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

Noufal H.J. Alsafi[1*], Bushra S.R. Zangana[2]

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 T_1, T_2, T_3, and T_4, and the treated by soaked in water for 48 hours for treatments T_5, T_6 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.

DOI Number: 10.14704/nq.2022.20.4.NQ22089 **NeuroQuantology 2022; 20(4):15-27**

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

Corresponding author: Noufal H.J. Alsafi
Address: [1*,2]Department of Animal Production, College of Agricultural Engineering, University of Baghdad, Iraq.
E-mail: [1*]Noufal.Hameed1101a@coagri.uobaghdad.edu.iq; [2]bushra.s@coagri.uobaghdad.edu.iq
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 18 January 2022 **Accepted:** 02 March 2022

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 (Poursalehi 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 Burker 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 (T_1). 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.

Table 1. The chemical composition of raw and treated quinoa seeds by soaking used in diets

Elements	Seed Soaking treatment	Raw quinoa seeds
chemical composition %		
protein	15.6	14.7
Fats	6.9	6.2
ash	3.9	3.5
moisture	10.7	10.4
carbohydrate	62.9	65.2
fibers	13.4	14.9
energy	375.1	374.6
(Minerals mg/kg)		
Iron	13.5	12.7
magnesium	196.2	194.0
phosphorous	428.1	423.6
Calcium	145.7	143.1
potassium	92.3	88.5
zinc	24.9	23.1
Fatty acids(%)		
Oleic	24.8	23.8
Palmatic	11.6	10.25
Linoleic	63.0	61.3
Linolenic	2.3	2.0
Stearic	2.5	1.8
Amino acids (mg/gm)		
Methionine	14.2	12.3
Leucine	15.7	14.5
valine	9.5	8.6
Phenylalanine	11.4	10.3
Tryptophan	6.8	5.9
Lysine	6.6	5.3
Glycine	3.9	-
Alanine	5.8	-
Histiden	3.2	-
Total phenols (mg/g)	84.2	68.6
Total saponins (%)	2.8	8.5

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:- (T_1): Control treatment of standard diet free of any addition, (T_2) adding 0.5% raw quinoa seeds to the standard diet, (T_3) adding 1% raw quinoa seeds to the standard diet, (T_4) adding 1.5% raw quinoa seeds to the standard diet. Likewise, (T_5) added 0.5% quinoa seeds treated with soaking for 48 hours to the standard diet, (T_6) added 1% quinoa seeds treated with soaking for 48 hours to the standard diet, (T_7) 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 m^2. 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:

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

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)

Components	**Treatments**						
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
yellow corn	45.5	45	45	44.5	45	45	45
wheat	10	10	10	10	10	10	10
Soybean meal (48% crude protein)	34	34	33.5	33.5	34	33.5	33.5
protein concentrate*	5	5	5	5	5	5	5
quinoa seeds**	-	0.5	1	1.5	0.5	1	1.5
oil	3	3	3	3	3	3	2.5
Di Calcium Phosphit***	0.7	0.7	0.7	0.7	0.7	0.7	0.7
limestone	1.2	1.2	1.2	1.2	1.2	1.2	1.2
salt	0.1	0.1	0.1	0.1	0.1	0.1	0.1
methionine	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100	100	100
Calculated chemical composition ****							
Represented energy (kilocalories/kg)	3041.20	3043.18	3049.71	3051.64	3043.21	3049.76	3023.52
crude protein	23.34	23.37	23.42	23.33	23.37	23.21	23.29
crude fat	5.57	5.58	5.61	5.62	5.58	5.61	5.15
crude fiber	2.74	2.80	2.86	2.92	2.80	2.86	2.94
methionine + cysteine	1.14	1.14	1.14	1.15	1.14	1.14	1.15
lysine	1.54	1.54	1.53	1.53	1.54	1.53	1.53
Calcium	0.98	0.98	0.98	0.98	0.98	0.98	0.98
available Phosphorous	0.48	0.48	0.48	0.48	0.48	0.48	0.48

* 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).

