoa seed extract at a level of 30 g/kg feed and stored in refrigerated for different periods (1, 4, and 7 days) compared to the additional treatment of 10g/kg and the control (T1). Similarly, (Ozer and Secen, 2018) added quinoa seed powder in four percentages (3, 5, 7, and 10%) to beef during frozen storage for different periods (1, 7, 15, 30, 60, 90 days). They were observed a significant decrease in TBA values for fresh and cooked meat compared to the control group and for all storage periods. On the other hand, (Fernandez-Lopez et al., 2020) showed that adding black quinoa seeds to Burker beef by 2.5% and storing them by freezing for different periods (0, 7, 14, 21 days) led to a significant decrease in TBA values for all stored days compared with the addition of fiber to Burker by 2.5% and control. The effect of starch (quinoa and corn) and quinoa seeds was also studied by (Park et al., 2021) which they added to minced chicken meatballs subjected to five cycles of freezing and thawing that was frozen at -18°C for seven days and then thawed for one day at 4°C. This study was resulted in decreasing TBA values and increased antioxidant activity in favor of treatments of chicken meatballs supplemented with ground quinoa seeds 10 g or ground quinoa seeds 10 g + 2.5 g quinoa starch / 100 g meat compared to other treatments. It was also noted that the POV values decreased when adding 10 g of ground quinoa seeds / 100 g to chicken meatballs compared to the other addition treatments including corn starch 2.5 g, quinoa starch 2.5 g, ground quinoa seeds 10 g + 2.5 g maize starch.

**Materials and Methods of Work**

- **Preparation of Quinoa Seeds and Treatments**

The white raw quinoa seeds were obtained from the local markets and from one source, which it was clean and free of impurities, as a quantity was taken from the raw seeds and soaked in water for 48 hours to remove the saponins responsible for the bitter taste. This is the most widely used method as recommended by (Choque-Quispe et al., 2021). Subsequently, dried at natural air temperature and chemical analysis of raw seeds and treated by soaking was conducted in the laboratories of the Ministry of Science and Technology - Department of Environment and Water - Department of Food Chemistry according to (AOAC, 1995) as shown in Table 1.
After that, it was added to the diets from the first day of chick life until the end of the experiment at the age of 42 days, as 100 kg of feed was prepared for each treatment and the seeds were added to a small amount of the prepared feed to ensure homogeneity. Then, this quantity was mixed with a larger amount, and so on until got 100 kg of homogeneous feed from the seeds. The treatments were as follows: (T1): Control treatment of standard diet free of any addition, (T2) adding 0.5% raw quinoa seeds to the standard diet, (T3) adding 1% raw quinoa seeds to the standard diet, (T4) adding 1.5% raw quinoa seeds to the standard diet. Likewise, (T5) added 0.5% quinoa seeds treated with soaking for 48 hours to the standard diet, (T6) added 1% quinoa seeds treated with soaking for 48 hours to the standard diet, (T7) added 1.5% quinoa seeds treated by soaking for 48 hours to the standard diet.

