Effect of partial replacement of sunflower seed oil instead of animal fat on the quality of frozen manufactured beef burgers

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Abstract

The current study aims to effect the partial replacement of sunflower (*Helianthus annuus*) seed oil instead of animal fat on some of the quality of frozen manufactured beef burgers. The low-fat processed beef burger was prepared, extraction of sunflower seed oil by gas chromatography with mass spectrometry (GC/MS). Burger were prepared in four replacement ratios of 25, 50, 75 and 100%. The fat and cholesterol content of burgers substituted with vegetable oil, then the burger discs were stored by freezing at (-18 ± 2) °C for 90 days, during which the changes in the values of thiobarbituric acid, water holding capacity, cooking yield, retained moisture percentage and retained fat percentage were monitored. The results showed that there was a significant decrease ($P<0.05$) in the fat and cholesterol content of the burger, in which the fat was replaced by 25, 50, 75 and 100%. The difference was significant at the replacement ratio of 75 and 100%, there was a significant ($P\leq0.05$) decrease in the values of peroxide and thiobarbituric acid by increasing the replacement ratio, thus, the storage period of the burger replaced with vegetable oil can be prolonged, to decrease the effect of oxidative stress. The results showed that there was a significant ($P\leq0.05$) increase in the water holding capacity, the retained moisture and fat percentages with an increase in the replacement rates, improves the tenderness and juiciness of the manufactured burger. The storage period significantly ($P\leq0.05$) affected all the studied qualitative traits, this effect has varied between high and low according to the type of trait studied.

Keywords: animal fat, sunflower oil, Freezing storge, manufactured beef burgers.

Introduction

Meat and meat products contain a high percentage of saturated fatty acids (SFA) and cholesterol, negatively affect human health, high consumption of saturated fat has become a concern, it is associated with an increased risk of heart disease in general and coronary artery disease in particular, it was noted that the relationship between high levels of cholesterol and low levels of polyunsaturated fatty acids and saturated fatty acids, an increase in heart disease, leads the consumer to avoid foods with high fat content, focuses heavily on increasing food purchases, contain low levels of fat (Mortensen and Nordestgaard. 2020).

Recently, consumer demand for healthy foods that are low in fat has increased, because of the increase in health awareness, and the increase in the spread of diseases resulting from food is rapid. The World Health Organization (WHO) recently confirmed the adoption of healthy eating, by reducing saturated fats, total fat should not exceed 30-35% of the caloric value, the amount of saturated fat should be less than 10% (World Health Organization, 2003). Thus, meat products are manufactured to make healthier, by reducing the level of fat by replacing it with vegetable oils and vegetable fibers, produces healthy food products, because it was free of cholesterol and the proportion of unsaturated fatty acids, compared to saturated fatty acids, it is higher (Akesowan, 2015).

Sunflower oil is one of the most popular oils, it is widely involved in food preparation, because of its pure color and light taste, high content of polyunsaturated fatty acids with double bonds 85-95% (Noreen and Ashraf, 2010). It contains natural antioxidants such as α-tocopherol and vitamins A, E, and D, which act as antioxidants to protect the body's cells against free radical damage, plays a major role in many chronic diseases. The oil also helps its oxidative stability due to its high content of saturated fatty acids, makes it more susceptible to oxidation. (Choi *et al*., 2013).

The study aimed to replace animal fat in beef burger with sunflower oil in different proportions, and studying the effect of replacement rates for some qualitative characteristics during the storage period of the manufactured burger discs.

Material and methods

Beef (thigh cut) and beef fat were purchased from the local market in Basra, *Helianthus annuus* seeds were used in the study, bought from local markets in Basra. The seeds were cleaned and impurities were removed before the oil was extracted. The fresh local garlic from the market were used, the husks were removed from it and mashed. The spice mixture for the burger industry was purchased from the local markets in Basra, wheat bran was used as a filler, it was obtained from the grain mills of the Basra Mill, it was ground and sieved until a fine powder was obtained. It was used for frying sunflower oil, type (Al-Dar), produced by Al-Ittihad Company for Food Industries Ltd., a volume of 900 ml, Iraqi-made, purchased from the local markets.

Extraction of sunflower oil

1,500 g of sunflower seeds were taken, squeezed using Iranian-made jars supplied by Niri Organic, Hydraulically operated, approximately 500 ml of oil was obtained.