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:

$$\text{(TBA) Value mg MDA/kg meat} = 5.2 \times A530$$

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)

Components	Treatments						
	T1	T2	T3	T4	T5	T6	T7
yellow corn	51.5	51	50.5	50	51	51	50.5
wheat	10	10	10	10	10	10	10
Soybean meal (48% crude protein)	28	28	28	28	28	27.5	27.5
protein concentrate*	5	5	5	5	5	5	5
quinoa seeds**	-	0.5	1	1.5	0.5	1	1.5
oil	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Di Calcium Phosphit***	0.5	0.5	0.5	0.5	0.5	0.5	0.5
limestone	1.14	1.14	1.14	1.14	1.14	1.14	1.14
salt	0.1	0.1	0.1	0.1	0.1	0.1	0.1
methionine	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Lysine	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total	100	100	100	100	100	100	100
Calculated chemical composition ****							
Represented energy (kilocalories/kg)	3140.80	3142.78	3144.01	3146.74	3142.81	3149.36	3151.37
crude protein	20.97	21	21.03	21.06	21	20.84	20.88
crude fat	6.27	6.25	6.26	6.27	6.25	6.28	6.3
crude fiber	2.64	2.70	2.76	2.83	2.7	2.76	2.82
methionine + cysteine	0.96	0.96	0.97	0.97	0.96	0.96	0.97
lysine	1.29	1.29	1.29	1.29	1.29	1.27	1.27
Calcium	0.89	0.89	0.89	0.89	0.89	0.89	0.89
available Phosphorous	0.44	0.44	0.44	0.44	0.44	0.44	0.48

* 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).

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

Components	**Treatments**						
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
yellow corn	55	54.5	54.5	54	54.5	54.5	54.5
wheat	10	10	10	10	10	10	10
Soybean meal (48% crude protein)	24	24	23.64	23.64	24	23.5	23.5
protein concentrate*	5	5	5	5	5	5	5
quinoa seeds**	-	0.5	1	1.5	0.5	1	1.5
oil	4.14	4.14	4	4	4.14	4.14	3.64
Di Calcium Phosphit***	0.4	0.4	0.4	0.4	0.4	0.4	0.4
limestone	1.1	1.1	1.1	1.1	1.1	1.1	1.1
salt	0.1	0.1	0.1	0.1	0.1	0.1	0.1
methionine	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Lysine	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total	100	100	100	100	100	100	100
Calculated chemical composition ****							
Represented energy (kilocalories/kg)	3228.05	3220.03	3217.38	3219.36	3220.06	3226.61	3200.37
crude protein	19.35	19.38	19.28	19.31	19.38	19.22	19.30
crude fat	6.97	6.98	6.87	6.88	6.99	7.02	6.55
crude fiber	2.56	2.62	2.68	2.74	2.62	2.68	2.76
methionine + cysteine	0.92	0.92	0.92	0.93	0.92	0.92	0.93
lysine	1.18	1.18	1.17	1.17	1.18	1.16	1.16
Calcium	0.84	0.84	0.84	0.84	0.84	0.84	0.84
available Phosphorous	0.42	0.42	0.42	0.41	0.42	0.41	0.41

* 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).

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:

