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Quality criteria of low and reduced fat beef burger using quinoa and Jerusalem artichoke as fat replacers during frozen storage at -18°C

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ABSTRACT

The present study was conducted to prepare low and reduced fat beef burgers by replacement of fat with rehydrated quinoa and Jerusalem artichoke at different levels (50, 75 and 100%). The effects of rehydrated quinoa and Jerusalem artichoke as fat replacers on chemical and physical properties, cooking parameters, texture profile analysis and sensory evaluation of low and reduced fat beef burgers were studied. The results indicated that quinoa seeds powder had significantly higher crude protein content than Jerusalem artichoke powder which it had significantly higher total dietary fibers content, soluble dietary fiber, total phenolic and total flavonoids than quinoa seeds powder. Replacement fat with water to prepare low fat burger control led to significant decreases in chemical and physical quality attributes, cooking parameters, texture profile and sensory properties. However, replacement of fat with rehydrated quinoa and Jerusalem artichoke at different levels (50, 75 and 100%) led to improve these quality attributes when compared with low or high fat control. Finally, it could be recommended commercially to use rehydrated quinoa seeds and Jerusalem artichoke as fat replacers to replace fat in beef burger up to 75% to produce healthy beef burger without negative effects on quality attributes.

***Keywords*:** Low reduced fat beef burger, quinoa seeds, Jerusalem artichoke, fat replacers, frozen storage.

INTRODUCTION

In our modern world, rising attention has been paid to specific types of healthy and beneficial food ingredients since consumers are becoming more and more health-conscious about the foodstuff they eat (Öztürk and Serdaroğlu, 2017). Fat is one of the major components in meat product formulations that has considerable impacts on their texture, flavor, eating satiety, and cook yield, therefore its reduction represents a big technological challenge due to the probability of deteriorated texture, undesired sensory characteristics, and losses in product yield (Han and Bertram, 2017). Although muscle foods are one of the essential sources of high-quality protein and many bioactive compounds, the high fat and saturated fatty acid content of meat products make them avoidable foods for health since they could trigger the risk of serious degenerative and chronic diseases (Cofrades *et al.,* 2017). Hence, one of the most useful strategies to produce meat products concerning health is to reformulate them to contain a reduced amount of total fat.

Olmedilla-Alonso *et al.* (2013) stated that the aims of fat reduction and/or modification strategies in meat products are to reduce saturated fat and cholesterol levels, beside modification of fatty acid composition. Therefore, the reduction of total fat in meat products are basically based on using lean meat cuts as raw materials (Carvalho *et al.,* 2019), which is probably the simplest way but it might increase costs in processed meat products, and replacing the animal fat with water plus a non-meat ingredient (proteins, carbohydrates, hydrocolloids, or dietary fibers) that brings a functional appeal and compensate for the quality losses caused by the absence of fat (Cofrades *et al.,* 2017; Carvalho *et al.,* 2019).

Beef burgers are popular food items at restaurants and at home and their heating results in major structural changes in the meat proteins, and losing weight in the form of water and fat. The most commonly detected dimensional change in beef burgers during the heating process is the decrease in the diameter of the patty caused by shrinkage Oroszvari *et al.* (2006).

Globe and Jerusalem artichoke tubers have a high concentration of inulin (Baldini *et al.,* 2004; Orlovskaya *et al.,* 2007). Low fat patties could be produced by replacing fat with Jerusalem artichoke (boiled or dried) up to 75% fat replacement level (EL-Beltagy *et al.,* 2007). Moreover, addition of Jerusalem artichoke to meat products such as sausage would supply the requisite quantities of inulin and natural antioxidants and may extend the shelf-life of food products (Gedrovica and Karklina, 2013). Incorporation of globe artichoke into beef burger patties, as a good functional and nutritional properties meat replacer, at levels, 10, 20, 30% of meat weight resulted in producing burger patties without detrimental effect on the sensory attributes besides improving physiochemical properties and cooking measurements of the product (Abd-Elhak *et al.,* 2014).

Quinoa (*Chenopodium quinoa*) was the most important seed crop in South America. It was of such importance to Inca people that it was considered sacred and called the “mother grain”. Its seeds have desirable nutritional properties, with considerably higher levels of minerals and some vitamins than conventional cereals, as well as high-lysine protein, fatty acids, vitamins, minerals, dietary fiber, more amino acids with good digestibility, besides it has been used for a variety of products, including gluten-free baked goods, pasta, infant food, extradites and other processed foods (Repo-Carrasco *et al.,* 2003, (Pellegrini *et al.,* 2018).

Therefore, our research was carried out to evaluate the chemical composition, chemical, physical properties, cooking parameters, texture profile analysis as well as sensory properties of low and reduced fat beef burgers prepared by replacement fat with rehydrated quinoa and Jerusalem artichoke as fat replacers and to compare with low and high fat beef burger (control) during frozen storage at - 18°C for 3 months.

MATERIALS AND METHODS

1. Materials:

1.1. Fresh lean beef meat and fat tissues

Fresh lean beef and fat tissues (sheep tail) were obtained from local market at Dokki Square, Giza, Egypt. Lean beef was obtained from boneless round and trimmed from all subcutaneous and intermuscular fat as well as thick visible connective tissues. Both trimmed lean beef and fat tissues were ground separately through 4.5 mm plate. The minced lean beef was analyzed for its chemical compositions and some chemical and physical properties before using in preparation of different low and reduced beef burger.

1.2. Fat replacers

1.2.1. Quinoa seeds (*Chenopodium quinoa* Willd.) were obtained from the local market (Harraz) at Cairo, Egypt.

1.2.2. Fresh Jerusalem artichoke tubers (*Helianthus tuberosus*L.) were obtained from Horticulture Research Station at Qanater EL-Khairiya., Egypt.

1.3. Spices and other ingredients for preparing burgers

Spices mixture (black pepper, cardamom, clove, coriander, cubeb, cumin, fennel, laurel, nutmeg, semolina) and starch were obtained from the local market (Harraz) at Cairo, Egypt. Other ingredients such as texturized Soy were obtained from Food Technology Research Institute, Agricultural Research Center, Giza, Egypt. Salt, fresh eggs, bread crust, ground onion, foam plates and polyethylene film were obtained from the local market in Giza Governorate, Egypt.