Fatty Acids diagnosis

The fatty acids in sesame oil were diagnosed using a gas chromatograph connected to a mass spectrometer type GC-MS QP210 Ultra, SHIMADZU, Japan, and the injection process was carried out with an automatic injector type SHIMADZU, AOC-20I+S. The separation conditions in both GC and MS were as follows:-

Gas chromatography	**Mass spectrometer**
Column oven temp. : 40.4 C°	**Ion source temp. :** 200.00 C°
Injection temp. : 280.00 C°	**Solvent cut time :** 3.00 min
Injection mode : Split	**Start time :** 3.00 min
Flow control mode : linear velocity	**End time :** 26.00 min
Pressure : 49.5 kpa	**ACQ Mode :** Scan
Total flow : 34.0 ml/min	**Event time :** 0.50 sec
Column flow : 1.00 ml/mi	**Scan speed :** 1250
Linear velocity : 36.1 cm/sec	**Start m/z :** 30.00
Purge flow : 3.0 ml/min	**End m/z :** 600.00
Split ratio : 30.0	

Preparation of treatment mixtures

3 kg of beef was minced using an electric mincing machine with holes with a diameter of 3 mm, then divide the meat according to Table (1). The treatments were prepared after calculating the quantities of the incoming materials and preparing them according to the table (1), then the burger discs were manufactured and placed in airless polyethylene bags, separate each disc and the last pieces of wax paper, it was stored by freezing at (-18 ± 2) °C for 90 days, during which changes in some qualitative characteristics were followed up during storage periods 0, 30, 60 and 90 days

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Table (1): Quantity of materials needed to prepare the proportions of the mixtures used in preparing the beef burger (g/ kg).

Items	Replacement of animal fat with vegetable oil				
	Control	5%	10%	15%	20%
Meat	765	765	765	765	765
Animal fat	200	150	100	50	-
Vegetable oil	-	25	50	75	100
Flour	13	13	13	13	13
Wheat bran	-	25	50	75	100
Salt	10	10	10	10	10
Spice mix	10	10	10	10	10
Garlic	2	2	2	2	2

Chemical content of burger

Fat: The percentage of fat was estimated by Soxhlet using hexane solvent, according to the method used in A. O. A. C (2000).

Cholesterol estimation: The cholesterol concentration in Berker meat was estimated by preparing the sample according to the method mentioned by Al-Obaidi (1999), modified by Al-Salihi (2012), using the kits supplied by the French company Biolabo SA, then the optical absorbance was measured at a wavelength of 560 nm. The cholesterol content was calculated according to the following equation:

$$Cholesterol\ (mg/g) = \frac{Sample\ absorbance\ value}{Standard\ Cholesterol\ Absorption\ Value} \times 5.17\ mmol/L$$

Chemical indicators:

Thiobarbituric acid (TBA): Thiobarbituric acid was estimated according to the method reported in Soltanizadeh and Ghiasi-Esfahani (2015). The absorbance was measured at a wavelength of 532 nm and the TBA value was calculated according to the following equation:-

TBA=Absorbance × 5.4

Free fatty acids (FFA): The acid value was estimated and from it the percentage of free fatty acids in the beef burger was calculated, according to the method mentioned in Al-Tai and Al-Mousawi (1992), the acid value was calculated as follows:-

$$Acid\ value = \frac{Number\ of\ milliliters\ of\ sodium\ hydroxide\ x\ 5.16}{sample\ weight}$$

$$Free\ fatty\ acids = \frac{Acid\ value}{2}$$

Physical properties:

Water Holding Capacity: The water holding capacity was estimated according to the method used in Al-Tai and Al-Mousawi (1992). The water holding capacity was calculated according to the following equation: -

Water holding capacity (ml) = Total water volume (ml) – Amount of water in the included cylinder (ml).

Cooking Yield: The percentage of cooking yield was calculated according to the equation mentioned in Ibrahim *et al*., (2018).

$$Cooking\ yield\ \% = \frac{The\ weight\ of\ the\ cooked\ burger\ discs}{The\ weight\ of\ the\ uncooked\ burger\ discs}$$

Cooking shrinkage: The percentage of shrinkage in diameter was calculated by measuring the diameter of the Berker discs before and after cooking (Kim *et al.*, 2020), according to the following equation:-

$$Cooking\ shrinkage\ \% = \frac{burger\ discs\ diameter\ after\ cooking\ -\ burgerdiscs\ diameters\ before\ cooking}{burger\ discs\ diameter\ after\ cooking}$$

Moisture retention: The percentage of retained moisture was estimated according to the method mentioned in Ibrahim et al. (2018) and according to the following equation:-

$$Moisture\ retention = \frac{Weight\ of\ the\ burger\ discs\ after\ cooking\ x\ \ moisture\ percentage\ in\ the\ burger\ after\ cooking}{Weight\ of\ the\ burger\ discs\ before\ cooking\ x\ moisture\ percentage\ in\ the\ burgers\ before\ cooking} \times 100$$

Fat retention*:* The percentage of retained fat in the Berker discs was estimated by calculating the percentage of fat in the Berker discs before cooking and after cooking, from which the percentage of retained fat was calculated according to the method mentioned by Ibrahim *et al.* (2018) and according to the following equation:-

$$Fat\ retention = \frac{Weight\ of\ the\ burger\ discs\ after\ cooking\ x\ fat\ percentage\ in\ the\ burger\ after\ cooking}{Weight\ of\ the\ burger\ discs\ before\ cooking\ x\ fat\ percentage\ in\ the\ burgers\ before\ cooking} \times 100$$

Results and Discussions

Percentage of oil yield

The percentage of oil in sunflower seeds was 43%, and the percentage of oil yield was 40%. These results were within the range obtained by Martínez-Force et al. (2015), when extracting oil from sunflower seeds, the oil yield reached 40-45%. The sunflower oil has a light yellow color and a natural oil smell.