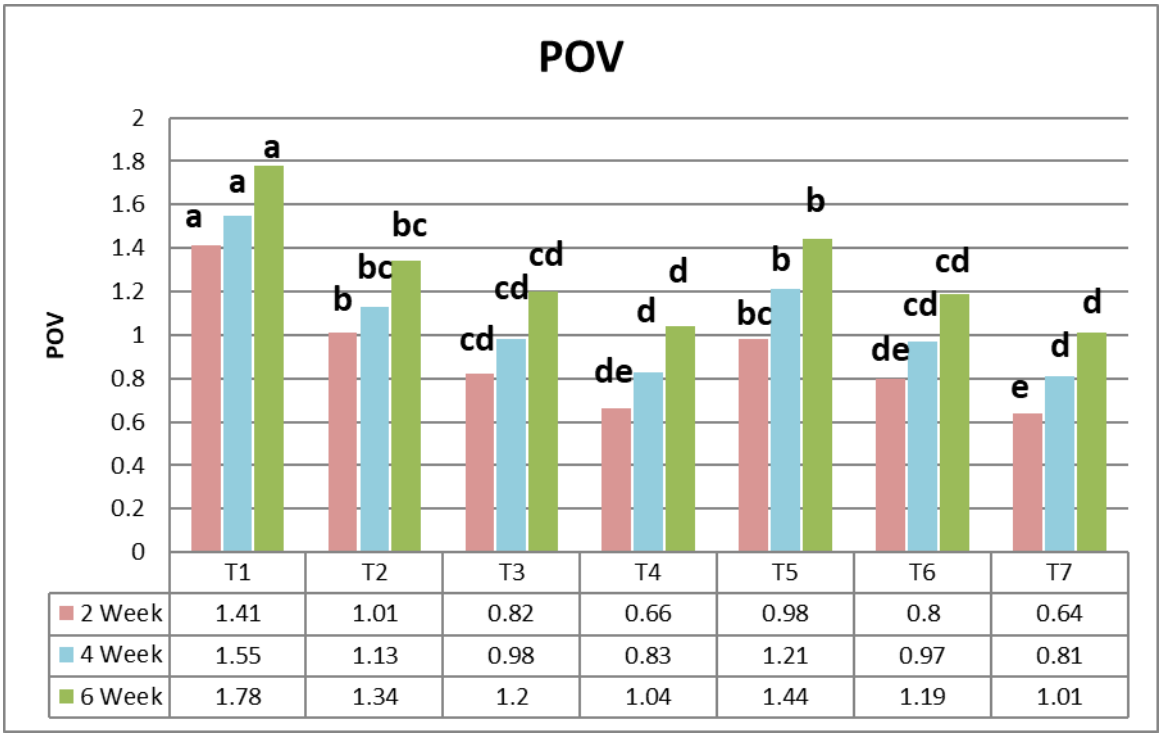
$$Y_{ij}=\mu+T_i+e_{ij}$$

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 T_7 compared to the control treatment T_1, and treatments T_2, T_3, and T_5 whose values were 0.64 compared to 1.41, 1.01, 0.82 and 0.98 meq /kg fat, respectively. The superior treatment in the significant decline was similar to the two addition treatments T_4 and T_6, whose values were recorded 0.66 and 0.82 meq /kg fat, and in turn, the two treatments did not achieve a significant difference compared to the two treatments T_3 and T. Although the addition treatments T_4, T_6, T_3 and T_5 achieved a significant decrease ($P < 0.05$) compared to the treatments T_1 and T_2 on one hand, and on the other hand, the addition treatment T_2 achieved a significant decrease (P<0.05) compared to treatment T_1 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 T_4 and T_7 compared to the control treatment T_1 and addition treatments T_2 and T_5 for the two periods. Besides,

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 T_3 and T_6 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.



	T1	T2	T3	T4	T5	T6	T7
2 Week	1.41	1.01	0.82	0.66	0.98	0.8	0.64
4 Week	1.55	1.13	0.98	0.83	1.21	0.97	0.81
6 Week	1.78	1.34	1.2	1.04	1.44	1.19	1.01

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

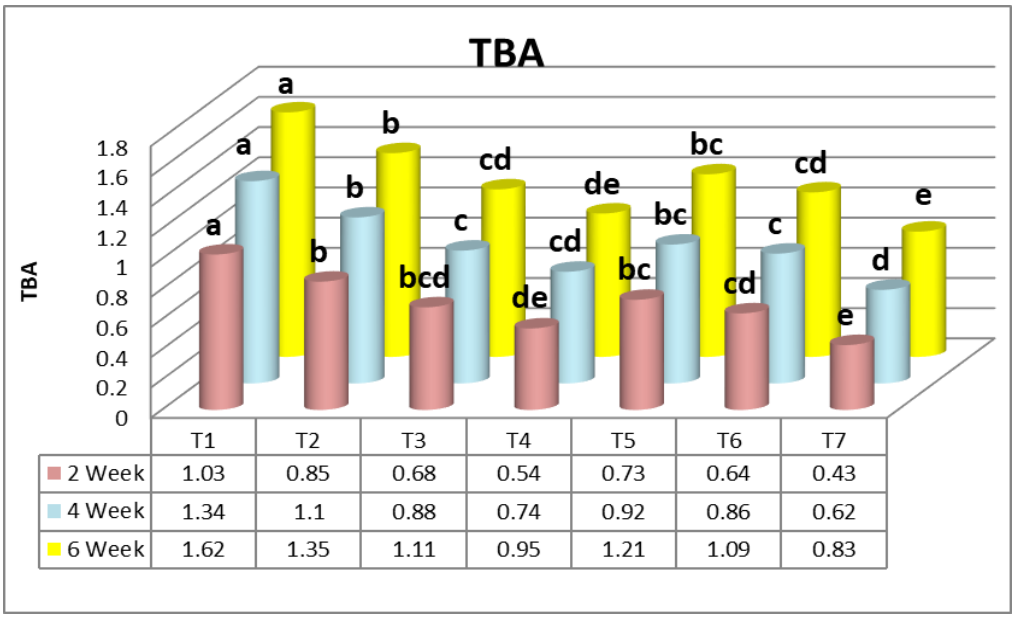
* Different letters within the same color mean that there are significant differences between the average treatments at the level of probability (P<0.05).