2. Methods:

2.1. Preparation of quinoa seeds powder:

Quinoa seeds were cleaned and freed of broken seeds, dust and other foreign materials. Whole seeds were washed with cold water 4-5 times or until there was no foam to remove saponins, then oven-dried at 45 ± 1°C for 24 h or until being dry. The whole quinoa seeds were ground into flour using stainless steel electric grinder using a laboratorial disc mill and sifted through a 60 mesh, packed in polyethylene bags and stored at -18 ± 1°C until used (Abugoch *et al.,* 2008). Quinoa seeds powder was hydrated by water at a ratio of 1: 1 w/v. immediately before using as protein and carbohydrate- based fat replacers.

2.2. Preparation of Jerusalem artichoke powder:

Fresh Jerusalem artichoke tubers were washed with tap water to remove the dust, and sliced into 0.2 mm and were soaked in diluted lemon juice (acidic solution) to inhibit the activity of polyphenol oxidase as recommended by Tchone *et al.* (2005). The obtained acidified slices were transferred directly to an electric oven and dried at 50ºC ± 2ºC for 12 hr. The dried slices were ground into a fine powder in a mill and sieved (60 mesh sieve) to fine particles. Finally, the obtained powders were packed in polyethylene bags and stored at -18 ˚C until used. Jerusalem artichoke powder was hydrated by water at a ratio of 1: 1 w/v. immediately before using as carbohydrate- based fat replacers.

2.3. Preparation beef burger treatments

Beef burger was processed as described by Feiner (2006) and Nageb (2015) and modified by ELKatry and Elsawy (2021). Eight formula of beef burger were processing in this study. The high fat beef control and other beef burger formula were prepared by mixing the minced lean beef meat with other ingredients as shown in Table (1). Low fat beef burger control was prepared by replacement of fat with water. Other formula of low and reduced beef burgers were prepared by replacement of fat at different levels (25, 50 and 100%) with both of rehydrated quinoa and rehydrated Jerusalem artichoke. After mixing the ingredients by hand, subjected to final grinding (0.4 cm plate) and processed into beef burger (10 cm diameter and 1 cm thick). Beef burger was placed on plastic foam meat trays, wrapped with polyethylene film and kept frozen at -18ºC up to 3 months. Samples were taken for analysis every month periodically.

Table (1). Formula of different beef burger treatments

Ingredients (%)	High fat control	Low fat control	Quinoa seeds rehydrated replacement fat level %			Jerusalem artichoke powder replacement fat levels %		
			50%	75%	100%	50%	75%	100%
Lean beef	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Fat tissues	20.0	0	10.0	5.0	0.0	10.0	5.0	0.0
Reh. texturized soy	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Water	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0
Fresh eggs	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Fresh onion	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Bread crust	2.0	2.0	2.0	2.0	2`.0	2.0	2.0	2`.0
Spices mix.	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Salt	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Quinoa powder seeds	0.0	0.0	10.0	15.0	20.0	0.0	0.0	0.0
Jerusalem artichoke powder	0.0	0.0	0.0	0.0	0.0	10.0	15.0	20.0
Total	100	100	100	100	100	100	100	100

2.4. Proximate composition:

Moisture, crude protein (total N × 6.25), crude fat and ash contents were determined according to A.O.A.C (2016). The total carbohydrates % was calculated as follows:

% Carbohydrate = 100 - (% moisture + % protein + % fat+% ash).

The total dietary fiber was determined according to the method described by A.O.A.C. (2016). The soluble and insoluble dietary fibers were determined according to method described by Prosky *et al.* (1988).

2.5. Determination of total phenols and flavonoids:

Extracts were prepared by adding 25 ml methanol to 1g of sample (quinoa seeds powder or Jerusalem artichoke). This mixture was left on the shaker for 24 hours, after that the mixture was centrifuged (3000 RBM for 15 min) and the supernatant was filtrated using whatman No. 41 filter papers. The supernatant was adjusted to 25 ml by adding methanol and then kept in the refrigerator (4°C). The total Phenol content was determined by the Folin–Ciocalteu micro-method according to Wu *et al.* (2007). Flavonoid content was determined by the modified method of Baba and Malik (2015) using of methanol instead of ethanol in crude extract.

2.6. pH value and chemical properties:

The pH values of the prepared sample were measured using a pH-meter (Jenway 3510 pH meter) with the technique of Fernández-López *et al.* (2006). The total volatile nitrogen (TVN as mg/100g) was determined using the method published by Winton and Winton (1958). The value of Thiobarbituric acid (TBA as mg malonaldehyde/kg sample) was determined colorimeterically as an indication for lipid oxidation by using the method published by Kirk and Sawyer (1991).Water holding capacity (WHC) and plasticity were determined by filter press method (Soloviev, 1966).

2.7. Cooking procedure:

Beef burgers were cooked in an electric grill at 180°C for 5 minutes per each side. The burger was weighed before and after cooking to determine cooking loss %

according to Choi *et al* (2009) as follows:

Cooking Loss % =
[(Uncooked sample wt.-Cooked sample Wt.) × 100]/Uncooked sample weight

The changes in beef burger diameter and length (Shrinkage) were measured on cooked samples as mentioned by Bigner-George and Berry (2000).

Shrinkage % =
[Uncooked diameter or length (cm) – Cooked diameter or length (cm)] ×100

Uncooked diameter or length (cm)

2.8. Texture profile analysis:

The texture was determined in Food Technology Research Institute, Agricultural Research Center Giza- Egypt, by a universal testing machine (Cometech, B type, Taiwan). An Aluminum 25 mm diameter cylindrical probe was used in a "Texture Profile Analysis" (TPA) double compression test to penetrate to 50% depth, at 1 mm/s speed test. Firmness (N), Cohesiveness, Gumminess g), Chewiness (g×mm), Springiness (mm), Adhesiveness negative force (N) was calculated from the TPA graphic. Both springiness and resilience give information about the after stress recovery capacity. Springiness refers to retarded recovery, while resilience refers to instantaneous recovery (immediately after the first compression, while the probe goes up as described by Bourne, 2002)**.**

2.9. Sensory evaluation:

Sensory evaluation of beef burgers was carried out by 12 staff members of Food Technology Research Institute Giza, Egypt. Fresh samples of burgers were cooked in an electric grill at 180 °C for 5 minutes per side and served warm to team members with randomly coded numbers. Members were asked to rate the samples of beef burgers with quinoa seeds powder and Jerusalem artichoke powder evaluated according to the procedure of Lamond (1973). Panelists were asked to score the color, odor, texture, taste, appearance, and overall acceptability properties according to 10-points hedonic scale.

