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Quality Characteristics of Camel Burger Formulated with Different Levels of Microalgae

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HIGHLIGHTS:

- *Spirulina* addition significantly affected fatty acids profile and amino acids content.
- Using *Spirulina* in formulation of camel burger resulted in delayed the lipid oxidation during frozen storage.
- Addition of *Spirulina* significantly affected color parameters.
- *Spirulina* addition improved fat retention and moisture retention.
- Formulation of camel burger with *Spirulina* had no significant effect on cooking loss or tenderness of camel burger.

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Acronyms and abbreviations
MUFA=Monounsaturated Fatty Acid
PUFA=Polyunsaturated Fatty Acid
SFA=Saturated Fatty Acid
TBA=Thiobarbituric Acid

ABSTRACT

Background: *Spirulina platensis* (*S. platensis*) is a microalga. It has high levels of protein, essential amino acids, fatty acids, high concentrations of vitamins, and minerals. This study aims to evaluate the effect of adding *S. platensis* on the quality characteristics of camel burger.

Methods: *Spirulina* was added at different levels (0.5, 1, and 1.5%) to the formulation of camel burger and its effect was studied on fatty acids profile, amino acids content, lipid oxidation, physical, and microbiological quality during frozen storage at -20 ºC for 90 days. Data were analyzed using statistical analysis system (SAS, 2000).

Results: Significant changes ($p<0.05$) were found in fatty acids profile and amino acids content of formulated camel burger. The highest fat retention and moisture retention was found in camel burger formulated with *Spirulina*. PH value increased as the level of *Spirulina* increased. Fresh camel burger formulated with *Spirulina* significantly ($p<0.05$) reduced color parameters (L*, a*, and b*) more than that of the control burger. No significant differences ($p>0.05$) were found in cooking loss, shear force, and microbiological profile of fresh camel burger treatments.

Conclusion: Addition of different levels of *Spirulina* in the formulation of camel burger improved fatty acids and amino acids profile, increased water retention and fat retention, and delayed lipid oxidation during frozen storage, without any negative effects on shear force values, cooking loss, and microbiological quality.

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Introduction

Meat and its products are the most important sources of nutrients especially proteins, fats, minerals, and vitamins. The increasing price of red meat has encouraged the manufactures to search for new, healthier, and cheaper alternatives required for processing of meat products (Abdel-Naeem and Mohamed, 2016). Although camel meat can be considered a valuable raw material for making meat products, the problem of higher connective tissue content in camel meat remains one of the most important obstacles facing the manufactures in meat processing (Kadim et al., 2008). Therefore, many studies have addressed improving the quality characteristics of camel meat in order to be more suitable for further processing of products; this was done to enhance the customers' willingness for consumption of camel meat products and encourage the manufactures for producing high quality camel meat products.

Lately, the strategies used to improve the quality of meat products basically depended on the modification of their composition by incorporating some functional and bioactive components. Cereals, legumes, and algae can constitute a good and rich source of bioactive compounds (Ursachi et al., 2020).

Microalgae are mainly composed of proteins, polysaccharides, fatty acids, and antioxidants, especially phenolic acids, flavonoids, and carotenoids (Barba et al., 2015). *Spirulina platensis* (*S. platensis*) is a microalga which belongs to the division cyanobacteria, class cyanophyceae, and family *Oscillatoriaceae*, originated from Africa and Latin America. *S. platensis* is a filamentous cyanobacteria (blue-green algae), with high levels of protein comparable to meat and soybeans, essential amino acids, fatty acids, and high concentrations of vitamins and minerals (Lupatini et al., 2017).

Recently, scientific researchers have been studied the effect of microalgae addition on processed meat and on the quality characteristics such as pork patties (Moroney et al., 2013), fish burger (Barkallah et al., 2019), beef patties (Žugčić et al., 2018), and pork sausage (Luo et al., 2017).

Therefore, this study aims to investigate the effect of adding different levels of *S. platensis* to camel burger formulation and its impacts on physicochemical and microbiological quality during frozen storage.

Materials and methods

Preparation of camel burger

Fresh camel meat and hump fat of 3-years-old Arabian one-humped camels (*Camelus dromedarius*) were obtained from a slaughter house (Cairo, Egypt) and transported to the laboratory for burger processing. Camel meat and hump fat were separately ground through a 3-4 mm plat meat grinder (K.R.SU: KMG1,700, China). Sixty-five percent lean camel meat, 17% hump fat, 7.5% onion, 1.8% sodium chloride, 0.2% black pepper, and 8.5% water were used for burger processing as described in Abdel-Naeem and Mohamed's study (2016). The mixture was divided into the following four treatment groups: (T1), control without adding *Spirulina* and the other treatments (T2, T3, and T4), were prepared with (0.5, 1.0, and 1.5%) of *S. platensis* as shown in Figure 1. Each formula was mixed by hand and through manual burger press machine (Metaltex No. 25.17.25, Made in PRC). Camel burgers (1 cm thickness, 10 cm diameter, and 65±2 g weight) were placed in foam trays packed in polyethylene bags and frozen at -20 ºC±2 until further analysis.

Chemical analysis

-Fatty acids profile

The fatty acids of camel burger was determined as described by Folch et al. (1957). The fatty acids are methylated with boron trifluoride in methanol, extracted with heptane and determined by a Gas Chromatograph (GC/MS/MS Agilent7, 000, Germany) with Flame Ionization Detector (FID) (PE Auto System XL) with an auto-sampler and EZ chrome integration system.