* Treatments:- T_1 Control treatment without any addition, T_2 using 0.5% raw quinoa seeds, T_3 using 1% raw quinoa seeds, T_4 using 1.5% raw quinoa seeds, T_5 using 0.5% treated quinoa seeds, T_6 using 1% treated quinoa seeds, T7 using 1.5% treated quinoa seeds.

Finally, it was noted that the addition treatments T_3 and T_6 achieved a significant decrease (P<0.05) compared to treatment T_5 for both periods. In turn, these treatments T_3, T_6, and T_5 did not differ significantly with the addition treatment T_2, although all the last addition treatments achieved a significant decrease (P<0.05) compared to the control treatment T_1 for the two periods in peroxide values.

Thiobarbutyric 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 T_7 compared to the control treatment T_1 and the addition treatments T_2, T_3, T_5 and T_6. 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 T_7 was similar in the significant effect for both periods to the treatment T_4 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 T_1 for each of the periods.



	T1	T2	T3	T4	T5	T6	T7
2 Week	1.03	0.85	0.68	0.54	0.73	0.64	0.43
4 Week	1.34	1.1	0.88	0.74	0.92	0.86	0.62
6 Week	1.62	1.35	1.11	0.95	1.21	1.09	0.83

Figure 2. Effect of using raw and treated Chenopodium quinoa seeds with the diet on estimating the oxidation indicators of broiler carcasses fat for thiobarbituric acid (TBA) values for 2, 4, and 6 weeks of storage

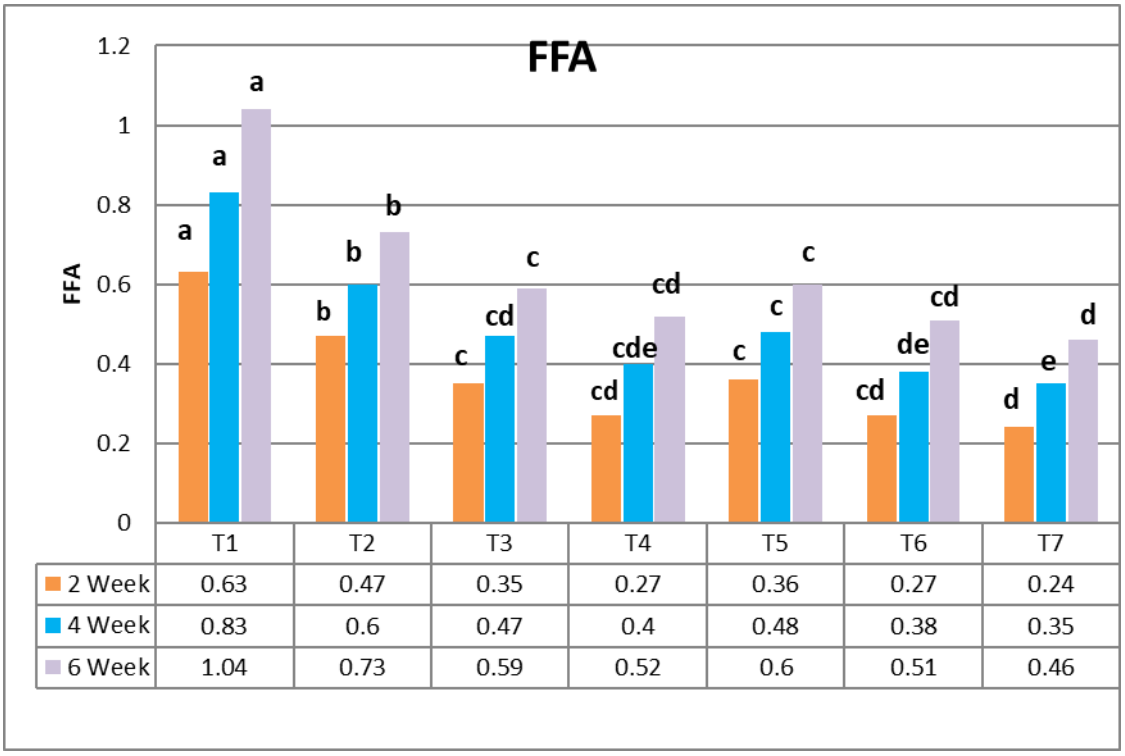
* Different letters within the same color mean that there are significant differences between the average treatments at the level of probability (P<0.05).
* Treatments:- T_1 Control treatment without any addition, T_2 using 0.5% raw quinoa seeds, T_3 using 1% raw quinoa seeds, T_4 using 1.5% raw quinoa seeds, T_5 using 0.5% treated quinoa seeds, T_6 using 1% treated quinoa seeds, T7 using 1.5% treated quinoa seeds.