2.10. Statistical analysis:

Statistical analysis was conducted according to **Sned**ecor and Cochran (1994). Data are presented as mean ± SD (standard deviations). Proximate composition, chemical and physical properties of fresh lean beef, proximate composition, total phenolic and flavonoids of quinoa seeds and Jerusalem artichoke as well as texture profile analysis of burgers were analyzed by one-way analysis. A completely randomized 2 (Fat levels for control) × 2 (type of fat replacers), 4 (levels of fat replacers) × 4 (storage period) × 3 (replication) factorial designs was used for beef burger. An analysis of variance was conducted using Costat version 6.311 (Copyright 1998-2005, CoHort software). When a significant main effect was detected, the means were separated with the Student Newman Keuls test. The predetermined acceptable level of probability was 5% (P ≤ 0.05) for all comparisons.

RESULTS AND DISCUSSION

1. Proximate composition, chemical and physical properties of fresh lean beef.

As shown in Table (2), fresh lean beef contained 77.15% moisture, 16.08% crude protein, 5.13% crude fat and 1.04% total ash and 0.60% carbohydrate (on wet weight basis). These values reached 70.37% crude protein, 22.45% crude fat, 4.44% total ash and 2.63% total carbohydrate (On dry weight basis). These results were in agreement with findings of Saleh (2023) who found that fresh beef meat contained

72.92% moisture, 19.97% crude protein, 5.87% crude fat, 1.06% ash and 0.18% total carbohydrates (on wet weight basis). Also, the current results were in line with those obtained by Mohammed (2023) who found that fresh beef meat on dry weight basis contained 68.50% crude protein, 26.49% crude fat and 4.26% total ash.

The chemical and physical characteristics of meat used in processing of various meat products significantly effect on the quality attributes, safety and shelf life of these products and their suitability for consumption (Osheba, 2003).

It was found that fresh lean beef had 7.21 mgN2/100g sample total volatile nitrogen, 0.25mg malonaldehyde / kg sample and5.88 pH, 0.12 (Table 2).

Moreover, water holding capacity (WHC) and plasticity of lean beef meat were 4.45 and 3.48 cm^2/0.3g of sample, respectively These results were in agreement with those reported by Saleh (2023) and Mohammed (2023).

Table 2. Chemical composition, chemical and physical properties of fresh lean beef meat

Parameters	Fresh lean Beef meat	
	W.W	**D.W**
Proximate composition (%)		
Moisture	**77.15 ±0.06**	**-**
Crude protein	**16.08 ±0.13**	**70.37±0.05**
Crude fat	**5.13 ±0.04**	**22.45±0.04**
Total ash	**1.04 ±0.07**	**4.55±0.04**
*** Total carbohydrate**	**0.60 ±0.26**	**2.63±0.10**
Chemical properties		**-----**
Total volatile nitrogen (mg/100g)	**7.21±0.06**	
****Thiobarbituric acid (mg/Kg)**	**0.25±0.04**	**-----**
PH (value)	**5.72±0.12**	**-----**
Physical properties	**4.16 ±0.04**	**-----**
Water holding capacity (cm^2/0.3g)		
Plasticity(cm^2/0.3g)	**3.48±0.08**	**-----**

*Calculated by difference. WW: wet weight DW: Dry weight
**Thiobarbituric acid (mgmalonaldehyde /Kg sample)

2. Proximate composition, total phenolic and flavonoids of quinoa seeds and Jerusalem artichoke:

From data in Table (3) it could be noticed that the proximate composition of both quinoa seeds powder and Jerusalem artichoke powder which used as fat-replacers in processing beef burger was 7.63 and 6.81% moisture, 15.60 and 7.76 % crude protein, 5.86 and 1.32% crude fat, 2.77 and 5.61% total ash, 6.85 and 7.04% crude fiber and 61.29 and 71.36% total soluble carbohydrate, respectively. These results were in agreement with those obtained by Luminita *et al* (2018) and Baioumy *et al.* (2021) who found that the proximate composition of quinoa seeds were 14.12% crude protein, and 6.27 % crude fat and 56.80% total carbohydrate, respectively.

In the current study quinoa seeds powder had significantly higher crude protein content than Jerusalem artichoke powder which had significantly higher crude fiber and total soluble carbohydrate content than quinoa seeds powder. The high protein content of quinoa seeds powder is important and required to bind water. Moreover, the high fiber and carbohydrate content in quinoa seeds powder and Jerusalem artichoke powder are required for binding more water and fat, besides, it is important for manufacturing of low-fat meat products with lowest cooking losses.

Table 3. Proximate composition and bioactive compounds of quinoa powder seeds and Jerusalem artichoke powder.

