Assessment of yoghurt quality from sheep, goat and camel milk production through laser technique

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Abstract: The study was conducted to evaluate the effect of heat and laser treatments on the chemical, physical, and rheological properties of yogurt made from sheep, goat, and camel milk during storage. Various chemical and physical properties were analyses and compared, including acidity, pH, viscosity, syneresis, and water-holding capacity, and sensory evaluation. Laser technology with a wavelength of 632.8 nm was used and compared with heat treatment. The results showed a slight significant effect on the chemical composition of the milk used in yoghurt manufacturing. Furthermore, the viscosity of yoghurt treated with heat or laser increased during storage. A clear inverse relationship between syneresis and water-holding capacity was evident with laser compared to heat treatments. This contributed to the improvement of the sensory properties of the final product during storage, thus improving the quality of the laser-treatment yoghurt.

Keywords: Laser, sheep milk, goat milk, camel milk, physico-chemical properties analysis, milk quality.

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1 Introduction

Yoghurt is one of the most important fermented dairy products worldwide, despite the different names. It is produced by mixing certain lactic acid bacteria, the most famous of which are *Lactobacillus delbrueckii* subsp. bulgaricus and *Streptococcus thermophiles* (Robinson, 2003; Rahman et al., 2016). The most famous type of yoghurt is produced from cow's milk, but other animal milk, such as buffalo, sheep, camel and goat milk, have also been used (Terzioğlu et al., 2023). Furthermore, plant milk has been used to enhance its functional value and therapeutic properties (Hughes and Hoover, 1991).

Studies have shown that high heat treatment contributed to improving the physicochemical properties, viscosity, syneresis, water-holding capacity, and sensory properties of yogurt made from goat milk (Desouky and El-Gendy, 2017) and from camel milk mixed with cow, sheep, and goat milk (Bulca et al., 2019). Camel yoghurt with different levels of stabilizers and calcium chloride also improved the physicochemical, rheological, and sensory properties compared to cow's yoghurt (Oselu

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et al., 2022). It also improved the physicochemical, biochemical, textural, and rheological properties of yogurt produced using buffalo, camel, cow, goat, and sheep milk when compared (Terzioğlu et al., 2023).

Dairy products manufacture; heat treatments are used to increase the shelf life and eliminate unwanted bacteria that cause spoilage of the product. Currently, lasers are being used to perform the same function as heat treatment, in addition to offering other benefits.

The application of monochromatic lasers (low-power LEDs) is a recent application that has demonstrated diverse biological effects in the food sector. Lasers have been used for qualitative analysis of various dairy products, including lactose-free milk, soy milk, and rice milk (Alfarraj et al. 2018), in addition to their ability to measure the efficiency of the homogenization process of various dairy products (Ransmark et al., 2019). Infrared light have also been used to activate starters, such as the effect of laser on the biomodification of *L. casei* bacteria used in the production of labneh (Elshaghabee et al., 2022), lactic acid bacteria, *L. casei* NRRL-B-1922 in fermented milk (Mohamed et al., 2020), as well as in the pasteurization process with the aim of eliminating harmful bacteria (Marouf and Siddiq, 2018) and also contributed to the treatment of cows infected with mastitis more than antibiotic treatment, it is considered as alternative green medicine (El-Shafii and Nagaty, 2015).

In a study conducted by Reinmann et al. (2006) and Makararpong et al. (2024) using ultraviolet radiation on bovine milk, they found that it had the ability to reduce bacterial content but affected flavour when used at the wrong dose. Meanwhile, Ham et al. (2009) demonstrated that yoghurt exposed to different doses of gamma rays had no effect on the chemical and sensory quality of yoghurt, but extended shelf life.

The aim of this work to evaluate the quality of yogurt produced from sheep, goat, and camel milk using laser technique (He-Ne-Laser ray) compared to heat treatment by studying characteristics associated with yoghurt product quality, such as chemical, physical, and rheological properties, and sensory evaluation during storage.