**Chick Management and Feeding**

This experiment was conducted in the poultry field of the College of Agricultural Engineering Sciences - the University of Baghdad for the period from 28-11-2020 to 9-1-2021 (42 days). It was aimed to study the use of different percentages of raw and treated quinoa seeds in the diet and their impact on Oxidation Indicators. The 336 sexed broilers (Ross308) were distributed randomly at one day old, with an average initial weight of 39 g/chick, distributed over seven treatments, with 48 chicks/treatment. Each treatment included three replicates, 16 chicks/replicate (8 males and 8 females), the chicks were raised from one day old until 42 days in a ground raising hall divided into two pins, the dimensions of one pin were 2 x 2 m². Gas incubators were used to heat the hall and obtain the required temperature, as it was 34°C during the first week of life, then it was gradually reduced with the use of a ventilation fan, at a rate of two degrees per week until reaching 24°C at the age of marketing. The relative humidity of the hall was 60-65% using the continuous lighting program, and then chicks are freely fed Ad libitum and crushed feed during the experiment period, noting that water was provided freely. The birds were fed on the starter diet from the age of one day to 14 days, the initial grower diet from the age of 15 days to 28 days, and the final grower diet from the age of 29 to 42 days, according to the breeding guide for broilers Ross308. They contained protein and energy ratios as in Tables (2), (3), and (4) which shows the percentages of the feed materials included in the composition of the diets with the chemical composition calculated for them. Then, 6 birds from each treatment were randomly taken, slaughtered, and scalded at a temperature of 54°C for two minutes. The feathers were removed, and the internal entrails were removed in an accurate anatomical manner according to the method of (Fletcher 1999), then the carcasses were cut into the main pieces (chest and thigh) as mentioned by (Al-Fayadh et al., 2011). Then the physical separation was carried out and the meat, skin, and bone were removed for the main pieces only, which included each of the chest and thigh separately. Afterward, the meat only consisting of the breast and thigh piece was taken and cut into small cubes for each treatment separately and kept in polyethylene bags at a temperature of -18°C for a period of 2, 4, and 6 weeks. Thus, the peroxide value (POV), the percentage of (Free Fatty Acid) FFA, and the number of thiobarbituric acids (TBA) were estimated based on (Zangana and Al-Safy 2017) method. The value of peroxide was estimated by weighting 2 g of fat extracted from meat using the saxolites device, and 30 ml of a mixture containing 3 parts of glacial acetic acid + 2 parts of chloroform was added to it with the addition of 0.5 ml of saturated potassium iodide.
Plus, 30 ml of distilled water, and 1 ml of starch index 1% concentration (prepared from adding 1 g of starch to 10 ml of boiled distilled water), and after dissolving the starch in it, the volume is supplemented in a volumetric flask to become 100 ml. Then the mixture is titrated with a 0.01 N sodium thiosulfate solution until the blue color disappears, and it is estimated based on the following equation:

$$POV (\text{meq}) = \frac{\text{number of millimeters of sodium thiosulfate} \times 0.01}{\text{Model Weight (g)}} \times 100$$

The oxidation of fats in meat samples was estimated by the determination of thiobarbituric acid (TBA), as 1 g of meat is homogenized with 25 ml of a cold solution containing 20% of Trichloroacetic acid (TCA) dissolved in phosphoric acid (concentration 85%, specific density 1.685, molecular weight 98), with a concentration of 2 M, in the homogenizer at a speed of 13800 rpm for 2 minutes. The mixture was transferred to a volumetric flask with a capacity of 50 ml and the volume was completed to the mark with distilled water. The mixture was shaken and 25 ml of the homogenized mixture was taken from it and centrifuged at a speed (30000 rpm) for 30 minutes, then the mixture was filtered through filter paper No. 1. In the same role, a 5 ml of the filtrate was transferred to a test tube and 5 ml of TBA reagent solution was added to it (concentration 0.005 M) molecular weight: 144.15 dissolved in distilled water. The control solution (Blank) was prepared by mixing all the contents except for the sample to be measured, then the contents were mixed and placed in test tubes, closed tightly, and kept in a sterile place for 15-16 hours at room temperature, or heating the contents of the tubes in a water bath for 30 minutes until the prepared mixture turned to light pink.

### Table 2. Components and chemical composition (%) of starter diet (1-14 days)

<table>
<thead>
<tr>
<th>Components</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
</tr>
<tr>
<td>yellow corn</td>
<td>45.5</td>
</tr>
<tr>
<td>wheat</td>
<td>10</td>
</tr>
<tr>
<td>Soybean meal (48% crude protein)</td>
<td>34</td>
</tr>
<tr>
<td>protein concentrate*</td>
<td>5</td>
</tr>
<tr>
<td>quinoa seeds**</td>
<td>-</td>
</tr>
<tr>
<td>oil</td>
<td>3</td>
</tr>
<tr>
<td>Di Calcium Phosphit***</td>
<td>0.7</td>
</tr>
<tr>
<td>limestone</td>
<td>1.2</td>
</tr>
<tr>
<td>salt</td>
<td>0.1</td>
</tr>
<tr>
<td>methionine</td>
<td>0.25</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.25</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Calculated chemical composition ****