Diagnosis of fatty acids in sunflower oil

Table (2) show the determination and characterization of the quantity and quality of fatty acids in sunflower oil by Gas Chromatography Mass Spectrometry (GC/MS) technique. The 20 peaks of fatty acids in sunflower oil appeared in sequence with their name and percentage of each acid. The highest peak number 4 represented by octadecenoic acid, methyl ester (Oleic acid) was 12, it formed the highest percentage of 38.42% of the total fatty acids, followed by the peak No. 3 as shown in the table represented by Methyl 11,14-Octadecadienoate fatty acid. There were two double acids in positions 11 and 14, with a percentage of 36.48%, then hexadeconoic acid methyl (palmitic acid) at the top number 1 and the percentage of 6.61%, as for other fatty acids, their percentages vary, and fatty acids appeared in very small percentages. The results showed that the total percentage of unsaturated fatty acids amounted to 80.26%.

Table (2) Fatty acids in sunflower oil diagnosed by GC/MC . technique.

Peak	**R.Time**	**Area**	**Area%**	**Name**
1	15.176	20391690	6.61	Hexadecanoic acid, methyl ester
2	15.656	2023339	0.66	n-Hexadecanoic acid
3	17.007	112449439	36.48	Methyl 11,14-octadecadienoate
4	17.098	118449631	38.42	12-Octadecenoic acid, methyl ester
5	17.311	13010839	4.22	Octadecanoic acid, methyl ester
6	17.433	2252592	0.73	9,12-Octadecadienoic acid (Z,Z)-
7	17.504	8527551	2.77	cis-Vaccenic acid
8	17.725	1309451	0.42	Octadecanoic acid, 2-(2-hydroxyethoxy)ethyl ester
9	18.776	2196789	0.71	7-Tetradecenal, (Z)-
10	18.943	3732578	1.21	Oxiraneoctanoic acid, 3-octyl-, methyl ester, trans-
11	19.273	2355291	0.76	trans-2-Pinanol
12	19.418	1150335	0.37	9-Octadecenal, (Z)-
13	20.116	1024444	0.33	9,12-Octadecadienoic acid (Z,Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester
14	20.167	1302335	0.42	Oleoyl chloride
15	20.257	971088	0.31	7-Hexadecenoic acid, methyl ester, (Z)-
16	20.549	4672114	1.52	9,12-Octadecadienoyl chloride, (Z,Z)-
17	20.596	7621654	2.47	13-Octadecenal, (Z)-
18	20.822	1414476	0.46	Octadecanoic acid, 2,3-dihydroxypropyl ester
19	21.060	2645194	0.86	Docosanoic acid, methyl ester
20	22.736	786026	0.25	Tetracosanoic acid, methyl ester
		308286856	100.00	

Fat:

Figure (1) shows the effect of fat source and replacement ratio on the percentage of fat in a beef burger, it was observed that the percentage of fat in the Berger decreased significantly ($P \leq 0.05$) when replacing animal fat with sunflower oil, in the control treatment (20% animal fat), the percentage of fat was 23.63%, and in the treatment containing 20% sunflower oil 12.13%.

The fat percentage also decreased with an increase in the replacement rate from 22.63% in the control treatment to 19.62% when replacing 25% and continued to decline to 17.12, 15.28 and 12.13% when replaced by 50, 75 and 100%, respectively. These results agreed with Barros *et al*. (2020) When preparing a low-fat beef burger by replacing animal fat with an earthy almond oil emulsion. It was observed that the percentage of fat in the burger patties decreased with the increase in the percentage of replacement, so the fat content in the control treatment reached 4.42% and decreased to 4.34% at the replacement rate of 50%, and the decrease increased to 3.01% at the replacement rate of 100%.