Whereas, the addition treatment T_4 decreased significantly (P<0.05) for both periods compared to addition treatment T_2. Also, T_5 did not differ significantly with treatments T_3 and T_6, although the treatment T_6 achieved a significant decrease (P<0.05) compared to T_2 on the one hand and did not differ with T_3 and T_5 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 T_7 compared to the control treatment T_1 and the addition treatments T_2, T_3, T_5 and T_6 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 T_4, which differed significantly from the addition treatments T_3, T_5, and T_6. Besides that, all the last treatments achieved a significant decrease compared to treatment T_1 and T_2, except for the treatment T_5, which had the same effect as treatment T_2 although the latter achieved a significant decrease compared to treatment T_1.

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 T_7, which reached the highest significant decrease (P<0.05). In comparison with the control treatment T_1 and the addition treatments T_2, T_3, and T_5, 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 T_4, 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 T_3, T_5, and T_6 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 T_1 and T_2, however, the last treatment had a significant decrease (P<0.05) compared to the control treatment T_1 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 T_7.

This treatment reached the highest significant decrease (P<0.05) compared to the control treatment T_1 and addition treatments T_2, T_3, and T_5 whose values were recorded 0.35% compared to 0.83, 0.60, 0.47, and 0.48%, respectively. Plus, the addition treatment T_7 was similar in effect to the addition treatments T_4 and T_6, 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 T_1 and the treatment T_2, although they were significantly similar to the treatment T_3 on the one hand and they were similar to T_3, T_4, and T_5 on the other hand. In turn, the addition treatment T_2 achieved a significant decrease compared to the control treatment T_1 in the values of FFA from the same storage period.



	T1	T2	T3	T4	T5	T6	T7
2 Week	0.63	0.47	0.35	0.27	0.36	0.27	0.24
4 Week	0.83	0.6	0.47	0.4	0.48	0.38	0.35
6 Week	1.04	0.73	0.59	0.52	0.6	0.51	0.46

Figure 3. Effect of using raw and treated Chenopodium quinoa seeds with the diet on estimating the oxidation indicators of broiler carcasses fat for free fatty acid (FFA) 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:- T_1 Control treatment without any addition, T_2 using 0.5% raw quinoa seeds, T_3 using 1% raw quinoa seeds, T_4 using 1.5% raw quinoa seeds, T_5 using 0.5% treated quinoa seeds, T_6 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 (Carciochi 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 provide protection 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 Panpipat, 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 polysaccharides 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 LypolyticKenzyme, 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-safy, 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 (Easssawy 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, (Easssawy 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

Al-Fayadh, H.A.A., Naji, S.A.H., & Al-Hajo, N.N. (2011). *Poultry Meat Technology. 2nd part.* Poultry Product Technology (part two) Poultry Meat Technology. 2ed. Ministry of higher education and scientific research. Univ. of Baghdad. Coll. of Agric.pp:224. (in Arabic).

Al-Rubeii, A.M., Al-Kaisey, M.T., & Khadom, M.J. (2009). Effect of Some Natural and Synthetic Antioxidants on Ground Beef Meat During Cold Storage. *Alex. J. Ft. Sci And Technol, 6*(1), 1-16.

Andrade, L.M., Andrade, C.J., Dias, M., Nascimento, C., & Mendes, M.A. (2018). Chlorella and spirulina microalgae as sources of functional foods. *Nutraceuticals, and Food Supplements, 6*(1), 45-58.