<table>
<thead>
<tr>
<th>Represented energy (kilocalories/kg)</th>
<th>3041.20</th>
<th>3043.18</th>
<th>3049.71</th>
<th>3051.64</th>
<th>3043.21</th>
<th>3049.76</th>
<th>3023.52</th>
</tr>
</thead>
<tbody>
<tr>
<td>crude protein</td>
<td>23.34</td>
<td>23.37</td>
<td>23.42</td>
<td>23.33</td>
<td>23.37</td>
<td>23.21</td>
<td>23.29</td>
</tr>
<tr>
<td>crude fat</td>
<td>5.57</td>
<td>5.58</td>
<td>5.61</td>
<td>5.62</td>
<td>5.58</td>
<td>5.61</td>
<td>5.15</td>
</tr>
<tr>
<td>crude fiber</td>
<td>2.74</td>
<td>2.80</td>
<td>2.86</td>
<td>2.92</td>
<td>2.80</td>
<td>2.86</td>
<td>2.94</td>
</tr>
<tr>
<td>methionine + cysteine</td>
<td>1.14</td>
<td>1.14</td>
<td>1.14</td>
<td>1.15</td>
<td>1.14</td>
<td>1.14</td>
<td>1.15</td>
</tr>
<tr>
<td>lysine</td>
<td>1.54</td>
<td>1.54</td>
<td>1.53</td>
<td>1.53</td>
<td>1.54</td>
<td>1.53</td>
<td>1.53</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
</tr>
<tr>
<td>available Phosphorus</td>
<td>0.48</td>
<td>0.48</td>
<td>0.48</td>
<td>0.48</td>
<td>0.48</td>
<td>0.48</td>
<td>0.48</td>
</tr>
</tbody>
</table>

* The protein concentrate produced by the Dutch company Wafi, which contains 40% of crude protein and 2107 kcal of metabolic energy / kg of feed, 5% crude fat, 2.81% crude fiber, 5% calcium, 3.7% methionine, 4.12% methionine + cysteine, 3.85% lysine and 4.68% available phosphorous, 0.42% tryptophan, 1.70% threonine, 2.50% sodium and chloride 3.80%.

** Raw Quinoa seeds, metabolic energy 3746 kcal /kg, 14.7% crude protein, 6.2% crude fat, 14.9% crude fiber, soaked quinoa seeds, metabolic energy 3751 kcal /kg, 15% crude protein, and 6.9% raw fat and 15.4% raw fibres.

*** Phosphorous 18%, Calcium 24%.

**** The chemical composition of the diet components as mentioned by the NRC (1994).
The absorbance of the resulting color A was measured at a wavelength of 530 nm using a spectrophotometer. The value of TBA was calculated by multiplying the absorbance value by a factor of 5.2. The value of TBA was expressed on the basis of mg Malone Dialdehyde (MDA) per kg of meat according to the following equation:

\[(TBA) \text{ Value } \frac{\text{mg MDA}}{\text{kg meat}} = 5.2 \times A_{530}\]

The free fatty acids (FFA) were estimated by cold process fat extraction from meat, where 10 g of the extracted fat was taken and added in a 250 ml flask. Then, a mixture of 25 ml ether, 25 ml ethanol at a concentration of 95% neutral, and 1 ml of phenolphthalein reagent (1%) was added to it and treated with a solution Sodium hydroxide (concentration 0.1N) with continuous shaking until the solution becomes pink. The percentage of free fatty acids was calculated as oleic acid by applying the following equation:

\[\text{FFA (\%) as oleic acid} = \frac{\text{mL of NaOH (0.1N)} \times 0.0282}{\text{lipid sample weight (g)}} \times 100\]

Table 3. Components and chemical composition (%) of the grower diet (15-28 days)