-Amino acid analysis

The amino acids profile of camel burger was carried out according to AOAC International (2012). Quantitative determination of amino acids was carried out using amino acid analyzer Biochrome 30+ (Biochrom Ltd Manufacturer, UK). EZ chrome software used for data collection and processing.

-Moisture and fat content

Moisture and fat content were determined according to AOAC International (2012).

The cooking yield and fat retention of camel burger were determined according to Murphy et al. (1975) as follows:

$$\text{Fat retention (\%)} = \frac{(\text{cooked sample weight}) \times (\%\text{fat in cooked sample})}{(\text{raw sample weight}) \times (\%\text{fat in raw sample})} \times 100$$

Moisture retention was determined according to El-Magoli et al. (1996) using the following equation:

$$\text{Moisture retention(\%)} = \frac{(\text{cooking yield \%} \times \text{moisture \% in cooked sample})}{100}$$

-Thiobarbituric Acid (TBA) value

The lipid oxidation in raw camel burger was determined

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by measuring 2- Thiobarbituric Acid Reactive Substances (TBARS) as described by AOCS (1998). Results were expressed as µmol TBARS/g.

Physical analysis

-pH value

pH values were measured in raw camel burger as described by Khalil, (2000) using a digital pH-meter (Jenway 3,320 conductivity and pH meter, England).

-Cooking measurements

The cooking loss of camel burger was determined as described by Naveena et al. (2006) as follows:

$$\text{Cooking loss (\%)} = \frac{(\text{uncooked sample weight}) - (\text{cooked sample weight})}{(\textit{uncooked sample weight})} \times 100$$

$$\text{Cooking yield (\%)} = \frac{(\text{cooked sample weight})}{(\text{uncooked sample weight})} \times 100$$

-Shear force value

Shear force value of each cooked camel burger was determined using Instron Universal Testing Machine (Model 2,519-105, USA) for three times at different positions. Results were expressed in Kg/f.

-Color measurements

Color parameters (L*, a*, and b*) of raw camel burger were measurements according to Commission International de l´Eclairage (CIE, 1977) using Chroma meter (Konica Minolta, model CR 410, Japan). The color was expressed as lightness (L* value), redness (a* value), and yellowness (b* value).

Microbiology analysis

The microbiological analysis of raw camel burger was determined at 0, 30, 60, and 90 days of storage at -20 °C. Total bacterial and psychrotrophic bacteria counts were determined according to Ercolini et al. (2009). Plate count agar (PCA; Oxoid) was used and incubated aerobically at 30 °C for 72 h and 7 °C for 10 days to enumerate psychrotrophic bacteria. Molds and yeasts were determined by potato dextrose agar medium (Biolab, PH EUR - USP, Hungary) according to NMKL (2005). The plates were incubated at 20-22 ºC for 72 h. Results were expressed as log Colony Forming Unit (CFU)/g.

Statistical analysis

All data were analyzed using statistical analysis system (SAS, 2000). Two-way ANOVA was applied for pH, shear force, cooking loss, color measurements, TBA values, and microbiological quality. One-way ANOVA was applied for fatty acid, amino acid, moisture retention, and fat retention.

Results

Fatty acids profile

Fatty acids profile of camel burger formulated with different levels of *Spirulina* are shown in Table 1. The largest proportion of Saturated Fatty Acids (SFAs) were palmitic (C16:0) and stearic (C18:0) acids, followed by myristic acid (C14:0). The burger formulated with 1% *Spirulina* had a high content of palmitic acid followed by burger with 0.5% *Spirulina*. No significant differences (p>0.05) were found between control burger and burger with 1.5% *Spirulina.* Stearic acid (C18:0) content significantly increased (p<0.05) as the level of *Spirulina* increased. In contrast, myristic acid (C14:0) content significantly decreased (p<0.05) as the level of *Spirulina* increased.

However, the highest SFA content was found in control burger formulated with 1% *Spirulina*, while burger formulated with 0.5 and 1.5% *Spirulina* had the lowest values. Oleic acid (C18:1ω9) was the major proportion of Monounsaturated Fatty Acid (MUFA) and significantly increased (p<0.05) as the level of *Spirulina* increased; therefore, burger formulated with 1.5% *Spirulina* exhibited the highest content. However, no significant differences were found in total MUFA of camel burger treatments. Among Polyunsaturated Fatty Acids (PUFA), linoleic acid (C18:2ω6) was predominant in burger formulated with 0.5% *Spirulina*, and no significant differences (p>0.05) were found in other formulated or control burgers. It can be noticed that increasing the level of *Spirulina* in burger formulations resulted in significant decrease in (p<0.05) α linolenic acid (C18:3ω3). However, the burger formulated with 0.5% *Spirulina* exhibited the highest proportion of PUFA and no significant differences (p>0.05) were found between the other treated samples or control burgers.

Amino acid analysis

Data of amino acids regarding camel burger formulated with different levels of *Spirulina* are shown in Table 2. The hydrolyzed amino acids profile of the camel burgers included 85% of total amino acids constituting food proteins. The highest non-essential amino acid in all burger samples was glutamic acid, followed by aspartic acid. Glutamic acid was significantly higher (p<0.05) in the burger formulated with high levels of *Spirulina* compared with the control burger. No significant differences were found in aspartic acid among burger treatments except for the burger formulated with 0.5% *Spirulina*. Regarding essential amino acids, lysine was the predominant amino acid in all burger treatments followed by leucine and arginine. No significant

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difference (p>0.05) was found with regard to lysine content between the burger formulated with 1.5% *Spirulina* and the control burger. Slight significant difference was found in the burger formulated with 1% *Spirulina*, while the lowest value was found in burger formulated with 0.5% *Spirulina.* A similar finding was observed in leucine and arginine. Data indicated that no significant differences (p>0.05) were found in leucine and arginine content of the burger formulated with 1 and 1.5% *Spirulina* and the control burger. The lowest content was found in the burger formulated with 0.5% *Spirulina*.