Andrade, L.M., Andrade, C.J., Dias, M., Nascimento, C., & Mendes, M.A. (2018). Chlorella and spirulina microalgae as sources of functional foods. *Nutraceuticals, and Food Supplements, 6*(1), 45-58.

A.O.A.C. (1995). *Official Methods of Analysis. Association of Official Analytical Chemists. 16th Edition.* AOAC International, Gaithersburg, MD.

Avila-Ramos, F., Pro-Martínez, A., Sosa-Montes, E., Cuca-García, J.M., Becerril-Perez, C., FigueroaVelasco, J.L., & Narciso-Gaytan, C. (2013). Dietary supplemented and meat-added antioxidants effect on the lipid oxidative stability of refrigerated and frozen cooked chicken meat. *Poultry Science, 92*(1), 243-249.

Aziz, A., Akram, N.A., & Ashraf, M. (2018). Influence of natural and synthetic vitamin C (ascorbic acid) on primary and secondary metabolites and associated metabolism in quinoa (Chenopodium quinoa Willd.) plants under water deficit regimes. *Plant Physiology and Biochemistry, 123*, 192-203.

Carciochi, R. A., Galván-D'Alessandro, L., Vandendriessche, P., & Chollet, S. (2016). Effect of germination and fermentation process on the antioxidant compounds of quinoa seeds. *Plant foods for human nutrition, 71*(4), 361-367.

Chaijan, M., & Panpipat, W. (2017). *Mechanism of oxidation in foods of animal origin.* In Natural Antioxidants (pp. 21-58). Apple Academic Press.

Choque-Quispe, D., Ligarda-Samanez, C.A., Ramos-Pacheco, B.S., Leguía-Damiano, S., Calla-Florez, M., Zamalloa-Puma, L.M., & Colque-Condeña, L. (2021). Phenolic Compounds, Antioxidant Capacity, and Protein Content of Three Varieties of Germinated Quinoa (Chenopodium quinoa Willd). *Ingeniería e Investigación, 41*(2).

Contreras-Jiménez, B., Torres-Vargas, O.L., & Rodríguez-García, M.E. (2019). Physicochemical characterization of quinoa (Chenopodium quinoa) flour and isolated starch. *Food chemistry, 298,* 124982.

Duncan, D.B., (1955). Multiple range and multiple of test biometrice 11.1.

Easssawy, M.M.T., Abdel-Moneim, M.A., & El-Chaghaby, G.A. (2016). The use of quinoa seeds extract as a natural antioxidant in broilers' diets and its effect on chickens' performance and meat quality. *Journal of Animal and Poultry Production, 7*(5), 173-180.

Fernández-López, J., Lucas-González, R., Roldán-Verdú, A., Viuda-Martos, M., Sayas-Barberá, E., Ballester-Sánchez, J., & Pérez-Álvarez, J.A. (2020). Effects of black quinoa wet-milling coproducts on the quality properties of bologna-type sausages during cold storage. *Foods, 9*(3), 274.

Fletcher, D.L. (1999). Color variation in commercially packaged broiler breast fillets. *Journal of Applied Poultry Research, 8*(1), 67-69.

Hassan, F.A., Roushdy, E.M., Kishawy, A.T., Zaglool, A.W., Tukur, H.A., & Saadeldin, I.M. (2019). Growth performance, antioxidant capacity, lipid-related transcript expression and the economics of broiler chickens fed different levels of rutin. *Animals, 9*(1), 7-11.

Heleno, S.A., Martins, A., Queiroz, M.J.R., & Ferreira, I.C. (2015). Bioactivity of phenolic acids: Metabolites versus parent compounds: A review. *Food chemistry, 173*, 501-513.

Hęś, M., Szwengiel, A., Dziedzic, K., Le Thanh-Blicharz, J., Kmiecik, D., & Górecka, D. (2017). The effect of buckwheat hull extract on lipid oxidation in frozen-stored meat products. *Journal of food science, 82*(4), 882-889.

Jang, A., Liu, X.D., Shin, M.H., Lee, B.D., Lee, S.K., Lee, J.H., & Jo, C. (2008). Antioxidative potential of raw breast meat from broiler chicks fed a dietary medicinal herb extract mix. *Poultry science, 87*(11), 2382-2389.

Jin, L.Z., Dersjant-Li, Y., & Giannenas, I. (2020). Application of aromatic plants and their extracts in diets of broiler chickens. *Feed Additives,* 159-185.