<table>
<thead>
<tr>
<th>Components</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
<th>T7</th>
</tr>
</thead>
<tbody>
<tr>
<td>yellow corn</td>
<td>51.5</td>
<td>51</td>
<td>50.5</td>
<td>50</td>
<td>51</td>
<td>51</td>
<td>50.5</td>
</tr>
<tr>
<td>wheat</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Soybean meal (48% crude protein)</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>27.5</td>
<td>27.5</td>
</tr>
<tr>
<td>protein concentrate*</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>quinoa seeds**</td>
<td>-</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>oil</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Di Calcium Phosphit***</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>limestone</td>
<td>1.14</td>
<td>1.14</td>
<td>1.14</td>
<td>1.14</td>
<td>1.14</td>
<td>1.14</td>
<td>1.14</td>
</tr>
<tr>
<td>salt</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>methionine</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

** The protein concentrate produced by the Dutch company Wafi, which contains 40% of crude protein and 2107 kcal of metabolic energy / kg of feed, 5% crude fat, 2.81% crude fiber, 5% calcium, 3.7% methionine, 4.12% methionine + cysteine, 3.85% lysine and 4.68% available phosphorous, 0.42% tryptophan, 1.70% threonine, 2.50% sodium and chloride 3.88%.

** Raw Quinoa seeds, metabolic energy 3746 kcal /kg, 14.7% crude protein, 6.2% crude fat, 14.9% crude fiber, soaked quinoa seeds, metabolic energy 3751 kcal /kg, 15% crude protein, and 6.9% raw fat and 15.4% raw fibres.

*** Phosphorous 18%, Calcium 24%.

**** The chemical composition of the diet components as mentioned by the NRC (1994).
Results

- Peroxide Values

It was observed from Figure (1) the effect of using different levels of raw and treated quinoa seeds with the diet on the values of peroxide of broiler meat for the periods of 2, 4, and 6 weeks of storage at a temperature of -18°C. The results showed that at the 2-week storage period, there was a significant decrease (P<0.05) in the peroxide value in favor of treatment T7 compared to the control treatment T1, and treatments T2, T3, and T5 whose values were 0.64 compared to 1.41, 1.01, 0.82 and 0.98 meq/kg, respectively. The superior treatment in the significant decline was similar to the two addition treatments T4 and T6, whose values were recorded 0.66 and 0.82 meq/kg, and in turn, the two treatments did not achieve a significant difference compared to the two treatments T3 and T. Although the addition treatments T4, T6, T3, and T5 achieved a significant decrease (P<0.05) compared to the treatments T1 and T2 on one hand, and on the other hand, the addition treatment T2 achieved a significant decrease (P<0.05) compared to treatment T1 in the peroxide value at 2-week storage. At the storage period of 4 and 6 weeks, it can be observed that the peroxide value decreased significantly (P<0.05) in favor of the addition treatments T4 and T7 compared to the control treatment T1 and addition treatments T2 and T5 for the two periods. Besides, the significant differences between the means of the studied traits.

The data was analyzed using the complete random design (CRD), and Duncan’s new multiple range tests (Duncan, 1955) were conducted to compare the significant differences between the means of the studied traits. The statistical program SAS (2010) was used to analyze the data, by adopting the following mathematical model:

\[ Y_{ij} = \mu + T_i + e_{ij} \]

### Table 4. Components and chemical composition (%) of the finisher diet (29-42 days)

<table>
<thead>
<tr>
<th>Components</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
</tr>
<tr>
<td>yellow corn</td>
<td>55</td>
</tr>
<tr>
<td>wheat</td>
<td>10</td>
</tr>
<tr>
<td>Soybean meal (48% crude protein)</td>
<td>24</td>
</tr>
<tr>
<td>protein concentrate*</td>
<td>5</td>
</tr>
<tr>
<td>quinoa seeds**</td>
<td>-</td>
</tr>
<tr>
<td>Di Calcium Phosphit***</td>
<td>0.4</td>
</tr>
<tr>
<td>limestone</td>
<td>0.1</td>
</tr>
<tr>
<td>methionine</td>
<td>0.13</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.13</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