Moisture and fat retention

Moisture and fat retention of the camel burger formulated with different levels of *Spirulina* are shown in Figure 2. No significant difference (p>0.05) was found in moisture retention among burger treatments, although the burger treated with different levels of *Spirulina* exhibited higher value than in the control group. On the other hand, the lowest fat retention was found in the control burger, while no significant differences (p>0.05) were found in treated camel burger.

pH value

Results of pH values of the raw camel burger formulated with different levels of *Spirulina* are shown in Table 3. It can be claimed that no significant differences (p>0.05) were found in pH values of camel burger; nevertheless, the burger treated with *Spirulina* exhibited slightly higher pH values compared with the control burger. Also, pH value increased as the level of *Spirulina* increased.

Regarding frozen storage, it can be noticed that pH values of all camel burger samples significantly increased (p<0.05) up to 60 days of frozen storage, then surprisingly decreased at the end of frozen storage period of 90 days.

Shear force value

Results of shear force values (tenderness) of camel burger formulated with different levels of *Spirulina* during frozen storage are demonstrated in Table 3. It can be noticed that at zero-time, control burger had higher shear force value (less tender) than formulated burger. Based on the present data, addition of *Spirulina* had no significant effect (p>0.05) on shear force values during frozen storage.

Cooking loss

Results of cooking loss (%) of camel burger formulated with different levels of *Spirulina* during frozen storage are presented in Table 3. It can be found that no significant differences (p>0.05) were found in cooking loss of fresh camel burger treatments. Regarding frozen storage, all burger treatments significantly increased (p<0.05) after 30 days of storage. Cooking loss of control burger sample and 0.5% *Spirulina* significantly decreased after 60 days and the decrease continued to the end of storage period 90 days. This was while cooking loss % of burger formulated with 1% *Spirulina* remained stable during 60 days and increased at the end of 90 days. The burger formulated with 1.5% *Spirulina* exhibited significant decrease (p<0.05) in cooking loss (%) during 60 days and increased at the end of storage time. During storage period up to 60 days, the burger formulated with *Spirulina* showed lower cooking loss than control samples. At the end of 90 days, the burger formulated with 0.5% *Spirulina* showed the lowest cooking loss.

Color parameters

Data of Table 3 illustrated color parameters (L*, a*, and b*) values of camel burger during frozen storage. It can be noticed that at zero-time, color parameters (L*, a*, and b*) of the camel burger formulated with *Spirulina* were lower than the control burger. On the other hand, the reduction in color parameters (L*, a*, and b*) were increased as the level of *Spirulina* increased. Regarding frozen storage, L* values significantly decreased (p<0.05) after 30 days and remained stable during 60 days in all burger samples except for the burger formulated with 1.5% *Spirulina* which exhibited stability in L* value during 30 days; it significantly decreased (p<0.05) after 60 days. At the end of storage period, significant increase (p<0.05) was found in L* values in all camel burgers. Control burger exhibited significant increase (p<0.05) in a* value after 30 days and significantly decreased (p<0.05) till the end of the frozen period. On the other hand, the burger formulated with *Spirulina* showed a different pattern. The burger formulated with 0.5% *Spirulina* significantly decreased (p<0.05) in a* value at the end of 90 days. The burger formulated with 1% showed a significant decrease (p<0.05) after 30 days and remained stable during 60 and 90 days. The burger formulated with 1.5% *Spirulina* exhibited instability in a* value during the storage time. Control burger showed significant increase (p<0.05) in b* value during 60 days and decreased at the end of the storage time. Camel burger formulated with *Spirulina* exhibited significant increase (p<0.05) in b* values after 30 days in all camel burgers except for the camel burger formulated with 1.5% *Spirulina*. The control burger and the burger with 0.5% *Spirulina* showed significant increase (p<0.05) after 60 days and significantly decreased again (p<0.05) at the end of storage time. Conversely, the burger formulated with 1% *Spirulina*

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decreased significantly after 60 days and significantly increased (p<0.05) at the end of storage time. This was while the burger with 1.5% *Spirulina* significantly increased (p<0.05) after 60 days and the increase continued till the end of the period.

TBA values

Results of TBA values for camel burger are shown in Table 3. Data showed that TBA values of the burger formulated with *Spirulina* exhibited the lowest TBA. Based on the present data, significant differences were found during frozen storage. TBA value of control burger gradually decreased during storage period for 90 days. In contrast, TBA value of the burger formulated with 0.5% of *Spirulina* gradually increased (p<0.05) during storage time. This was while the burger formulated with 1% *Spirulina* exhibited significant decrease (p<0.05) after 30 days and increased up to the end of the storage period.

Microbiological quality

Total bacterial count, mold, yeast, and psychrophilic bacterial of camel burger formulated with different levels of *Spirulina* are shown in Table 4. Concerning *Spirulina* addition, no significant differences (p>0.05) were found in microbiological profile among burger samples. During frozen storage, total bacterial, mold, yeast, and psychrophilic counts significantly increased (p<0.05) after 60 days, and surprisingly, decreased at the end of 90 days.