Items	Quinoa seeds powder	Jerusalem artichoke powder	LSD at 0.05%
Proximate composition			
Moisture (%)	$7.63^{a}\pm0.06$	$6.81^{b}\pm0.05$	0.24
Crude protein (%)	$15.60^{a}\pm0.03$	$7.86^{b}\pm0.02$	0.05
Crude fat (%)	$5.86^{a}\pm0.01$	$1.32^{d}\pm0.04$	0.06
Ash (%)	$2.77^{b}\pm0.02$	$5.61^{a}\pm0.02$	0.04
Crude fiber (%)	$6.85^{b}\pm0.04$	$7.04^{a}\pm0.05$	0.09
* Total carbohydrate (%)	$61.29^{b}\pm0.06$	$71.36^{a}\pm0.07$	0.25
Fractionation of dietary fibers			
Total dietary fiber (TDF) (%)	$10.51^{b}\pm0.04$	$58.89^{a}\pm0.06$	0.12
Insoluble dietary fiber (IDF) (%)	$8.36^{a}\pm0.02$	$5.76^{b}\pm0.01$	0.08
Soluble dietary fiber (SDF) (%)	$2.15^{b}\pm0.01$	$53.13^{a}\pm0.05$	0.22
Bioactive compounds			
Total phenolic(mgGAE/g)	$6.96^{b}\pm0.01$	$9.39^{a}\pm0.02$	0.19
Total flavonoids(mgQE/g)	$1.26^{b}\pm0.02$	$6.76^{b}\pm0.03$	0.07

*Calculated by difference. LSD: Least significant differences

Jerusalem artichoke powder had significantly higher values of total and soluble dietary fiber content (58.89%, 53.13%, respectively) than those of quinoa seeds powder (10.51%, 2.15, respectively) but had significantly lower insoluble dietary fiber (5.76%) than quinoa seeds powder (2.15%). These results were in agreement with those given by Kahlon and Chiu (2015).

Quinoa seeds and Jerusalem artichoke powder are a good source of total phenolic and total flavonoids contents (Table 3). Jerusalem artichoke had significantly higher total phenolic (9.39 mg GAE/ g) and total flavonoids (6.76 mg QE /g) than quinoa seeds powder (6.96 mg GAE/ g and 1.26 mg QE /g, respectively). In this respect, Ozgoren *et al.* (2019) reported that the total phenolic content of Jerusalem artichoke powder was 624.18 mg GAE/100 g. Also, Naimati *et al.* (2022) mentioned that, quinoa seeds powder content were 287.01-1295.77 mg GAE/100g. The variation in phenolic content is likely due to the differences in local production area and the environmental conditions, agro technical processes and genetic contextual.

3. Effect of fat levels, type and levels of fat replacers and frozen storage at -18±1°C for 3 months on proximate composition of beef burger

Proximate composition of beef burgers as affected by fat levels, type and levels of fat replacers as well as frozen storage at -18±1°C up to 3 months are presented in Table (4). Moisture and fat contents of beef burger were highly affected by fat level ($p\leq0.05$). However, crude protein, total ash and carbohydrates contents were not significantly ($p>0.05$) affected by fat level. Low fat burger control had higher significantly ($p\leq0.05$) moisture content (71.64%) and lower fat content (4.52%) than high fat burger control. This is due to replacement of fat with water to prepare low fat burger control. Although fat tissue was not added during the manufacturing of low fat burger control (Table 1), butit contained 4.52%

fat when determined, this is due to the lean meat used in manufacturing containing 5.13% fat as shown in Table (2).These results were in line with those of Osheba *et al.,* (2008) who reported that high fat sausage had lower moisture content when compared with low fat sausage.

Moreover, all proximate composition of beef burgers was not significantly ($p>0.05$) affected by the type of fat replacers, except protein content was affected ($p\leq0.05$) by fat replacer type. Beef burger prepared with rehydrated quinoa seeds powder had significantly higher ($p\leq0.05$) protein content (14.88%) than beef burger prepared with rehydrated Jerusalem artichoke powder. This is due to quinoa had higher protein content (15.60%) than Jerusalem artichoke powder (7.86%) as shown in Table (3). These results were in agreement with those reported by ELKatry and Elsawy (2021); Shaat *et al.* (2020) and El-Beltagy *et al.* (2007).

The proximate composition of beef burgers was significantly affected ($p\leq0.05$) by levels of fat replacers. The moisture, protein, ash and carbohydratecontents of beef burgers significantly ($p\leq0.05$) increased by increasing levels of fat replacers from 0.0 to 100%. However, crude fat of beef burgers significantly decreased by increasing levels of fat replacers. Beef burger prepared by replacement fat with 100% fat replacers (rehydrated quinoa and Jerusalem artichoke) had a higher moisture (62.14%), crude protein (14.88%) and total ash content (3.89%) followed by beef burgers prepared by 75% fat replacers with no significant differences ($p>0.05$). These results were in agreement with those reported by El-Beltagy *et al.* (2007) who noticed that the proximate composition of patties as affected by replacing fat with different levels (25, 50, 75 and 100%) of boiled and rehydrated dried Jerusalem artichoke. Beef patties formulated with different levels of Jerusalem artichoke had significantly ($p\leq0.05$) higher moisture. Except for fat content which was significant increased in all chemical constituents of beef patties formulated by replacing 25, 50, 75 and 100% of fat**.**

Fat content of beef burgers significantly decreased from 21.11% for burger prepared without fat replacers (high fat control) to 13.09, 8.91 and 6.86% for burgers prepared by replacement fat with 50, 75 and 100% fat replacers, respectively.

Ash content of beef burgers was not significantly ($p>0.05$) affected by increasing fat replacers levels from 50 to 100%. However, carbohydrate content increased significantly ($p\leq0.05$) from 7.84% for burger prepared without fat replacers to 10.22, 11.94, 14.14% for burgers containing 50, 75 and 100% fat replacers, respectively.

Also, the proximate composition of beef burgers was significantly affected ($p< 0.05$) by frozen storage periods at -18±1°C for 3 months. Moisture and protein contents of beef burgers were significantly ($p \leq 0.05$) decreased by increasing frozen storage periods. This decrease in moisture content during storage may be due to the drip loss and partially the evaporation through the polyethylene bags, which were used for beef burger packing as reported by Mohamed (2011). The decrease in protein content during storage may be due to protein hydrolysis by natural meat enzymes and bacterial enzymes that are produced as well as the loss of water soluble protein with separated drip (EL-Desouky, 2009).

On the other hand, the crude fat, total ash and carbohydrates contents of beef burgers were significantly ($p\leq0.05$)

increased by increasing frozen storage periods. These increments might be attributed to the reduction of moisture and protein contents during frozen storage periods.These results were in accordance with those obtained by ELKatry and Elsawy (2021); Shaat *et al.* (2020) and El-Beltagy *et al.* (2007) who noticed that, beef patties formulated with boiled or dried Jerusalem artichoke had a significantly ($p \leq 0.05$) higher moisture, ash, protein and carbohydrate contents than those of control.