2 Materials and methods

2.1 Milk samples

Fresh bulk samples of sheep, goat, and camel milk were collected (during the period from June to August 2024.) in sterile glass bottles from Halaib and Shalateen Areas, Halaib Research Station, Desert Research Center, Ministry of Agriculture and Land Reclamation, Egypt (located in Southeastern Egypt between latitudes 23-22 South in the zone, The Red Sea Governorate). These samples were stored under refrigerated conditions and transported to the laboratory. The chemical composition of raw milk used in the manufacture of yoghurt is shown in Table 1.

Table 1 Chemical composition of raw milk used in yogurt manufacture

Group	pH	Fat %	Protein %	Ash %	Total carbohydrates %	Total solids %
Sheep milk	6.67	4.45^{a}	4.05^{a}	0.91	6.01^{a}	15.80^{a}
Goat milk	6.65	3.45^{ab}	3.61^{b}	0.84	5.45^{ab}	13.30^{b}
Camel milk	6.64	2.63^{b}	3.27^{b}	0.81	4.87^{b}	11.58^{c}
±SE	0.008	0.465	0.113	0.037	0.175	0.769

Note: $^{a-c}$ Superscript lowercase letters in each column indicate statistically significant difference ($P < 0.05$)

2.2 Bacterial starters

The commercial freeze-dried DVS mixed bacterial starters of Yo-Fast 1 (containing of *Lactobacillus delbruecki* ssp. *bulgaricus* and *Streptococcus thermophilus*) as yoghurt starter (from Chr. Hansen Laboratory Copenhagen, Denmark) was used in the fermentation process. Yogurt culture (Yo-Fast 1) was cultivated (0.02% (w/v)) using sterilized skimmed milk and incubated at 42°C for 24 h.

2.3 Description of the apparatus of laser beam

The opto- electronic apparatus was used to provide irradiation in Figure 1, milk samples with 20 minutes as exposure time for irradiating. The Opto – electronic apparatus is shown consists of the following main parts:

Stand holder: It was designed and fabricated of iron as a shape square with length 45 mm and total length 900 mm , it contains seven holes to adjust the height and direction of laser and beam expander to insure a good aliment of the laser beam on measurement area. The stand holder was fixed as a vertical on an optical bench by two screw bolts.

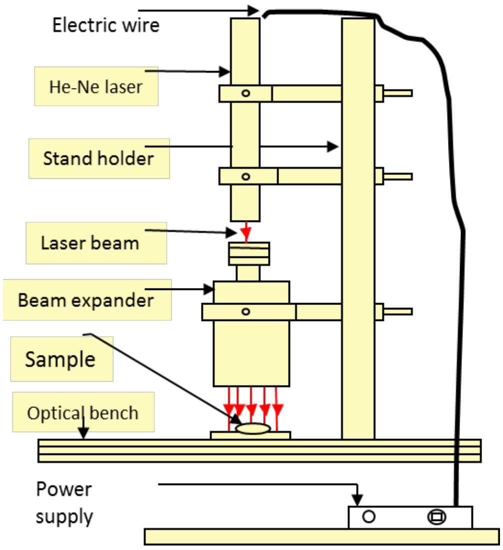
Beam expander: The reverse Galilean telescope design provides a certain angular magnification, called the Expander Power. The beam diameter is first increased in size by its power. The expander was used in the optical unit in front of Helium-Neon laser. Each laser beam size 1 mm expanded in order to cover area 20 × 30 mm^2. The specifications of beam expander were as follows:

Dimensions of the expander with length of 280 mm, maximum and minimum diameters of 110 mm and 50 mm, beam expander covered 15 mm × 15 mm circular area

Source of manufacture: Egypt made in hard Aluminum, electrostatic black paint.

He-Ne laser: A helium-neon (He-Ne) laser with a wavelength of 632.8 nm, and power of 4 mW, was used as the light source. The laser was supported by a stand. The laser source and the conditions used to show in Table 2.