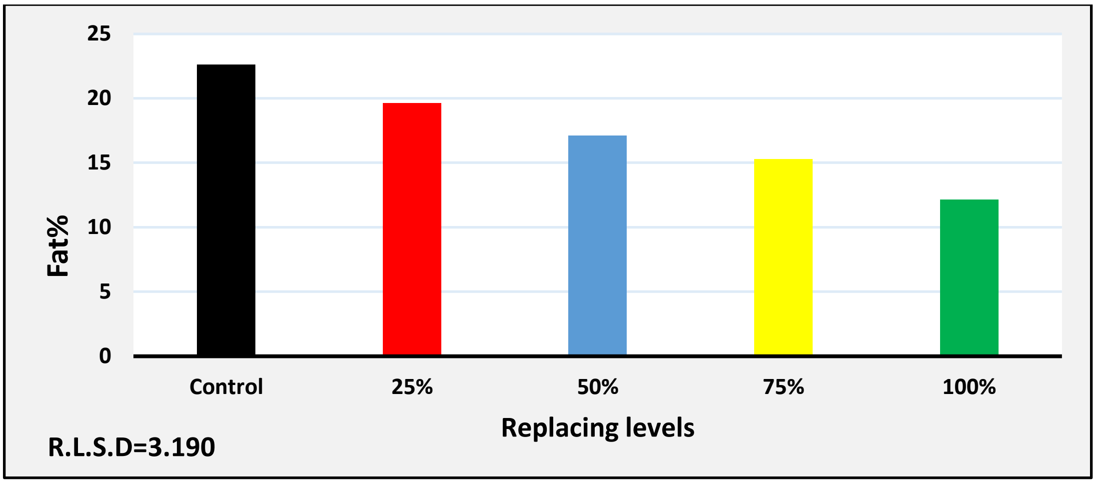

Figure 1: Effect of fat source and replacement ratio on the percentage of fat in beef burger.

Cholesterol

Figure (2) indicates the effect of fat source and replacement ratio on cholesterol concentration in beef burger, the results of the statistical analysis showed that the source of fat had a significant effect ($P \leq 0.05$) on the cholesterol content of the burger. The highest value of cholesterol was in the control treatment (20% fat), it reached 78.82 mg/ 100g, and the lowest cholesterol content was in the treatments completely replaced with sunflower oil 61.27 mg/ 100g. It was also observed that the cholesterol concentration decreased significantly ($P \leq 0.05$) with an increase in the replacement ratio, which amounted to 76.71 mg/100 g at a replacement ratio of 25% and decreased to 73.51 mg/100 g at a replacement ratio of 50% and 67.55 mg/100 g at a replacement ratio of 75%. It continued to decline until it reached 61.27 mg / 100 g at a replacement rate of 100%, due to the fact that vegetable oils are free of cholesterol, therefore, when you increase the replacement of animal fat with vegetable oils, it leads to a decrease in the concentration of cholesterol. These results were in agreement with Franco *et al*. (2019), when preparing low-fat Frankfurt sausages, replacing animal fat with flaxseed oil at 25 and 50%, they found that there is a clear difference in cholesterol content between the control and the replacement treatments. The cholesterol content in the control treatment was 25.08 mg/100g, and it decreased to 20.12 mg/100g in the treatment in which the fat was replaced by 25% flaxseed oil. The cholesterol content decreased more when the percentage of fat was replaced by 50%, as it reached 17.23 mg/ 100 g.

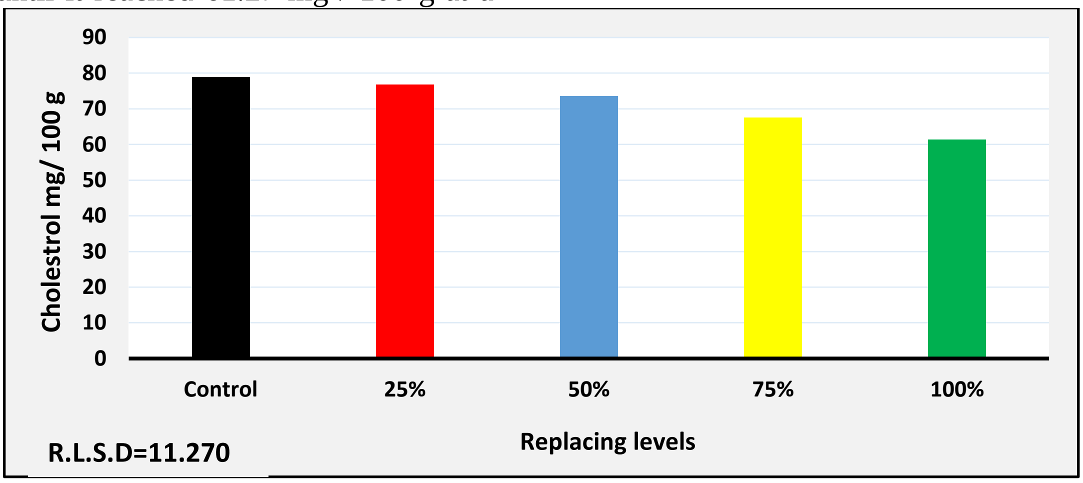

Figure (2): Effect of fat source and replacement ratio on cholesterol concentration in beef burger.

Thiobarbituric acid (TBA):

Figure (3) shows the effect of fat source, replacement ratios and storage period on the value of thiobarbituric acid in beef burger. It was noticed that the source of fat had a significant effect (P<0.05) on the acid values. The highest value of acid in the control treatment (20% fat) was 0.46 mg malonaldehyde /kg. The lowest values of acid in the treatment in which animal fat was replaced with sunflower oil by 100%, which amounted to 0.28 mg malonaldehyde/ kg. The reason for the decrease in acid values in the treatments replaced with vegetable oil compared to the control treatment may be due to the content of sunflower oil of vitamin E, which is an antioxidant.