Table 4. Proximate composition of beef burger as affected by fat levels, type and levels of fat replacersas well as frozen storage at -18±1°C up to 3 months.

Items	Moisture (%)	Crude protein (%)	Crudefat (%)	Total ash (%)	Carbohydrates (%)
Levels of add fatfor control					
High fat control (20%)	54.72^{b}	13.08^{a}	21.11^{a}	3.26^{a}	7.83^{a}
Low fat control (0.0%)	71.64^{a}	13.39^{a}	4.52^{b}	3.04^{a}	7.41^{a}
LSD at 0.05%	2.354	1.287	0.861	0.631	2.159
Type of fat replacers					
Rehydrated Quinoa seeds	60.75^{a}	14.88^{a}	9.07^{a}	3.50^{a}	11.78^{a}
Rehydrated JA powder	60.69^{a}	14.22^{b}	8.88^{a}	3.80^{a}	12.41^{a}
LSD at 0.05%	1.483	0.410	2.977	0.392	1.524
Level of fat replacers					
0.0%	54.72^{c}	13.08^{c}	21.11^{a}	3.26^{b}	7.83^{d}
50%	59.04^{b}	14.22^{b}	13.09^{b}	3.44^{ab}	10.22^{c}
75%	60.98^{a}	14.56^{ab}	8.91^{c}	3.62^{ab}	11.94^{b}
100%	62.14^{a}	14.88^{a}	6.86^{d}	3.89^{a}	14.14^{a}
LSD at 0.05%	1.205	0.554	1.432	0.480	0.777
Storage periods (month)					
0	62.84^{a}	14.78^{a}	9.37^{d}	2.95^{d}	10.06^{d}
1	61.69^{b}	14.44^{b}	9.73^{c}	3.50^{c}	10.64^{c}
2	60.78^{c}	14.02^{c}	10.10^{b}	3.70^{b}	11.39^{b}
3	60.05^{d}	13.64^{d}	10.53^{a}	3.94^{a}	11.83^{a}
LSD at 0.05%	0.140	0.080	0.079	0.040	0.044

Mean values in the same column with different letters are significantly different ($p \leq 0.05$).

4. Effect of fat levels, type and level of fat replacers as well as frozen storage at-18±1°C up to 3 months on chemical quality characteristics and pH value beef burgers

Chemical quality attributes and pH values of beef burgers as affected not only by fat levels, type and levels of fat replacers and frozen storage at -18±1°C up to 3 months are presented in Table (5). From statistical analysis of these data it could be noticed that thiobarbituric acid (TBA) and pH value of beef burgers were significantly affected ($p < 0.05$) by the level of fat added to prepare high and low fat control samples. However, the total volatile nitrogen (TVN) of beef burgers was not affected ($p > 0.05$) by fat level. Low fat beef burger control had a significantly lower TBA (0.18 mg malonaldehyde/Kg of sample) and a significantly higher ($p > 0.05$) pH value (6.14) when compared with high fat beef burger control. This is due to low fat burger control prepared by replacement of fat with water. Also, pH values and thiobarbituric acid (TBA) of beef burgers were significantly affected

($p \leq 0.05$) by the type of fat replacers. However, the total volatile nitrogen (TVN) of beef burgers was not affected ($p > 0.05$).

Beef burgers prepared by replacement of fat with Jerusalem artichoke powder had significantly lower TBA value (0.44 mg malonaldehyde/Kg of sample) than beef burger prepared with quinoa seeds powder (0.55 mg malonaldehyde/Kg of sample). This is due to Jerusalem artichoke had significantly higher phenolic and flavonoids than quinoa seeds (Table 3) which could retard lipids oxidation beside had acidic effect. Also, beef burgers prepared by Jerusalem artichoke powder had significantly lower pH value (5.35) than that prepared with quinoa seeds powder 6.20). This may be due to Jerusalem artichoke had acidic effect because it treated with diluted lemon juice during it preparation.These results were in agreement with those reported by ELKatry and Elsawy (2021); Shaat *et al*. (2020) and El-Beltagy *et al*. (2007).

The pH values and chemical quality attributes (TBA and TVN) of beef burgers were not significantly ($p > 0.05$) affectedby replacement of fat with fat replacers at different levels (25, 75 and 100%). The pH values of beef burgers slightly ($p > 0.05$) increased from 5.40 to 5.73 by increasing fat replacers levels from 0.0 to 75.0%. These results are in agreement with Shaat *et al*. (2020) who reported increasing in pH of beef burger by increasing addition of whole quinoa flour (5, 10, 15%). On the hand, TBA values were slightly decreased from 0.54 to 0.49 mg malonaldehyde/Kg of sample by increasing levels of fat replacers from 0.0 to 75.0%. Moreover, the total volatile nitrogen of beef burgers significantly ($p \leq 0.05$) decreased from 12.39 to 9.93 mg/100g by increasing fat replacers levels from 0.0 to 100%. Beef burger prepared with 100% fat replacers had significantly lower TVN (9.53mg/100g), TBA0.44 mg malonaldehyde/Kg of sample) and had significantly higher pH value (5.97) when compared with burger prepared without fat replacer (high fat control).

The TVN, TBA and pH values of beef burgers were significantly ($p \leq 0.05$) increased by increasing frozen storage period. The increment of TVN during frozen storage could be attributed to the bacterial breakdown associated with the formation of some alkaline substances such as ammonia and confirmed the rapid development in total volatile nitrogen. Similar results were obtained by El-Beltagy *et al.* (2007) and Shaat *et al.* (2020) who found that increase in TVN and TBA of substituted samples were lesser than the control sample. The TVN and TBA increased with increasing storage time. At the end of cold storage period, TVN value of beef burger samples were within permissible levels as reported by the Egyptian standard (2005) which recommend that the TVN content in frozen beef burger not exceed 20 mg N_2/100g sample.

Also, the increment of TBA values during the frozen storage could be indicated continuous oxidation of lipids and consequently the production of oxidative by-products (Osheba *et al.,* 2013). In addition to ice crystals formed could injure the cell and cause the release of pro-oxidation, especially free iron (Osman and Zidan, 2014). Moreover, this increase in TBA value during frozen storage could be attributed to the psychrophilic bacteria producing lipases causing lipolytic activities of fats as well as increase the level of free fatty acid (Davies and Board, 1998).