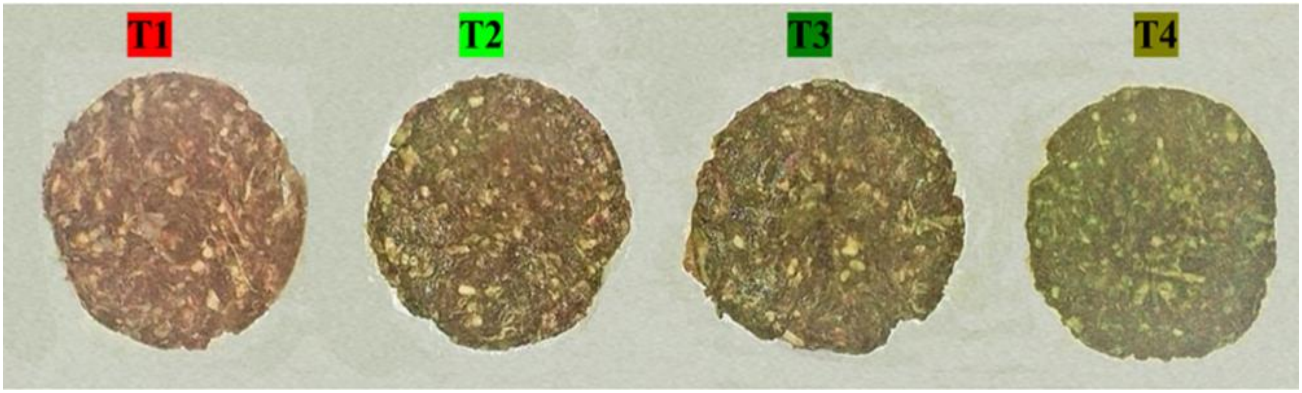

Figure 1: Camel burger formulation. T1: control burgers; T2: burgers formulated with 0.5% *Spirulina*; T3: burgers formulated with 1% *Spirulina*; T4: burgers formulated with 1.5% *Spirulina*

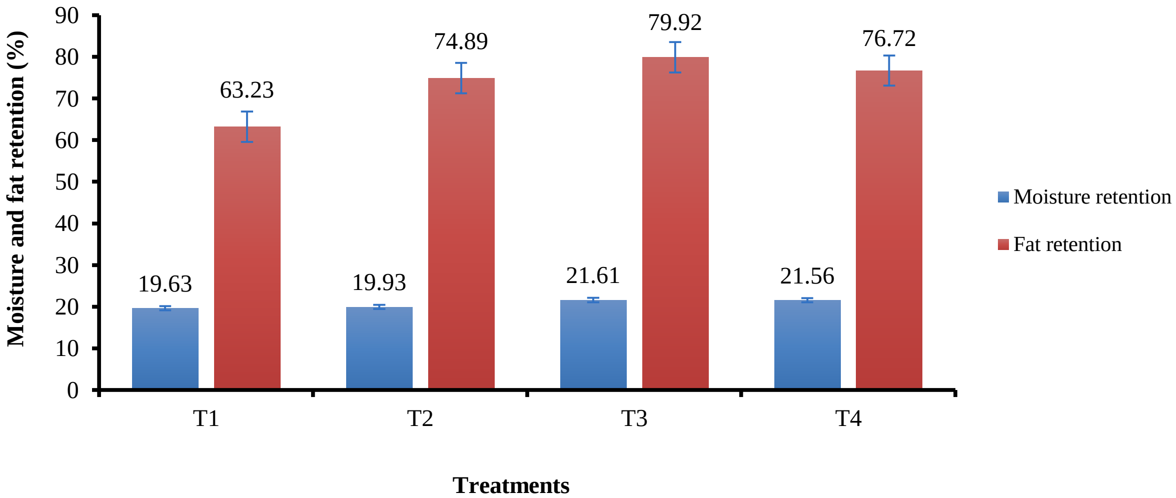

Figure 2: Moisture and fat retention (%) of camel burger

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Table 1: Fatty acids composition (% of total fatty acids) of camel burger formulated with different levels of *Spirulina*