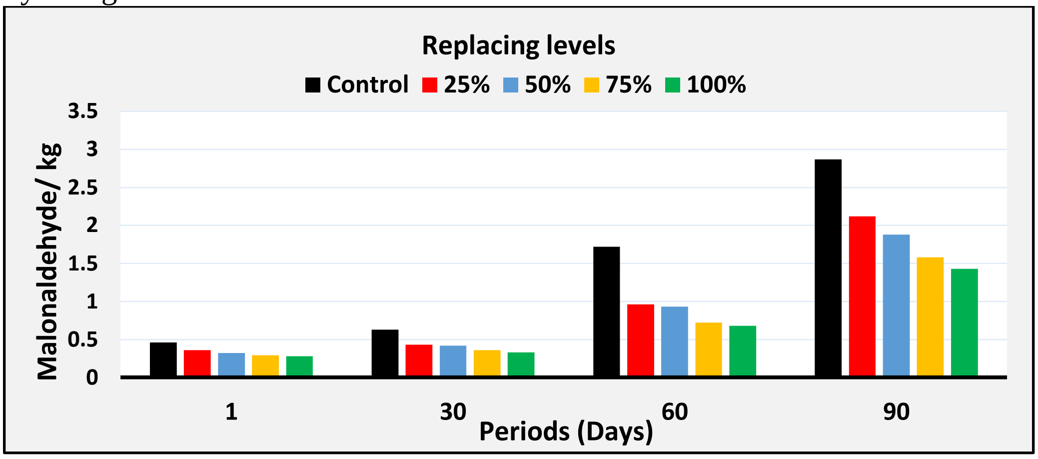

Figure (3): Effect of fat source, replacement ratios and storage period on the value of thiobarbituric acid in beef burger. R.L.S.D: for triple interference effect: 0.4772

The results of the statistical analysis showed that the values of TBA decreased significantly (P≤0.05) with an increase in the percentage of replacement with sunflower oil. The highest value of TBA at the percentage of replacement of 25% was 0.36, it decreased to 0.32 mg malonaldehyde/kg and 0.29 and 0.28 mg malonaldehyde/kg at 50, 75 and 100% replacement ratios, respectively.

As for the effect of storage period, the results of the statistical analysis showed that the value of TBA increased significantly (P≤0.05) with an increase in the storage period of 90 days, in the control treatment, it increased from 0.46 before storage to 0.63 after 30 days and then to 1.72 after 60 days, it reached 2.87 at the end of storage after 90 days, when replacing animal fat with sunflower oil. Acid values before storage were 0.36, 0.32, 0.29 and 0.28 mg malonaldehyde/kg, it increased at the end of the storage period to 2.12, 1.88, 1.58 and 1.43 mg malonaldehyde / kg. The reason for the increase in acid values is due to the oxidation of fats during storage, lead to the formation of peroxides, aldehydes and ketones (Al-Halafi and Al-Mousawi 2016). These results agree with Özer and Celegen (2020), in their study, a low-fat beef burger was prepared by replacing animal fat with an emulsifier of olive oil, they observed changes in TBARS values in burger meat during the 7-day period of cryopreservation. The results showed that TBA gradually increased with the progression of the shelf life in all burger treatments, the highest value for the control treatment was due to the fact that the control treatment contained a high percentage of fat, they recorded the lowest value of TBA in the treatment completely replaced by olive oil, the results also agreed with Al-Baydani and Al-Mousawi (2019), they found an increase in TBA values in burger meat with the progression of the freeze-storage period.

Water Holding Capacity (WHC)

Figure (4) show the effect of fat source, replacement ratio, and storage time on the water holding capacity of the beef burger. The water holding capacity was significantly (P<0.05) affected by the source of fat, the lowest water holding capacity in the control treatment containing 20% animal fat was 14.52 ml, the highest value was in the treatment in which animal fat was replaced by 100% (20% sunflower oil) amounted to 16.91 ml. The reason why the water bearing capacity is affected by the fat source is due to the formation of an emulsion between water, fat and protein, an attraction occurs between the water molecules with the protein, due to the difference in shipments. There were two types of water in meat, free water, which can be easily separated from the meat and bound water Bound water, which was difficult to separate from meat because it is chemically bound to protein molecules (Taher, 1990).

Figure (4) showed that the water holding capacity of the burger increases significantly (P<0.05) with the increase in the percentage of fat replacement with vegetable oil. The water holding capacity was 15.13 ml at a replacement rate of 25% and rose to 15.61 ml at a 50% replacement rate, then to 16.76 ml at a 75% replacement rate and 16.91 ml at a 100% replacement rate. The reason for the higher water holding capacity is due to the increase in the replacement ratio. Wheat bran is a filling material rich in fibers that have the ability to absorb and retain large amounts of water, these results agreed with Lee *et al*. (2015), they found that the holding capacity of water increases with the increase in the proportions of replacing animal fat with a mixture of vegetable oils. The water holding capacity in the control treatment was 73.15% and rose to 87.73% when the replacement rate was 20%, then it rose to 89.82% when the replacement rate was increased to 50%.