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**** The chemical composition of the diet components as mentioned by the NRC (1994).
the values of duration of the fourth week were 0.83 and 0.81 compared to 1.55, 1.13, and 1.21 meq/kg fat respectively, and the values of duration of the sixth week were 1.04 and 1.01 compared to 1.78, 1.34, and 1.44 meq/kg fat respectively. It was noted that these two treatments achieved the highest significant decrease was matched in the effect by the addition treatments T₃ and T₆ for both periods, where the values of the fourth week recorded 0.98 and 0.97, and the values of the sixth week recorded 1.20 and 1.19 meq/kg fat, respectively.

![POV Graph](image.png)

**Figure 1.** Effect of using raw and treated Chenopodium quinoa seeds with the diet on estimating the oxidation indicators of broiler carcasses fat for peroxide values (PV) during 2, 4, and 6 weeks of storage

* Different letters within the same color mean that there are significant differences between the average treatments at the level of probability (P<0.05).

* Treatments:- T₁: Control treatment without any addition, T₂ using 0.5% raw quinoa seeds, T₃ using 1% raw quinoa seeds, T₄ using 1.5% raw quinoa seeds, T₅ using 0.5% treated quinoa seeds, T₆ using 1% treated quinoa seeds, T₇ using 1.5% treated quinoa seeds.

Finally, it was noted that the addition treatments T₃ and T₆ achieved a significant decrease (P<0.05) compared to treatment T₅ for both periods. In turn, these treatments T₃, T₆, and T₅ did not differ significantly with the addition treatment T₂ although all the last addition treatments achieved a significant decrease (P<0.05) compared to the control treatment T₁ for the two periods in peroxide values.

**Thiobarbituric Acid Values (TBA)**

Figure (2) shows the results of using different levels of raw and treated quinoa seeds with the diet in estimating the values of TBA of broiler meat carcass fat for 2, 4, and 6 weeks of storage at -18°C. It was observed from the same figure that there was a significant decrease (P<0.05) in the value of that trait for the two periods of storage for 2 and 6 weeks in favor of treatment T₇ compared to the control treatment T₁ and the addition treatments T₂, T₃, T₅ and T₆. Since, the storage period of 2 weeks has recorded a value of 0.43 compared to 1.03, 0.85, 0.68, 0.73, and 0.64 mg MDA/kg fat, and at the storage period of 6 weeks, the values were 0.83 compared to 1.62, 1.35, 1.11, 1.21 and 1.09 mg MDA/kg fat, respectively. The addition treatment T₇ was similar in the significant effect for both periods to the treatment T₄ whose values in the period 2 weeks were recorded 0.54 and in the 6 weeks recorded 0.95 mg MDA/kg fat compared to the control treatment T₁ for each of the periods.
Figure 2. Effect of using raw and treated Chenopodium quinoa seeds with the diet on estimating the oxidation indicators of broiler carcass fat for thiobarbituric acid (TBA) values for 2, 4, and 6 weeks of storage

* Different letters within the same color mean that there are significant differences between the average treatments at the level of probability (P<0.05).

Treatments:
- T1: Control treatment without any addition
- T2: Using 0.5% raw quinoa seeds
- T3: Using 1% raw quinoa seeds
- T4: Using 1.5% raw quinoa seeds
- T5: Using 0.5% treated quinoa seeds
- T6: Using 1% treated quinoa seeds
- T7: Using 1.5% treated quinoa seeds.