Fatty acids		T1	T2	T3	T4	SEM
Lauric acid	C12:0	0.28 ^{b}	0.39 ^{a}	0.22 ^{c}	0.18 ^{c}	0.01
Myristic acid	C14:0	5.48 ^{ab}	5.57 ^{a}	5.35 ^{b}	4.88 ^{c}	0.06
Pentadecanoic acid	C15:0	1.37 ^{ab}	1.38 ^{a}	1.31 ^{ab}	1.32 ^{b}	0.01
Palmitic acid	C16:0	28.72 ^{c}	29.32 ^{b}	30.21 ^{a}	28.48 ^{c}	0.13
Heptadecanoic acid	C17:0	2.10 ^{ab}	1.99 ^{c}	2.05 ^{b}	2.12 ^{a}	0.01
Stearic acid	C18:0	24.00 ^{a}	21.94 ^{c}	23.17 ^{b}	23.94 ^{a}	0.21
Arachidic acid	C20:0	0.23 ^{a}	0.22 ^{a}	0.20 ^{a}	0.22 ^{a}	0.01
∑SFA		62.19 ^{a}	60.82 ^{b}	62.52 ^{a}	61.19 ^{b}	0.12
Tetradecenoic acid	C14:1ω5	0.18 ^{b}	0.19 ^{b}	0.19 ^{b}	0.23 ^{a}	0.03
	C16:1ω7	2.24 ^{a}	2.39 ^{a}	2.27 ^{a}	0.91 ^{b}	0.33
	C18:1ω13	-	0.22	-	0.21	
Oleic acid	C18:1ω9	25.50 ^{b}	25.23 ^{b}	25.48 ^{b}	26.34 ^{a}	0.15
Vaccinic acid	C18:1ω7	2.93 ^{a}	2.89 ^{a}	3.07 ^{a}	3.03 ^{a}	0.05
	C18:1ω5	1.17 ^{a}	1.17 ^{a}	1.22 ^{a}	1.26 ^{a}	0.03
Gadolic acid	C20:1ω9	0.13	0.14	0.14	-	
∑MUFA		32.16 ^{a}	32.03 ^{a}	32.39 ^{a}	32.04 ^{a}	0.40
	C16:2ω4	0.16 ^{a}	0.15 ^{ab}	0.14 ^{b}	0.15 ^{ab}	0.04
	C18:2ω7	-	0.16	-	0.19	
Linoleic acid	C18:2ω6	2.55 ^{b}	3.66 ^{a}	2.43 ^{b}	2.60 ^{b}	0.08
	C18:2ω5	-	1.18	1.23	-	
	C18:2ω4	0.14	0.16	0.16	-	
Decatrienoic acid	C16:3ω4	0.43 ^{a}	0.41 ^{a}	0.39 ^{a}	0.42 ^{a}	0.01
γ Linolenic acid	C18:3ω6	0.19 ^{b}	0.19 ^{b}	0.20 ^{b}	0.23 ^{a}	0.04
α Linolenic acid	C18:3ω3	0.72 ^{b}	0.83 ^{a}	0.66 ^{c}	0.60 ^{d}	0.06
α Octadectetraenoic	C18:4ω3	0.32 ^{a}	0.31 ^{a}	0.30 ^{a}	0.30 ^{a}	0.07
Arachidonic acid	C20:4ω6	0.18	0.23	-	0.15	
∑PUFA		4.71 ^{b}	6.46 ^{a}	4.42 ^{b}	4.62 ^{b}	0.09
∑UFA		36.88 ^{b}	38.48 ^{a}	36.81 ^{b}	36.67 ^{b}	0.45
UFA/SFA		0.59 ^{b}	0.63 ^{a}	0.59 ^{b}	0.59 ^{b}	0.07
MUFA/SFA		0.52 ^{a}	0.52 ^{a}	0.52 ^{a}	0.52 ^{a}	0.06
PUFA/SFA		0.07 ^{b}	0.10 ^{a}	0.07 ^{b}	0.07 ^{b}	0.02
∑ω6		2.93 ^{b}	4.08 ^{a}	2.63 ^{c}	2.99 ^{b}	0.08
∑ω3		1.04 ^{b}	1.14 ^{a}	0.96 ^{c}	0.90 ^{d}	0.01
n-6: n-3		2.79 ^{c}	3.57 ^{a}	2.74 ^{c}	3.29 ^{b}	0.07

$^{a-d}$ Means within the same row with different superscripts letters are different (p<0.05). T1: control; T2: contains 0.5% *Spirulina*; T3: contains 1% *Spirulina*; and T4: contains 1.5% *Spirulina*. SEM: Standard Error of Means. MUFA=Monounsaturated Fatty Acid; PUFA=Polyunsaturated Fatty Acid; SFA=Saturated Fatty Acid; UFA=Unsaturated Fatty Acid

Table 2: Amino acid content (% of total amino acids) of camel burger formulated with different levels of Spirulina

Amino acids	T1	T2	T3	T4	SEM
Aspartic acid	3.30 ^{a}	2.98 ^{b}	3.32 ^{a}	3.33 ^{a}	0.03
Threonine	1.74 ^{a}	1.66 ^{a}	1.78 ^{a}	1.64 ^{a}	0.04
Serine	1.32 ^{b}	1.20 ^{c}	1.45 ^{a}	1.19 ^{c}	0.02
Glutamic acid	5.76 ^{c}	5.39 ^{d}	6.10 ^{a}	5.91^{b}	0.02
Glycine	2.46 ^{a}	2.25 ^{b}	2.24 ^{b}	2.22 ^{b}	0.02
Alanine	2.22 ^{a}	1.99 ^{c}	2.13 ^{ab}	2.05 ^{bc}	0.03
Valine	1.71 ^{a}	1.54 ^{b}	1.56 ^{b}	1.81 ^{a}	0.03
Isoleucine	1.55 ^{a}	1.29 ^{c}	1.42 ^{b}	1.57 ^{a}	0.02
Leucine	2.82 ^{a}	2.45 ^{b}	2.73 ^{a}	2.74 ^{a}	0.04
Tyrosine	0.12 ^{c}	0.84 ^{b}	0.93 ^{a}	1.00 ^{a}	0.02
Phenylalanine	1.57 ^{a}	1.33 ^{c}	1.43 ^{b}	1.47 ^{b}	0.02
Histidine	1.03 ^{a}	0.87 ^{b}	0.98 ^{a}	1.02 ^{a}	0.01
Lysine	3.15 ^{a}	2.87 ^{b}	3.01^{ab}	3.13 ^{a}	0.04
Arginine	2.36 ^{a}	2.10 ^{b}	2.30 ^{a}	2.24 ^{a}	0.03
Proline	1.93 ^{a}	1.77 ^{b}	1.96 ^{a}	1.96 ^{a}	0.03
Cystine	0.71 ^{b}	0.63 ^{c}	0.59 ^{c}	0.91 ^{a}	0.02
Methionine	0.62 ^{a}	0.50 ^{b}	0.67 ^{a}	0.66 ^{a}	0.01

$^{aa-c}$ Means within the same row with different superscripts letters are different (p<0.05). T1: control; T2: contains 0.5% *Spirulina*; T3: contains 1% *Spirulina*; and T4: contains 1.5% *Spirulina*.
SEM=Standard Error of Means.