The results indicated that the water carrying capacity decreased significantly (P<0.05) with the progression of the storage period, at the control treatment, it decreased from 14.52 ml before storage to 12.43 ml at the end of storage, from 15.31, 15.61, 16.76 and 16.91 ml to 13.55, 14.4, 14.55 and 15.52 ml at the end of the storage period at the replacement rates of 25, 50, 75 and 100%, respectively. The reason for this decrease may be due to the effect of freezing and the formation of ice crystals that affect and destroy tissue cells, thus, a larger amount of exuded liquid comes out during the thawing and cooking period (Taher, 1990), the results agreed with Al-Asadi and Al-Mossawi (2021), they found that the water-carrying capacity of the beef burger decreased continuously during the freezing storage period for 120 days.

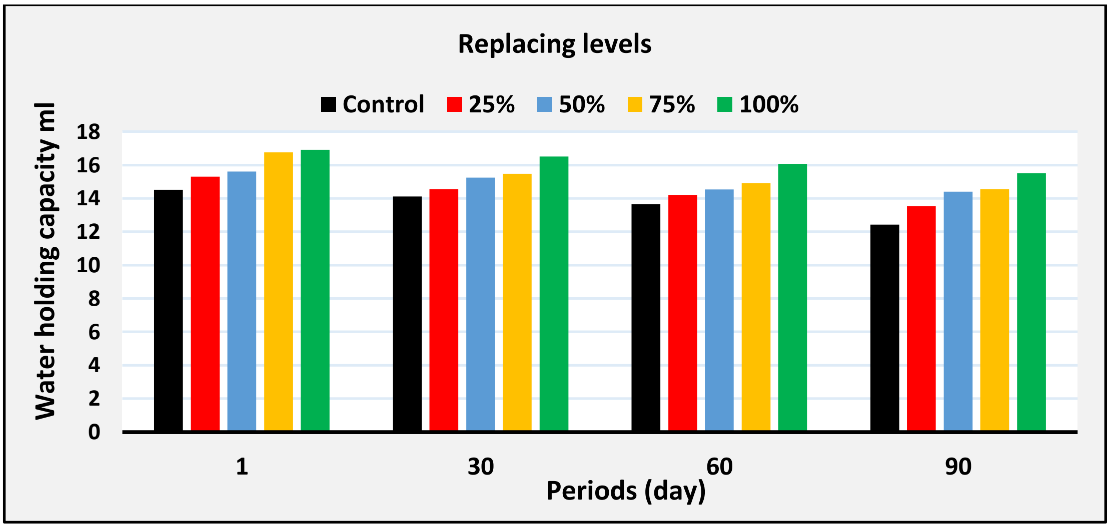

Figure (4): Effect of fat source, replacement ratio and storage period on the water carrying capacity of beef burger. R.L.S.D: for triple interference effect: 0.1842

Cooking Yield

Figure (5) shows the effect of fat source, replacement ratios, and storage time on the percentage of cooking yield in beef burgers, the results of the statistical analysis showed that the source of fat had a significant effect ($P<0.05$) on the percentage of yield, it increased from 65.58% in the control treatment (20% fat) to 78.78% in the treatment replaced by 100% sunflower oil. The reason for the discrepancy in the cooking yield is due to the loss that occurs during cooking, from the results it became clear that the highest percentage of loss by cooking was in the control treatment containing 20% animal fat.
The percentage of the yield was significantly ($P<0.05$) affected by the replacement percentage, the percentage of the yield increased with the increase in the percentage of replacement, it increased from 65.56% in the control treatment to 67.55% at a 25% replacement rate and at a 50% replacement rate it rose to 72.75% and then increased to 75.76% at a 75% replacement rate and reached 78.78% at a 100% oil replacement rate. The reason for the high percentage of cooking yield is that the substituted treatments have a higher ability to retain moisture and fats, therefore, the percentage of loss during cooking is low, and this is reflected in the percentage of the cooking yield. These results agreed with Afshari *et al*. (2017), they noticed an increase in the cooking yield from 66.38% in the control treatment to 73.74% in the treatment in which the fat was completely replaced by vegetable oil with breadcrumbs.
The results showed that the yield percentage decreased significantly ($P<0.05$) during the period of freezing storage, at the control treatment, the percentage of cooking yield decreased from 65.58% before storage to 65.17% after 30 days, it decreased to 64.64% after 60 days and to 63.33% after 90 days of freezing storage, as for the treatment replaced by 25, 50, 75 and 100%, the percentage of cooking yield during the storage period ranged from 67.55 to 74.88%. The reason for this decrease is due to the increased loss in cooking, in addition to the loss that occurred during defrosting, and the loss of part of the moisture during the storage period.