Table 5. Chemical quality attributes and pH value of beef burger as affected by fat levels, type and levels of fat replacers as well as frozen storage at -18±1°C up to 3 months.

Items	pH value	TVN (mg/100g)	TBA (mgmalonaldehyde/kg)
Levels of fat for control			
High fat control	5.40[b]	12.39[a]	0.59[a]
Low fat control	6.14[a]	11.20[a]	0.18[b]
LSD at 0.05%	0.079	1.31	0.230
Type of fat replacers			
Rehydrated Quinoa seeds	6.20[a]	10.09[a]	0.55[a]
Rehydrated JA powder	5.35[b]	9.68[a]	0.44[b]
LSD at 0.05%	0.226	1.210	0.105
Level of Fat replacers			
0.0%	5.40[b]	12.39[b]	0.59[b]
50%	5.63[ab]	10.23[a]	0.54[ab]
75%	5.73[ab]	9.92[a]	0.49[ab]
100%	5.97[a]	9.53[a]	0.44[a]
LSD at 0.05%	0.530	1.520	0.138
Storage periods (month)			
0	5.64[d]	8.40[d]	0.33[d]
1	5.70[c]	9.76[c]	0.41[c]
2	5.83[b]	10.87[b]	0.52[b]
3	5.93[a]	12.43[a]	0.63[a]
LSD at 0.05%	0.055	0.039	0.036

Means in the same column with different letters are significantly different ($p \leq 0.05$).

5. Effect of fat levels, type and levels of fat replacers and frozen storage at -18±1°C for 3 months on physical and cooking properties parameters of beef burger.

From data in **Table (6)** it could be observed that water holding capacity and cooking properties (shrinkage, cooking yield and cooking loss) were significantly affected($p > 0.05$) not only by fat levels, type and levels of fat replacers but also by frozen storage at -18±1°C up to 3 months. High fat beef burger control had significantly ($p \leq 0.05$) higher water holding capacity (lower separated free water, 3.66 cm^2/0.3g) than low fat beef burger control (higher separated free water, 4.77cm^2/0.3g), this may be attributed to low fat control had higher moisture content (71.64%) than high fat burger control (54.72%) as shown in table (4) due to replacement of fat with water. High fat beef burger had lower ($p < 0.05$) shrinkage (27.05%) and cooking loss (28.83%), but higher ($p < 0.05$) cooking yield (71.17%) compared with low fat control The high losses in low fat burger control might be attributed to the excessive water separation during cooking and lower water holding capacity. These results were in agreement with El-Beltagy *et al.* (2007) they reported that, water holding capacity and cooking yield significantly increased by increasing of replacement level (25, 50, 75 and 100%) of fat with boiled or dried Jerusalem artichoke.

The water holding capacity and cooking parameters were significantly affected by the type and levels of fat replacers. Beef burgers prepared with rehydrated Jerusalem artichoke had significantly lower WHC (higher separated free water, 3.24cm^2 /0.3g) than beef burger prepared with rehydrated quinoa (2.78 cm^2/0.3 g). This may be due to lower pH value of Jerusalem artichoke which led to decrease ability of protein to bind water. Moreover, beef burger prepared with rehydrated Jerusalem artichoke had significantly higher shrinkage (19.70%), cooking loss (24.78%) and significantly lower cooking yield (75.22%) compared with beef burger prepared with rehydrated quinoa. This might be due to the loss of water holding capacity

Significant differences were recorded in WHC and cooking properties between burger prepared without fat replacers (0.0%) and burgers prepared with fat replacers at different levels (25, 50 and 100%). Also, WHC and cooking properties were significantly improved by increasing replacement levels with fat replacers. Similar results were obtained by Baioumy *et al*. (2018) who reported that cooking loss (%) of beef burger decreased by increasing the concentration of added quinoa seeds.

The water holding capacity and cooking properties of beef burgers were significantly affected (p≤ 0.05) by frozen storage periods at -18±1°C.The water holding capacity was significantly decreased (i.e., separated free water increased) with advancement of storage time from 2.95 cm^2/0.3g at zero time to 3.48 cm^2/0.3g at the third month of storage. Shrinkage and cooking loss of beef burger were significantly (p≤0.05) increased from 20.24 and 22.81% at zero time to 22.37 and 26.50%, respectively at the 3th month of storage. This might be due to protein denaturation and the loss of protein solubility which led to decrease the water holding capacity. This may be attributed to protein denaturation and loss of protein solubility. In this concern, Abd EL-Qader (2014) who reported that as the protein denaturants, its ability to bind water decreases.

Table 6. Physical properties of beef burger as affected by fat levels, type and levels of fat replacers and frozen storage at -18±1^{o}C up to 3 months.

Items	WHC ($cm^{2/}$0.3g)	Shrinkage (%)	Cookingloss (%)	Cookingyield (%)
Levels of add fat for control				
High fat control	3.66^b	27.05^b	28.83^b	71.17^a
Low fat control	4.17^a	28.99^a	32.11^a	67.89^b
LSD at 0.05%	0.39	1.31	2.65	3.55
Type of fat replacers				
Rehydrated Quinoa seeds	2.78^b	18.30^b	20.15^b	79.85^a
Rehydrated JA powder	3.24^a	19.17^a	24.78^a	75.22^b
LSD at 0.05%	0.193	0.79	2.037	2.186
Level of fat replacers				
0.0%	3.66^a	27.05^a	28.83^a	71.17^c
50%	3.15^b	19.45^b	24.90^b	75.10^b
75%	3.02^{bc}	18.76^{bc}	21.73^c	78.27^a
100%	2.86^c	18.00^c	20.77^c	79.23^a
LSD at 0.05%	0.27	1.12	3.06	2.68
Storage periods (month)				
0	2.95^d	20.24^d	22.81^d	77.19^a
1	3.19^c	20.63^c	23.76^c	76.24^b
2	3.33^b	20.98^b	24.80^b	75.20^c
3	3.48^a	22.37^a	26.50^a	73.50^d
LSD at 0.05%	0.03	0.24	0.44	0.48

Means in the same column with different letters are significantly different (p≤0.05).