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Table 3: Physicochemical properties of camel burger during frozen storage at -20 °C for 90 days

Storage periods (days) **Treatments**	**0**	**30**	**60**	**90**	**SEM**
			pH value		
T1	6.16 ^{Ac}	6.18 ^{Ac}	6.54 ^{Aa}	6.42 ^{Ab}	0.02
T2	6.21 ^{Ab}	6.22 ^{Ab}	6.46 ^{Aa}	6.29 ^{Bb}	0.02
T3	6.25 ^{Ab}	6.28 ^{Ab}	6.50 ^{Aa}	6.34 ^{ABb}	0.02
T4	6.23 ^{Ab}	6.26 ^{Ab}	6.49 ^{Aa}	6.26 ^{Bb}	0.02
			Tenderness (Shear force value Kg/f)		
T1	3.30^{Aa}	2.42 ^{Aa}	2.15 ^{Aa}	2.11^{Aa}	0.59
T2	2.36 ^{Aa}	2.60 ^{Aa}	1.86 ^{Aa}	2.20 ^{Aa}	0.59
T3	2.62 ^{Aa}	2.37 ^{Aa}	2.80 ^{Aa}	1.95 ^{Aa}	0.59
T4	2.05 ^{Aa}	1.75 ^{Aa}	2.14 ^{Aa}	2.09 ^{Aa}	0.59
			Cooking loss (%)		
T1	37.39 ^{Ac}	48.93 ^{Aa}	42.76 ^{Ab}	42.65 ^{Bb}	0.97
T2	34.32 ^{Ac}	43.14 ^{Ba}	40.49 ^{Ab}	39.31 ^{Bb}	0.97
T3	34.38 ^{Ab}	41.67 ^{Ba}	41.71 ^{Aa}	45.01 ^{Aa}	0.97
T4	35.96 ^{Ab}	47.80 ^{Aa}	39.48 ^{Ab}	44.53 ^{Aa}	0.97
			Color measurements		
			L*		
T1	44.91 ^{Aa}	40.63 ^{Ab}	40.79 ^{Ab}	41.30 ^{Bb}	0.44
T2	42.60 ^{ABa}	38.11 ^{cB}	38.90 ^{Bc}	40.73 ^{Bb}	0.44
T3	40.50 ^{Bb}	39.72 ^{ABb}	39.96 ^{ABb}	44.54 ^{Aa}	0.44
T4	37.21 ^{Cb}	37.29 ^{Bb}	34.10 ^{Cc}	41.57 ^{Ba}	0.44
			a*		
T1	9.83 ^{Aab}	10.28 ^{Aa}	9.32 ^{Ab}	7.95 ^{Ac}	0.15
T2	4.97 ^{Ba}	4.26 ^{Bb}	4.30 ^{Bb}	3.34 ^{Bc}	0.15
T3	3.80 ^{Ca}	3.07 ^{Cb}	2.00 ^{Cc}	2.01 ^{Cc}	0.15
T4	-0.12 ^{Dc}	0.62 ^{Da}	-0.46 ^{Dc}	0.17 ^{Db}	0.15
			b*		
T1	4.09 ^{Ab}	6.20 ^{Aa}	6.91 ^{Aa}	4.32 ^{Ab}	0.19
T2	2.88 ^{Bc}	3.88 ^{Bb}	4.66 ^{Ba}	3.64 ^{Ab}	0.19
T3	2.30 ^{BCc}	3.26 ^{Bb}	2.72 ^{Cbc}	4.23 ^{Aa}	0.19
T4	1.97 ^{Ca}	0.84 ^{Cb}	1.72 ^{Da}	2.12 ^{Ba}	0.19
			TBA value (μmol TBARS/g)		
T1	56.96 ^{Aa}	35.17 ^{Ab}	32.33 ^{Abc}	21.43 ^{Bc}	3.30
T2	22.91 ^{BCc}	28.17 ^{Bb}	30.31^{Aab}	32.81 ^{Aa}	3.30
T3	29.94 ^{Ba}	16.63 ^{Cb}	29.34 ^{Aa}	31.17 ^{Aa}	3.30
T4	14.40 ^{Cb}	14.56 ^{Cb}	17.75 ^{Bb}	22.73 ^{Ba}	3.30

$^{a-c}$ Means within the same row with different superscripts letters are different (p<0.05).
$^{A-D}$ Means within the same column with different superscripts letters are different (p<0.05).
T1: control; T2: contains 0.5% *Spirulina*; T3: contains 1% *Spirulina*; and T4: contains1.5% *Spirulina*.
SEM=Standard Error of Means; TBA=Thiobarbituric Acid.