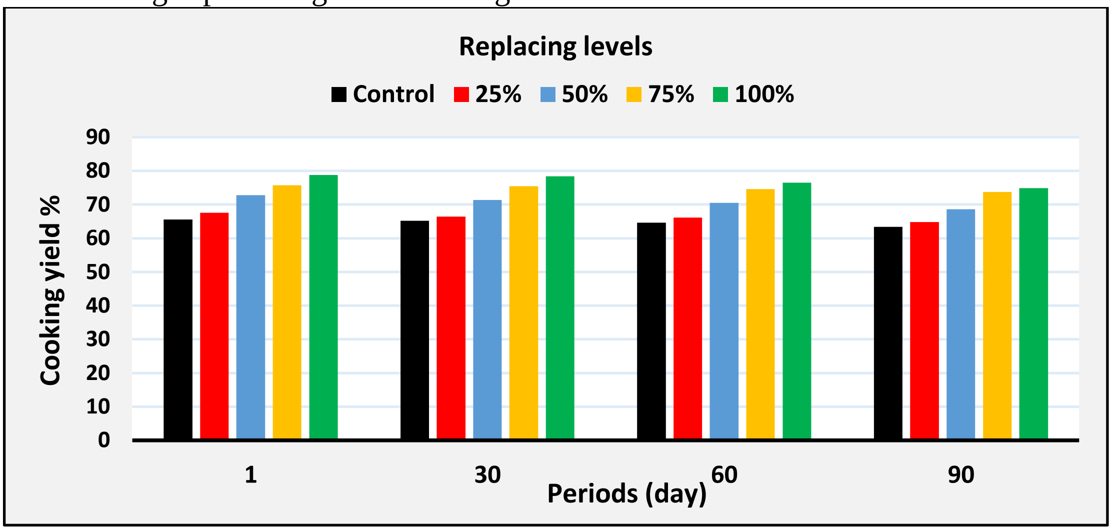

Figure (5): Effect of fat source, replacement ratios and storage period on the percentage of cooking yield in beef burger. R.L.S.D: for triple interference effect: 2.2861.

Moisture retention

Figure (6) shows the effect of fat source, replacement percentage, and storage time on the percentage of moisture retained in the beef burger, it was noticed from the results that the percentage of retained moisture was significantly ($P<0.05$) affected by the source of fat. The lowest retained moisture was 40.66% in the control treatment (20% fat), as it reached 55.66% when replacing 100% with sunflower oil. The highest value was in the treatment in which animal fat was replaced by 100% (20% oil), as it reached 16.88 ml.

The percentage of retained moisture increased significantly (P<0.05) with the increase in the percentage of animal fat replaced with sunflower oil, it increased from 40.66% in the control treatment to 44.23% at the 25% replacement rate, then increased to 47.06% at the 50% replacement rate and to 51.23% at the 75% replacement rate. It continued to rise until it reached 55.66% when replacing 100% with sunflower oil, these results were in agreement with Heck *et al*. (2017), they noticed an increase in the moisture retained when replacing by 50% with flaxseed oil to 61.5%. The reason for the high percentage of retained moisture may be due to the increase in the percentage of replacement due to the increase in the ability of wheat bran added with oils to retain water and thus the percentage of loss during cooking decreases.

The retained moisture percentage decreased significantly (P<0.05) with the progression of the freeze storage period, at the control treatment, the retained moisture percentage decreased from 40.66% before storage to 39.45% after 30 days and then decreased to 38.63 and 37.18% after 60 and 90 days of freezing storage. The retained moisture decreased from 44.23, 47.02, 51.22 and 55.66% before freezing to 43.42, 46.88, 50.18 and 54.22% after 30 days, down to 40.55, 44.08, 48.58 and 52.12% at the end of the freeze storage period, on the exchange rates were 25, 50, 75 and 100%, respectively. The reason for the decrease in the percentage of retained moisture during the storage period is due to the loss that occurred during defrost and during cooking, so this is reflected in the percentage of retained moisture.

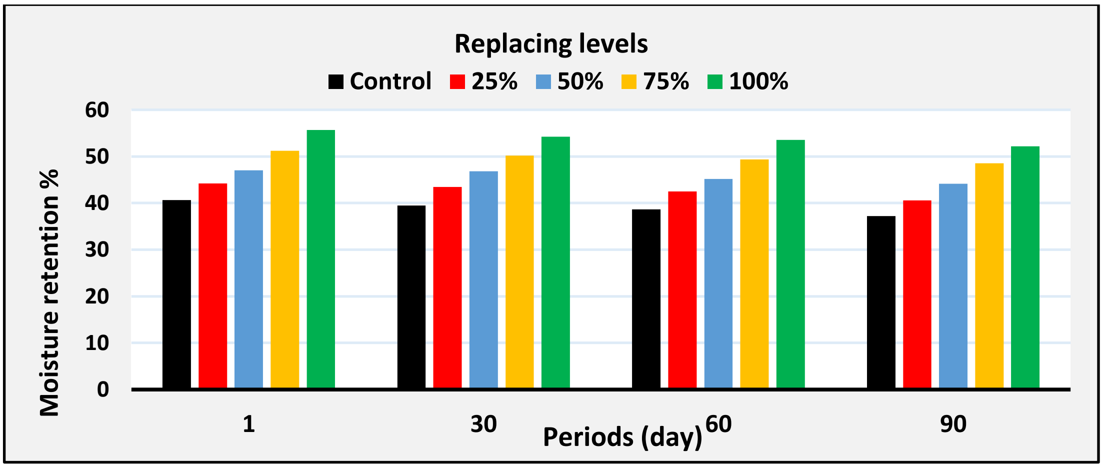

Figure 6: Effect of fat source, replacement percentage and storage time on the percentage of moisture retained in the beef burger. R.L.S.D: for triple interference effect: 1.6003