Whereas, the addition treatment T4 decreased significantly (P<0.05) for both periods compared to addition treatment T2. Also, T5 did not differ significantly with treatments T3 and T6, although the treatment T6 achieved a significant decrease (P<0.05) compared to T2 on the one hand and did not differ with T3 and T5 on the other hand in TBA values for the same two storage periods, however, at the fourth week, it can notice the continuation of the highest decrease in the values of TBA in favor of the addition treatment T7 compared to the control treatment T1 and the addition treatments T2, T3, T5 and T6 whose values were 0.62 mg MDA /kg fat compared to 1.34, 1.10, 0.88, 0.92 and 0.86 mg MDA /kg fat, respectively. Furthermore, it was noted that this treatment, which achieved the highest significant decrease, was similar in effect to treatment T4, which differed significantly from the addition treatments T3, T5 and T6. Besides that, all the last treatments achieved a significant decrease compared to treatment T1 and T2, except for the treatment T5, which had the same effect as treatment T2 although the latter achieved a significant decrease compared to treatment T1.

Free Fatty Acid Values (FFA)

Figure (3) showed the results of using different levels of raw and treated quinoa seeds with the diet in estimating the values of free fatty acids (FFA) for broiler meat carcass fat and periods of 2, 4, and 6 weeks of storage at a temperature of -18 °C. It was found that there was a significant decrease (P<0.05) in the concentration values of free fatty acids FFA at the periods of 2 and 6 weeks of storage in favor of the addition treatment T7, which reached the highest significant decrease (P<0.05). In comparison with the control treatment T1 and the addition treatments T2, T3, and T5, as the values of the storage period in the second week were 0.24% compared to 0.63 and 0.47, 0.35 and 0.36%, respectively, and the values of the storage period in the sixth week were 0.46%, compared to 1.04, 0.73, 0.59 and 0.60%. It was observed that this superior treatment was similar in effect to the addition treatment T4, whose values at storage for the second and sixth weeks, respectively were recorded 0.27 and 0.52%. It was also found that the last treatment was similar in effect to the addition treatments T3, T5, and T6 that were similar to each other, and in turn, all of these treatments had a significant decrease (P<0.05) when compared to the treatments T1 and T2, however, the last treatment had a significant decrease (P<0.05) compared to the control treatment T1 in FFA values for periods of 2 and 6 weeks of storage. At the 4-week storage period, it can notice a decrease in the values of FFA in favor of the addition treatment T7.
This treatment reached the highest significant decrease (P<0.05) compared to the control treatment T1 and addition treatments T2, T3, and T5 whose values were recorded 0.35% compared to 0.83, 0.60, 0.47, and 0.48%, respectively. Plus, the addition treatment T7 was similar in effect to the addition treatments T4 and T6 which recorded values of 0.40 and 0.38%, respectively. These two treatments achieved a significant decrease (P<0.05) when compared to the control treatment T1 and the treatment T2, although they were significantly similar to the treatment T3 on the one hand and they were similar to T4, T6, and T5 on the other hand. In turn, the addition treatment T3 achieved a significant decrease compared to the control treatment T1 in the values of FFA from the same storage period.

* Different letters within the same color mean that there are significant differences between the average treatments at the level of probability (P<0.05).
* Treatments: T1 Control treatment without any addition, T2 using 0.5% raw quinoa seeds, T3 using 1% raw quinoa seeds, T4 using 1.5% raw quinoa seeds, T5 using 0.5% treated quinoa seeds, T6 using 1% treated quinoa seeds, T7 using 1.5% treated quinoa seeds.