Table 4: Microbiological quality of camel burger during frozen storage at -20 °C for 90 days

Treatments			**Storage periods (days)**		
	0	**30**	**60**	**90**	**SEM**
			Total bacterial count (log CFU/g)		
T1	5.16 ^{Ab}	5.50 ^{ABb}	7.84 ^{Aa}	4.80 ^{Ab}	0.19
T2	5.01 ^{Ab}	4.93 ^{Bb}	7.28 ^{Aa}	5.01 ^{Ab}	0.19
T3	5.37 ^{Ab}	4.83 ^{Bb}	6.64 ^{Ba}	5.51 ^{Ab}	0.19
T4	5.14 ^{Acb}	5.88 ^{Ab}	6.88 ^{Ba}	4.91 ^{Ac}	0.19
			Mold and yeast (log CFU/g)		
T1	3.79 ^{Ab}	4.02 ^{Ab}	4.95 ^{Ba}	3.75 ^{Bb}	0.27
T2	4.02 ^{Aab}	3.66 ^{Ab}	2.89 ^{Cb}	4.99 ^{Aa}	0.27
T3	3.91 ^{Ab}	3.19 ^{Ab}	7.14 ^{Aa}	3.31 ^{Bb}	0.27
T4	3.96 ^{Ab}	2.20 ^{Bc}	7.22 ^{Aa}	3.10 ^{Bb}	0.27
			Psychrophilic (log CFU/g)		
T1	2.89 ^{Abc}	2.72 ^{Ac}	6.65 ^{Aa}	4.00 ^{Ab}	0.30
T2	3.55 ^{Ab}	2.16 ^{Ac}	7.10 ^{Aa}	3.39 ^{Ab}	0.30
T3	3.06 ^{Ab}	2.64 ^{Ab}	6.35 ^{Aa}	3.11 ^{Ab}	0.30
T4	2.75 ^{Abc}	2.01 ^{Ac}	6.60 ^{Aa}	3.26 ^{Ab}	0.30

$^{a-c}$ Means within the same row with different superscripts letters are different (p<0.05).
$^{A-C}$ Means within the same column with different superscripts letters are different (p<0.05).
T1: control; T2: contains 0.5% *Spirulina*; T3: contains 1% *Spirulina*; and T4: contains
1.5% *Spirulina*.
SEM=Standard Error of Means; CFU=Colony Forming Unit.

Discussion

Adding different levels of *Spirulina* in formulation of camel burger significantly affected fatty acids profile. These results were close to the one obtained by Barros et al. (2021). They found that using algal oil in beef burgers formulation resulted in significant effect on fatty acids profile. Algal oil decreased the SFA and MUFA and increased the PUFA in treated than control burger. The n-6 significantly decreased in *Spirulina* levels, while n-3 significantly increased with the increase of *Spirulina*. Similar findings were obtained by Alejandre et al. (2017). They found that adding algal oil as fat replacer in the formulation of low-fat beef patties significantly decreased the saturated fatty acids, omega-6/omega-3 ratio, and significantly increased the long chain n-3 fatty acids content in the formulated beef patties. In the same line, Barros et al. (2021) found that using algal oil as fat replacer in beef burgers formulation resulted in significant increase in omega-3 content, PUFA concentration, and improved the n-6/n-3 and PUFA/SFA ratios. The n-6/n-3 ratio in all burger treatments were in accordance with the recommendation of less than 4 (Simopoulos, 2004).

Significant changes were found in amino acids of the camel burger formulated with different levels of *Spirulina*. These results were consistent with Žugčić et al.'s research (2018). They determined the amino acid profile of beef patties formulated with algal origin (*Chlorella* and *Spirulina*) and found a similar finding. The results of the current study were in line with the study by Thirumdas et al. (2018), who evaluated the effect of the addition of algae (*Chlorella* and *Spirulina*) on amino acid profile of fermented Spanish “chorizo” sausages. They found that *Chlorella* and *Spirulina* are a good source of amino acids containing sulfur. Marti-Quijal et al. (2019) studied the effect of adding *Chlorella* and *Spirulina* in the formulation of turkey burger on amino acid profile and found significant differences in glutamic acid, valine, lysine, isoleucine, leucine, and phenylalanine.

Data of moisture retention and percentage of fat retention of camel burger formulated with different levels of *Spirulina* are consistency with the results that obtained by Barkallah et al. (2019). They found that fish burger formulated with 1% *Spirulina* showed the highest moisture and oil holding capacity than control group. Also, Ben Atitallah et al. (2019) they found that the highest water and oil holding capacity were found in fish burger formulated with 1% *Chlorella minutissima, Isochrysis galbana,* and *Picochlorum* sp. and no significant differences were found among treated burger. Similar results were found by Hentati et al. (2019). On the other hand, Cofrades et al. (2008) found that addition different levels of seaweeds Sea Spaghetti (*Himanthalia elongata*), Wakame (*Undaria pinnatifida*), and Nori (*Porphyra umbilicalis*) significantly improved water and fat release of pork meat.

Addition of *Spirulina* increased the pH values of camel burger. These results are in line with Thirumdas et al. (2018) they indicated that addition of (*Chlorella* and *Spirulina*) as a protein source on “chorizo” sausages formulation resulting in significant increase in pH values. Similar results were obtained by Žugčić et al. (2018). They found a noticeable higher pH value of patties formulated with (*Chlorella* and *Spirulina*) than control patties. On the other hand, Ben Atitallah et al. (2018) reported that the incorporation of *C. minutissima*, *I. galbana*, and *Picochlorum* sp. with different levels (0.5, 1, and 1.5%) into fish burger formulations had no significant effect on pH values. However, the higher pH value of formulated camel burgers may be attributed to the high pH of the algal protein concentrates.