5. Effect of fat levels, type and levels of fat replacers on texture profile analysis of cooked beef burger.

The Textural profile analysis (firmness, cohesiveness, gumminess, chewiness, springiness and resilience) ofcooked beef burger samples as affected by fat level, type and levels of fat replacers are shown in Table (7). From these data, it could be noticed that, firmness was significantly ($p>0.05$) increased from 16.48 to 17.16 N by replacement of fat (high fat beef burger control) with water (low fat beef burger control). These results are agreement with Zapata and Pava (2018) they reported that the hardness and shear force of the sausages increased with the addition of quinoa flour. This may be due to a lower moisture content was observed, which may explain the higher hardness values.

On the other hand, other texture profile such as cohesiveness, gumminess, chewiness and springiness were significantly ($p\leq0.05$) decreased from 0.77, 12.68, 10.27 and 0.81 for high fat control to 0.71, 12.18, 8.40 and 0.69, respectively for low fat control. This might be due to higher water loss from low fat control sample than fat loss from high fat control sample during cooking which led to hardness of low fat control sample during measuring.

Firmness and other texture profile were significantly affected ($p\leq0.05$) bythe type and levels of fat replacers. Firmness of beef burger was significantly ($p\leq0.05$) increased by increasing fat replacement levels withfat replacers which increased from 16.48 for high fatcontrol to 16.92, 18.73 and 20.54 for rehydrated quinoa and to 16.54, 17.50 and 18.49 for rehydrated Jerusalem artichoke at 50, 75 and 100% replacement levels, respectively.

Also, cohesiveness, gumminess, chewiness and springiness were significantly ($p\leq0.05$) increased by increasing fat replacers levels from 50 to 75% and then decreased ($p\leq0.05$) by increasing fat replacers to 100%. Cohesiveness values ranged from 0.59 to 0.92. The highest cohesiveness value was recorded for beef burger prepared by replacement fat with rehydrated quinoa 75% followed by beef burger with rehydrated Jerusalem artichoke at 75% withoutsignificant differences between them. The gumminess,chewiness and springiness of different beef burger ranged from 9.76 to 17.23 g,8.11 to 18.43 and 0.65 to 1.07, respectively. Beef burger prepared by substitute fat with rehydrated quinoa at 75% had significantly ($p\leq0.05$) higher gumminess (17.23 g), chewiness (18.43) and springiness (1.07) than other beef burger treatments. These results were in line with the results of sensory evaluation which obtained by panelists. The values of texture profile analysis are similar to that reported by some researchers on different cooked burger and sausages treated with quinoa seed flour, ELKatry and Elsawy (2021) and Shaat*et al.* (2020) noticed that, texture properties of sausage are affected by substitute levels of quinoa seed flour of beef sausage.

Table (7): Texture profile analysis of beef burgers as affected by fat levels, type and levels of fat replacers.

Treatments		Texture profile parameters				
		Firmness (N)	Cohesiveness	Gumminess (g)	Chewiness (g×mm)	Springiness (mm)
High fat control		16.48^{h}	0.77^{bc}	12.68^{e}	10.27^{e}	0.81^{d}
Low fat control		17.16^{e}	0.71^{d}	12.18^{f}	8.40^{f}	0.69^{e}
Rehydrated quinoa	50%	16.92^{f}	0.63^{e}	10.66^{g}	8.21^{g}	0.77^{d}
	75%	18.73^{b}	0.92^{a}	17.23^{a}	18.43^{a}	1.07^{a}
	100%	20.54^{a}	0.78^{b}	16.02^{b}	10.41^{d}	0.65^{e}
Rehydrated Jerusalem artichooke	50%	16.54^{g}	0.59^{e}	9.76^{h}	8.11^{h}	0.83^{cd}
	75%	17.50^{d}	0.87^{a}	15.22^{c}	14.91^{b}	0.98^{b}
	100%	18.49^{c}	0.72^{cd}	13.31^{d}	11.85^{c}	0.89^{c}
LSD at 0.05%		0. 56	0.06	0.35	0.18	0.06

6. Effect of fat levels, type and levels of fat replacers and frozen storage at -18±1°C for 3 months on sensory evaluation of beef burgers

From statistical analysis of data in Table (8) it could be noticed that some sensory properties such as taste, odor and overall acceptability of beef burger samples were significantly affected ($p \leq 0.05$) by fat level. High fat beef burger control had significantly higher taste score (9.23), odor (8.19) and overall acceptability (8.80) than low fat beef burger control. On the other hand, color and texture scores were not significantly affected ($p > 0.05$) by replacement of fat in high fat control (9.31 and 7.81, respectively) with water in low fat control (8.80 and 7.73, respectively).

All sensory properties of beef burgers were not significantly affected by type of fat replacers, but affected ($p \leq 0.05$) by fat replacement levels with fat replacers. Beef burgers prepared with rehydrated quinoa slightly ($p > 0.05$) higher odor (8.68), color (8.89), texture (8.36) and overall acceptability (9.17) than burgers prepared with rehydrated Jerusalem artichoke which had slightly ($p > 0.05$) higher taste score (8.96).

Taste scores of beef burgers tend to decrease with increasing fat substitution with fat replacers, but these decreases were not significantly affected by increasing fat replacers levels up to 75% when compared with high fat control sample. The highest taste score (9.23) was recorded for high fat control followed by burgers prepared with replacement fat by fat replacers at 50 and 75% without significant differences. The lowest taste score (8.48) was given by panelists for burger prepared with 100% fat replacers followed by burger prepared with 75% fat replacers (8.79) with no significant differences between them.

Replacement fat with fat replacers increased odor scores of beef burgers. These increases were significant higher at 50% replacement level when compared with high fat beef burger control, but not significant higher at 75 and 100% fat replacer when compared with high fat control. The highest odor score (8.84) was recorded for beef burgers prepared with50% fat replacers followed by beef burger contain 75.0% fat replacers without significant differences ($p > 0.05$), also between high fat control and burgers prepared with 50.0% fat replacers.