Fat Retention

Figure (7) shows the effect of fat source, replacement percentage and storage period on the percentage of fat retained in the beef burger, it was noted that the source of fat had a significant effect (P<0.05), the lowest percentage of fat retained in the control treatment was 66.57%, and the highest percentage was in the burger tablets replaced with 100% sunflower oil, which amounted to 79.55%. The reason for this discrepancy is that animal fat melts when cooking and separates, and thus its loss is greater (Heck *et al*., 2017).

As for the effect of the percentages of replacing fat with vegetable oil on the percentage of retained fat, it increased significantly (P<0.05) with an increase in the replacement percentages, at the treatment that was replaced with sunflower oil, it increased from 66.57% (without replacement) to 72.65, 75.55, 77.16 and 78.55%, at 25, 50, 75 and 100% replacement rates, respectively, these results are in agreement with Heck *et al*.

(2017). The percentage of retained fat increased to 85.8 and 88.4% in the treatments in which the fat was replaced by chia seed oil and flaxseed oil, respectively, compared to 53.8% of the control treatment. The reason is due to the thermal stability of the emulsion produced from fine oil particles with meat protein, in addition to the interconnection of the protein matrix, resulting in fat retention during cooking, the proportion of retained fat was high.

The storage period affected the percentage of retained fat, as the percentage of retained fat decreased significantly ($P<0.05$) in the control treatment from 66.57% before storage to 64.43% at the end of the storage period. At the treatments in which the fat was replaced with sunflower oil, the percentage of retained fat decreased from 72.63, 75.52, 77.12 and 78.56% to 71.56, 74.18, 76.06 and 77.52% at the end of the freeze storage period, for the substitutable ratios of 25, 50, 75 and 100%, respectively. The reason for this decrease is due to the weakening of the protein matrix due to the formation of ice crystals between the tissues during the storage period, it was easy to clear fat from between muscle tissue, in addition to the change in the weight of the burgers before and after cooking, as the calculation of the percentage of retained fat depends on the weight of the tablets before and after cooking, these results agreed with what was found by Al-Asadi and Al-Mossawi (2021), the percentage of fat retained in the beef burger decreased from 68.76% before storage to 66.32% after 120 days of freezing storage.

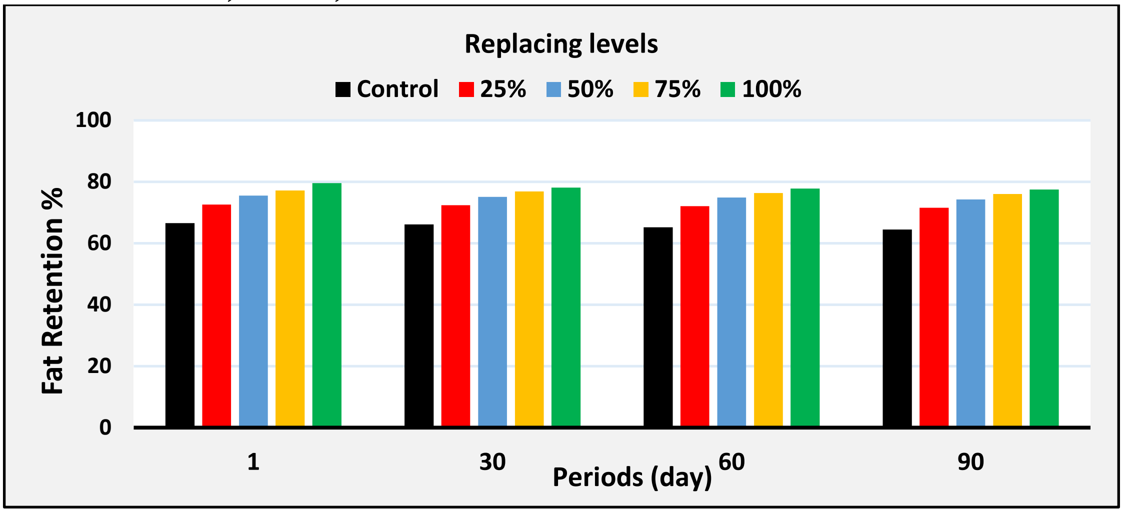

Figure (7): Effect of fat source, replacement rate and storage period on the percentage of fat retained in the beef burger. R.L.S.D: for triple interference effect: 4.8009.

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