Frozen storage significantly changed the pH values of camel burger. These results are close to that obtained by Luo et al. (2017) they found that pH values of Chinese-style sausages formulated with different levels (0.1, 0.25, and 0.5%) of *S. platensis* polysaccharides were decreased at the end of cold storage. Generally, the decrease and increase in pH values of camel burger during frozen storage is related to the growth and activity of bacteria. Psychrophilic bacteria activity increased leading to deteriorations of carbohydrate and producing lactic acid which decreased the pH value. On the other hand, decomposition bacteria and enzymes activity increased resulting in protein deamination and producing alkali compounds which increased the pH values (Leygonie et al., 2012).

The changes in shear force values of control and formulated burger are consistency with Cox and Abu-Ghannam (2013) they found that addition of *H. elongata* seaweed (10-40% w/w) resulting in increased the tenderness of treated patties than control. On the other hands, shear force values not significantly affected by frozen storage. These results are confirmed by López-López et al. (2010) they found that frozen storage had no significant effect on shear force values of patties with 3% Wakame seaweed during frozen storage for 152 days.

Results of cooking loss are consistent with the results of Moroney et al. (2013) they found that addition of (*Laminaria digitata*) extract at levels (0.01, 0.1, and 0.5%) had no significant effect on cooking loss of pork patties. Also, Žugčić et al. (2018) found that no significant differences were found in cooking loss % of beef patties formulated with different microalgal (*Chlorella* and *Spirulina*) proteins. Barros et al. (2021) found that no significant differences were found in cooking loss of beef burger formulated with algal as fat replacer. In the same line, Foggiaro et al. (2022) found that using algal oil in the

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formulation of pork burger had no significant effect on cooking loss. The changes in cooking loss during frozen storage are concordant with the results obtained with López-López et al. (2010) they found that patties formulated with 3% Wakame seaweed showed lower cooking loss during storage time for 152 days.

Formulated camel burger with different levels of *Spirulina* resulting in significant decreased in color parameters. These results are consistent with data of Žugčić et al. (2018) they indicated that beef patties treated with *Chlorella* and *Spirulina* showed the lower (L*, a*, and b*) values than other samples. Also, Ben Atitallah et al. (2019) found that burger prepared with 1% microalgae (*I. galbana*, *C. minutissima*, and *Picochlorum* sp) were characterized by lower color parameters (L*, a*, and b*) than control sample. Likewise, Thirumdas et al. (2018). They found a significant decrease in (L*, a*, and b*) values of "chorizo" sausages formulated with *Chlorella* and *Spirulina* proteins compared to the control sausage. However, the decrease in color parameters (L*, a*, and b*) was mainly due to the richness of green pigment of *Spirulina*. The changes in color parameters (L*, a*, and b*) during storage were consistent with the results obtained by Cox and Abu-Ghannam (2013). They observed that significant changes were found in color parameters of beef patties prepared with *H. elongata* seaweed (10-40% w/w) during storage. L* values decreased after day 30, and there was a significant increase ($p<0.05$) in a* values for all samples (except 20 and 30% seaweed patties) and also a significant increase ($p<0.05$) in b* values for all patties samples observed (except 10 and 20% seaweed patties) by day 30.

Addition of *Spirulina* significantly affected TBA values of camel burger. These results were consistent with results obtained by Luo et al. (2017). They revealed that sausages containing *S. platensis* polysaccharides at levels (0.1, 0.25, and 0.5%) had lower TBA values compared with control samples.

The camel burger formulated with 1.5% *Spirulina* showed the lowest TBA value and remained stable to the end of 90th day. These results were in line with Luo et al.'s research (2017). They indicated that during cold storage, TBA values significantly increased ($p<0.05$) as the time of storage increased in all sausage samples; however, sausages treated with high level of *S. platensis* polysaccharides had the lowest value. Similar findings were found by Hentati et al. (2019). They studied the impact of addition of *Cystoseira compressa* and *Jania adhaerens* at concentrations 0.5, 1, and 1.5% regarding the formulation of fish burger and found that algae can be used as natural antioxidant in fish burger processing.

Generally, the antioxidants' activity of *S. platensis* may be due to its high content of bioactive compounds like carotenoids, polyphenolic compounds, and tocopherols with antioxidative properties (López-López et al., 2009).

Changes in microbiological quality of camel burger formulated with *Spirulina* during frozen storage were consistent with the data by Luo et al. (2017). They found that the growth of total viable counts of mesophilic and psychrotrophic was not affected by addition of different levels of *S. platensis* polysaccharides to Chinese-style pork sausage. Moreover, they found that counts of mesophilic and psychrotrophic gradually increased during cold storage. On the same line, Moroney et al. (2013) found that addition of *L. digitata* extracts (laminarin, 9.3 and fucoidan, 7.8%) had no effect on microbiological counts (mesophilic and psychrotrophic) compared to the control case in fresh pork patties. Furthermore, a significant increase was found in mesophilic and psychrotrophic counts during cold storage.

Conclusion

Addition of *Spirulina* significantly changed fatty acids profile and amino acids of camel burger, increased pH values, improved water retention and fat retention, decreased the color parameters (L*, a*, and b*), and delayed the lipid oxidation. On the other hand, addition of *Spirulina* had no significant effect on shear force values, cooking loss, and microbiological quality. Therefore, using *Spirulina* can be successfully used in the formulation of camel burger without any negative effects on quality characteristics of camel burger during frozen storage.

Authors' contributions

Not applicable

Conflicts of interest

The author declared no conflict of interest.

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