Color scores of beef burgers significantly decreased from 9.09 to 8.60 by increasing fat replacers level from 50 to 100%. On the contrary, texture scores were significantly increased from 8.09 to 8.57 by increasing fat replacers from 50 to 100%. No significant differences were recorded in color and texture scores between beef burgers prepared with 50% and 75% fat replacers ($p > 0.05$), also between high fat control and burgers prepared with 50.0% fat replacers.

Overall acceptability scores of beef burgers were significantly ($p> 0.05$) increased from 8.80 for high fat control to 9.32 by substitution fat with 50% fat replacers. On the other hand, overall acceptability scores of beef burgers significantly decreased from 9.32 to 8.96 by increasing fat replacers level from 50 100%.

Table (8). Sensory properties of beef burger as affected by fat levels, type and levels of fat replacers as well as frozen storage at -18±1°C up to 3 months.

Items	Taste (10)	Odor (10)	Color (10)	Texture (10)	Overall Acceptability (10)
Levels of add fat for control					
High fat control	9.23[a]	8.19[b]	9.13[a]	7.81[a]	8.80[a]
Low fat control	7.00[b]	7.49[a]	8.80[a]	7.73[a]	7.31[b]
LSD at 0.05%	0.77	0.68	0.71	1.13	0.80
Type of fat replacers					
Rehydrated Quinoa seeds	8.58[a]	8.68[a]	8.89[a]	8.36[a]	9.17[a]
Rehydrated JA powder	8.96[a]	8.49[a]	8.80[a]	8.29[a]	9.09[a]
LSD at 0.05%	0.38	0.37	0.27	0.355	0.286
Levels of fat replacers					
0.0%	9.23[a]	8.19[b]	9.13[a]	7.81[c]	8.80[c]
50%	9.05[a]	8.84[a]	9.09[ab]	8.09[bc]	9.32[a]
75%	8.79[ab]	8.56[ab]	8.85[bc]	8.31[ab]	9.12[ab]
100%	8.48[b]	8.35[b]	8.60[c]	8.57[a]	8.96[bc]
LSD at 0.05%	0.46	0.42	0.26	0.39	0.31
Storage periods (month)					
0	9.03[a]	8.92[a]	9.20[a]	8.63[a]	9.26[a]
1	8.83[a]	8.57[b]	8.98[ab]	8.30[b]	9.04[a]
2	8.46[b]	8.20[c]	8.80[b]	7.98[c]	8.72[b]
3	8.11[c]	7.88[d]	8.51[c]	7.68[d]	8.44[c]
LSD at 0.05%	0.230	0.236	0.240	0.234	0.233

Mean values in the same column with different letters are significantly different ($p \leq 0.05$).

Sensory properties of beef burgers were significantly affected ($p \leq 0.05$) by frozen storage periods at -18±1°C. The taste, odor, color, texture and overall acceptability scores of beef burger were significantly ($p < 0.05$) decreased by increasing the storage period. This might be attributed to oxidation potential of fatty acids present in all beef burger resulted in generation of secondary products of fatty acid auto-oxidation such as aldehydes, ketones, hydrocarbons, esters, fuirans and lactans. Sensory properties of beef burgers were significantly affected ($p \leq 0.05$) by frozen storage periods at -18±1°C. The taste, odor, color, texture and overall acceptability scores of beef burger were significantly ($p < 0.05$) decreased by increasing the storage period. This might be attributed to oxidation potential of fatty acids present in beef burgers resulted in generation of secondary products of fatty acid auto-oxidation such as aldehydes, ketones, hydrocarbons, esters, fuirans and lactans. These products are probably responsible for flavor deterioration during storage (Hyldig *et al.,* 2012). These results are in agreement with Bahmanyar *et al.* (2021) and Shaat *et al.* (2020) they noticed that, beef sausage samples containing quinoa flour exhibited a good sensory characteristics and better acceptability, especially those contained 5 and 10 %, even after frozen storage for 3 months. It was concluded that using quinoa flour into beef sausage partial replacement of meat improving nutritional, functional, sensory evaluation and lowering the cost of product.

CONCLUSION

The present study highlighted on properties of low and reduced fat beef burgers prepared by replacement of fat at different levels (50, 75 and 100%) with rehydrated quinoa seeds and rehydrated Jerusalem artichoke as fat replacers. From the data, it could be noticed that the quinoa seeds and Jerusalem artichoke are a good source of the total phenolic and flavonoids contents as well as the total dietary fiber. Replacement of fat with fat replacers at different levels led to improve the chemical and physical quality besides cooking parameters (shrinkage and cooking yield) as well as sensory properties. It could be recommended commercially to use rehydrated quinoa seeds and Jerusalem artichoke (as fat replacers) to replace fat in beef burger up to 75% to produce healthy beef burger without negative effects on quality attributes.

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معايير جودة برجر اللحم منخفض و قليل الدهن باستخدام الكينوا و خرشوف القدس كبدائل للدهون أثناء التخزين المجمد عند - ١٨درجة مئوية

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المستخلص

الهدف من الدراسة انتاج هامبورجر اللحم البقري قليل ومنخفض الدهون المحضر باستبدال الدهون بمستويات مختلفة (٥٠، ٧٥، ١٠٠%) ببذور الكينوا المعاد ترطيبها وخرشوف القدس المعاد ترطيبها كبدائل للدهون. وقد اتضح من البيانات أن بذور الكينوا و الخرشوف القدس يعتبر مصدرًا جيدًا لمحتويات الفينول والفلافونويد الكلية بالإضافة إلى إجمالي الألياف الغذائية. أدى استبدال الدهون ببدائل الدهون بمستويات مختلفة إلى تحسين ليس فقط سمات الجودة الكيميائية والفيزيائية ولكن أيضًا معايير الطهي (الانكماش وإنتاجية الطهي) أيضًا. كخصائص حسية. يمكن التوصية تجاريًا باستخدام بذور الكينوا المعاد ترطيبها والخرشوف القدس (كبديل للدهون) لاستبدال الدهون في برجر اللحم البقري بنسبة تصل إلى ٧٥٪ لإنتاج برجر لحم بقري صحي دون آثار سلبية على صفات الجودة.