Khaligh, F., Hassanabadi, A., Nassiri-Moghaddam, H., Golian, A., & Kalidari, G.A. (2018). Effects of in ovo injection of chrysin, quercetin and ascorbic acid on hatchability, somatic attributes, hepatic oxidative status and early post-hatch performance of broiler chicks. *Journal of animal physiology and animal nutrition, 102*(1), e413-e420.

Navruz-Varli, S., & Sanlier, N. (2016). Nutritional and health benefits of quinoa (Chenopodium quinoa Willd.). *Journal of Cereal Science, 69,* 371-376.

Nickel, J., Spanier, L.P., Botelho, F.T., Gularte, M.A., & Helbig, E. (2016). Effect of different types of processing on the total phenolic compound content, antioxidant capacity, and saponin content of Chenopodium quinoa Willd grains. *Food Chemistry, 209*, 139-143.

Nowak, V., Du, J., & Charrondière, U.R. (2016). Assessment of the nutritional composition of quinoa (Chenopodium quinoa Willd.). *Food chemistry, 193,* 47-54.

NRC.National Research Council. (1994). *Nutrient Requirements of Poultry. 9th ed.* National Academic Press, Washington DC.

OZER, C.O., & Secen, S.M. (2018). Effects of quinoa flour on lipid and protein oxidation in raw and cooked beef burger during long term frozen storage. *Food Science and Technology, 38,* 221-227.

Panda, A.K., & Cherian, G. (2013). Role of vitamin E in counteracting oxidative stress in poultry. *The Journal of Poultry Science,* 0130134.

Park, J.H., Lee, Y.J., Lim, J.G., Jeon, J.H., & Yoon, K.S. (2021). Effect of Quinoa (Chenopodium quinoa Willd.) Starch and Seeds on the Physicochemical and Textural and Sensory Properties of Chicken Meatballs during Frozen Storage. *Foods, 10*(7), 1601.

Pasko, P., Bartoń, H., Zagrodzki, P., Gorinstein, S., Fołta, M., & Zachwieja, Z. (2009). Anthocyanins, total polyphenols and antioxidant activity in amaranth and quinoa seeds and sprouts during their growth. *Food chemistry, 115*(3), 994-998.

Pereira, E., Encina-Zelada, C., Barros, L., Gonzales-Barron, U., Cadavez, V., & Ferreira, I.C. (2019). Chemical and nutritional characterization of Chenopodium quinoa Willd (quinoa) grains: A good alternative to nutritious food. *Food Chemistry, 280,* 110-114.

Pinuel, L., Boeri, P., Zubillaga, F., Barrio, D.A., Torreta, J., Cruz, A., & Carrillo, W. (2019). Production of white, red and black quinoa (Chenopodium quinoa Willd Var. Real) protein isolates and its hydrolysates in germinated and non-germinated quinoa samples and antioxidant activity evaluation. *Plants, 8*(8), 257.

Poursalehi, M., Zeynali, F., Alizadeh Khaledabad, M., & Almasi, H. (2021). Production of Functional Chicken Sausage by Quinoa Flour and Studying of Physicochemical and Textural Properties. *Journal of Food Research, 31*(3), 85-107.

Rajani, J., Torshizi, M.K., & Rahimi, S. (2011). Control of ascites mortality and improved performance and meat shelf-life in broilers using feed adjuncts with presumed antioxidant activity. *Animal Feed Science and Technology, 170*(3-4), 239-245.

Repo-Carrasco-Valencia, R. (2020). *Nutritional Value and Bioactive Compounds in Andean Ancient Grains.* In Multidisciplinary Digital Publishing Institute Proceedings (Vol. 53, No. 1, p. 1).

SAS, Intstitue. (2010). *SAS User's Guide: Statistics Version 6. 12 edn.,* SAS Institute, Inc., Cary, NC. USA.

Sezgin, A.C., & Sanlier, N. (2019). A new generation plant for the conventional cuisine: Quinoa (Chenopodium quinoa Willd.). *Trends in Food Science & Technology, 86,* 51-58.

Tang, Y., Li, X., Chen, P. X., Zhang, B., Hernandez, M., Zhang, H., & Tsao, R. (2015a). Characterisation of fatty acid, carotenoid, tocopherol/tocotrienol compositions and antioxidant activities in seeds of three Chenopodium quinoa Willd. genotypes. *Food chemistry, 174,* 502-508.