**Discussion**

This study showed that the oxidation indicators (PV, TBA, FFA) for the carcass’s meat stored at freezing at a temperature of -18°C for different periods decreased significantly. The reason for this is attributed to the role of quinoa seeds, which contributed to preventing deterioration of the meat stored for different periods by inhibiting the processes that help to oxidize it due to the positive role that contributed to protecting it from decomposition. Also, preventing the occurrence of rancidity of fats and fatty acids and the appearance of unpleasant odors while increasing the preservation of the meat quality from oxidative damage in different storage conditions. These seeds have a strong activity and natural antioxidant properties by terminating the initiation reactions and processes that help the proliferation of oxidative chains (Pasko et al., 2009; Tang and Tsao, 2017). It is also evident that there was a more decrease in the values of oxidation indicators in the meat samples of the treatment birds that used the treated quinoa seeds, and this is due to the increase in the overall antioxidant activities of the quinoa seeds in the water-treated samples due to the germination process (Nickel et al., 2016; Choque-Quispe et al., 2021). However, the increase in antioxidant activity is due to the response of the
seeds to the physiological and biochemical changes that the seeds are exposed to at the beginning of germination. Therefore, germination is used as a strategy to increase this ability and the phenolic content of these compounds and there was an increase in the total phenols in quinoa seeds as well as an increase in the content of quinoa seeds of ascorbic acid and total tocopherols. compared to raw quinoa seeds (Carcióchí et al., 2016; Torres et al., 2018; Pinuel et al., 2019). It was observed from Table (1) for the current study the high phenolic compounds in quinoa seeds treated with soaking, which indicates that the phenol content is a good indicator of the antioxidant activity. Accordingly, there is a high positive relationship, whenever the phenolic compounds increased, the antioxidants of the seeds increase. For this reason, quinoa seeds worked with their ability and their compounds to protect the physiological system in the body and protect prevention from the negative effects resulting from oxidative damage that causes damage to cells (Yael et al., 2012). This effect is one of the important factors in the poultry industry because it reduces fat oxidation, improves the quality of meat products, and increases the nutritional value of meat. As well as, extending its storage life through interaction with fatty radicals and hydroxyl and converting them into stable compounds (Wu et al., 2012). These findings are attributed to its higher content of highly effective phenolic and flavonoid compounds than other seeds (Vidueiros et al., 2015). Because the phenolic compounds of quinoa seeds are characterized by their natural properties, they work to protect the biomolecules (proteins, nucleic acids, unsaturated fatty acids, and sugars) from oxidative damage caused by reactions of free radicals. Their inhibition or suppression or delay of oxidation and disposal factors and their removal or reducing the ability to produce hydrogen peroxide and lipid peroxide. In addition to harmful HO-hydroxy radical by increasing the activity of hepatic enzymes that inhibit oxidation processes such as (GPX), (CAT) and (SOD). Thus, it will reduce the concentrations of Malone Dialdehyde (Heleno et al., 2015) because the presence of free radicals in the physiological system in large quantities will enhance its combination with hydroxyl radicals. Forming active fatty radicals, which in turn interact with oxygen to form peroxyl fats radicals (LOO*), which activate chains of lipid Peroxidation (LOOH*) (Chaijan and Panpipit, 2017). (Hassan et al., 2019) have previously shown that the active compounds in quinoa seeds have a high ability to increase the activity and effectiveness of antioxidant enzymes such as peroxidase (PX), catalase (CAT), ascorbate peroxidase (APX), superoxidase (SOD). Besides, glutathione peroxidase (GPX) and their role in maintaining and providing protection of muscle cells and tissues in animal tissues from the formation of free radicals in lipid membranes through their elimination and capture. The basic status of phenolic compounds in their antioxidant effect is related to their reducing properties by breaking down chains resulting from oxidation reactions. Likewise, the high ability to donate hydrogen or electron to free radicals or fatty acids, made these compounds radical scavengers or their association with metals through their chelating activities for metals, especially for iron and copper. Thus, it inhibits mineral-stimulated free radical formation (Vuolo et al., 2019). Donating hydrogen atoms or electrons will work to cancel the position of the unpaired electron within the phenolic ring, which is the main mechanism for protecting biological molecules from oxidation (Jin et al., 2020). The decrease in the values of oxidation indicators in meat may be due to the presence of vitamins possessed by quinoa seeds, where