Tang, Y., Li, X., Zhang, B., Chen, P. X., Liu, R., and Tsao, R. 2015b. Characterisation of phenolics, betanins and antioxidant activities in seeds of three Chenopodium quinoa Willd. genotypes. *Food chemistry, 166,* 380-388.

Tang, Y., Li, X., Chen, P.X., Zhang, B., Liu, R., Hernandez, M., & Tsao, R. (2016). Assessing the fatty acid, carotenoid, and tocopherol compositions of amaranth and quinoa seeds grown in Ontario and their overall contribution to nutritional quality. *Journal of agricultural and food chemistry, 64*(5), 1103-1110.

Tang, Y., & Tsao, R. (2017). Phytochemicals in quinoa and amaranth grains and their antioxidant, anti-inflammatory, and potential health beneficial effects: a review. *Molecular Nutrition & Food Research,* 61(7):1-16.

Torres, A., Cova, A., & Valera, D. (2018). Efecto del proceso de germinación de granos de Cajanuscajan en la composición nutricional, ácidos grasos, antioxidantes y bioaccesibilidad mineral. *Revista chilena de nutrición, 45*(4), 323-330.

Shokry, A.M. (2016). The usage of quinoa flour as a potential ingredient in production of meat burger with functional properties. *Middle East Journal of Applied Sciences, 6*(4), 1128-1137.

Surface, C.L.F.U.R. (2014). Optimization of the Polyphenolics Extraction from Chamomile Ligulate Flowers Using Response Surface Methodology. *International Journal of Plant Research, 4* (2): 43–50.

Velasco, V., & Williams, P. (2011). Improving meat quality through natural antioxidants. *Chilean journal of agricultural research, 71*(2), 313.

Vidueiros, S.M., Curti, R.N., Dyner, L.M., Binaghi, M.J., Peterson, G., Bertero, H.D., & Pallaro, A.N. (2015). Diversity and interrelationships in nutritional traits in cultivated quinoa (Chenopodium quinoa Willd.) from Northwest Argentina. *Journal of Cereal Science, 62,* 87-93.

Vilcacundo, R., & Hernandez-Ledesma, B. (2017). Nutritional and biological value of quinoa (Chenopodium quinoa Willd.). *Current Opinion in Food Science, 14,* 1-6.

Vilcacundo, R., Miralles, B., Carrillo, W., & Hernández-Ledesma, B. (2018). In vitro chemopreventive properties of peptides released from quinoa (Chenopodium quinoa Willd.) protein under simulated gastrointestinal digestion. *Food Research International, 105,* 403-411.

Vuolo, M.M., Lima, V.S., & Junior, M.R.M. (2019). *Phenolic compounds: Structure, classification, and antioxidant power.* In Bioactive compounds (pp. 33-50). Woodhead Publishing.

Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., & Enser, M. (2004). Effects of fatty acids on meat quality: a review. *Meat science, 66*(1), 21-32.

Wu, X., Ouyang, H., Duan, B., Pang, D., Zhang, L., Yuan, T., & Li, G.P. (2012). Production of cloned transgenic cow expressing omega-3 fatty acids. *Transgenic research, 21*(3), 537-543.

Yael, B., Liel, G., Hana, B., Ran, H., & Shmuel, G. (2012). Total phenolic content and antioxidant activity of red and yellow quinoa (Chenopodium quinoa Willd.) seeds as affected by baking and cooking conditions. *Food and Nutrition Sciences, 3*: 1150-1155.

Yao, Y., Shi, Z., & Ren, G. (2014). Antioxidant and immunoregulatory activity of polysaccharides from quinoa (Chenopodium quinoa Willd.). *International journal of molecular sciences, 15*(10), 19307- 19318.

Zangana, B.S., & AL-Safy, N.H. (2017). Effect of adding two types of nutritional flavorings (cardamom and cinnamon) and their mixture to the diet in oxidation indicators for the meat of broilers chickens. *Euphrates Journal of Agriculture Science, 9*(4), 1-12.

Zevallos, V.F., Herencia, I.L., Chang, F., Donnelly, S., Ellis, J.H., & Ciclitira, P.J. (2014). Gastrointestinal Effects of Eating Quinoa (Chenopodium quinoaWilld.) in Celiac Patients. *Official journal of the American College of Gastroenterology| ACG, 109*(2), 270-278.