the most important of which are E and C, which have antioxidant properties. Generally, the presence of fat-soluble vitamin E and a group of carotenoids combined with the most important beta-carotene synergistic with vitamin E protects all fatty acids in these seeds well and is not exposed to oxidation factors (Tang et al., 2015b). Vitamine E is one of the very powerful antioxidants in biological systems as it is useful in resisting the harmful effect of oxidative stress (Sezgin and Sanlier, 2019) whose content in seed oil ranges about 1.69-17.69 mg/kg (Tang et al., 2015a). These synergistic compounds, which have antioxidant properties, played an important role in their work by interacting with unsaturated fatty acyl groups and providing high strength by breaking and smashing the generated chains, stabilizing cell membranes and maintaining their integrity, and forming coatings that prevent the oxidation of fatty acids in the phospholipids of cell membranes and preserve them from the harmful effects formed by lipid peroxides and oxidative damage caused by free radicals by releasing different types of reactive oxygen (Tang et al., 2016b). Vitamin C is also highly soluble in water and extracellular fluids, and with its nourishing and antioxidant properties on the other hand. It works to maintain cell membranes from
the effect of free radicals (Reactive oxygen species) ROS. Restricting and removing them that form during the aqueous phase before the process of its initiation or enabling it to control the attack and oxidation of lipids and fatty acids due to its ability to donate electrons (Padayatty et al., 2003; Khaligh et al., 2018) where this vitamin content in seeds is about 4.0-16.4 mg/100 g (Navruz-Varli and Sanlie, 2016). These vitamins had an effective effect in combating free radicals and preventing their formation or reducing their activity through their synergistic action with each other in creating a strength to counteract oxidative processes (Vidueiros et al., 2015; Pirgozliev et al., 2019). As well as, the role of the long-chain polyunsaturated fatty acids possessed by quinoa seeds, the most important of which is linoleic acid, which is called omega-6 fatty acid, and alpha-linolenic acid, which is called omega-3 fatty acid. In addition to monounsaturated fatty acids, the most important of which is oleic acid, which is known for its high antioxidant activity (Zevallos et al., 2014; Tang et al., 2016). The presence of these two groups of Omega-6 and Omega-3 essential fatty acids in the meat of birds fed on a diet containing quinoa seeds has proven effective as they are one of the natural active antioxidant systems in birds' meat (Andrade et al., 2018). Linoleic fatty acid works in combination with Glutathione peroxidase and work to remove the free radicals formed in the meat of stored birds and allow it to prolong the periods needed for storage and maintain its specific characteristics from deterioration without being exposed to the processes of oxidation, rancidity, and change during freezing and storage for a long period (Wood et al., 2004). In addition to the activity of this acid by preventing the formation of intermediate compounds such as butylhydroxytoluene that help the production of free radicals that cause oxidative damage (Wu et al., 2012). In addition, studies have indicated that the polyunsaturated fatty acids of quinoa seed starch have antioxidant properties (Yao et al., 2014a). Besides the role of the biological activities of quinoa seed protein, animal and clinical studies have shown that it is used as an anti-oxidant and anti-bacterial treatment (Vilcacundo and Acherson, 2018). The reason for the increase in FFA free fatty acids in the control treatment at 6 weeks of storage is due to the role of LypoypyticKenzyyme, such as the lipase enzyme and phospholipase, and what results from fat rancidity and unacceptable odors by increasing the storage period, which negatively affects the nutritional value of meat and products (Al-Rubeii et al., 2009; Zangana and Al-safty, 2018). However, these percentages of acids decreased in treatments of adding quinoa seeds, as they are natural antioxidants with strong activity and effectiveness in inhibiting and scavenging free radicals (Eassawy et al., 2016). The results of this study are consistent with (Jang et al., 2008) that found a decrease in oxidation indicators and an increase in antioxidant activity when adding medicinal herb extract to the broiler diet. Similarly, (Eassawy et al., 2016) found a significant decrease in TBA values for meat in both chest and thigh of broilers who fed a diet supplemented with quinoa seed extract at a level of 30 g/kg feed and refrigerated storage for different periods (1, 4, 7 days). The above studies and the current one presented good agreement ith (Poursalehi et al., 2021) when adding quinoa seed flour to chicken meat sausages by 10% as natural antioxidants.

Content

All concentrations of raw and treated quinoa seeds contributed to reducing the meat's exposure to rancidity and preserving it from oxidation during different storage periods, and the effectiveness of the effect was higher when using treated quinoa seeds by 1.5%.

References