Holders: Holders fabricated from copper were used to hold the lens, sample, luxmeter detector.



(a) photo of Helium Neon laser (b) the designed apparatus

Figure 1 Laser optical apparatus for exposure milk samples of laser beam

Table 2 Laser source and conditions used

Variable	Experimental conditions
Laser	Helium–Neon (632.8 nm)
Wave emission	Continuous (CW)
Power and power density	7 mW; 4.02 mW cm-2
Duration of the irradiation	20 minutes
No. irradiation	Single
Distance from the sample	20 mm
Room temperature	22°C ± 1°C
Laser polarization	Linear

2.4 Laser exposure of milk

Laser beam exposure were done in Agricultural Engineering Lab, at the National Institute of Laser Enhanced Sciences (NILES), Cairo University, Egypt., and Agricultural Engineering Research Institute, Agricultural Research Center, Egypt. The laser power was monitored before and after each exposure using a laser power meter (Gentec, Canada) to ensure proper energy delivery to the target site, a laser spot size of diameter 15 mm using a focusing lens. The laser beam was carried via an optical fiber of core diameter 200 lm (transmittance 90%; Ocean

Optics) and coupled to a beam expander held at a constant distance above the surface of the milk (noncontact mode) providing a laser spot size of diameter 15 mm using a focusing lens. Before each experiment, it was confirmed that the laser beam was spread out uniformly over the entire target area.

Milk were exposure with a helium-neon (He-Ne) laser with a wavelength of 632.8 nm, a surface radiation power density of 2 W m^{-2}, and an output radiation power of 8 mW cm^{-2}. A laser beam diffusion system with a diameter of 8 cm was used; the exposure time was 20 min, and non-stimulated milks were the control treatment. Laser light emitted from the standard device is generally characterized in terms of power (in units of watts and milliwatts). The power levels vary from laser type to another (Alawacy, 1988). The energy is defined as the power × time interval during which it is emitted, i.e. energy revealed (Joules) = power (W) × time (sec). The laser beam has a spherical shape of the particles, with an average other parameter which are especially important (Achauer et al., 1992).

2.5 Yoghurt manufacture

Fresh goat, sheep and camel milk were divided into two equal portions for each species. The first portion served as the control, where the milk was heated to 95°C for 30 min, cooled to 42°C then inoculated with 3% (v/v) of Yo-Fast 1 mother culture. The second portions raw goat, sheep and camel milk processed with dose of beam laser for 20 minutes for exposure time was done. Then heated 42°C then inoculated with 3% (v/v) of Yo-Fast 1 mother culture. All milk samples were incubated at 42ºC for 4-6 hours until complete coagulation. Then immediately cooled and stored at 5°C for 24 h. Samples were collected for analysis either fresh (day 1) or during the fourteen days of cold storage.

2.6 Physico-chemical properties of yogurt

Fat(using Gerber method), total nitrogen (using micro-Kjeldahelmethod), ash (using Thermolyne, type 1500 MuffleFurnace) contents and the total solids, as well as pH values determined by usingdigital pH meter (HI 8314, Hanna Instruments, and Italy) and the titratable acidity (% lactic acid) of the yoghurt samples was measured according to AOAC (2023). Total carbohydrates were calculated by thedifference for all samples analyzed.

2.7 Rheological properties of yoghurt

The water-holding capacity (WHC) was measured by the method reported Bong and Moraru (2014). Yoghurt samples (10 g) were centrifuged at 1250× g for 10 min at 5˚C and the WHC was defined as follows:

$$WHC\ \% = (10 - W)/10 \times 100\% \quad (1)$$

where: W = mass of the separated whey (g).

The tests were carried out in triplicate. The viscosity of yogurt samples was assessed following the method described by Denin-Djurdjević et al. (2002a). Measurements were conducted at 6 C–8 C using Brookfield DV-E Viscometer. Viscosity was monitored during storage at 4ºC after 1, 7 and 14 days and each measurement repeated three times. The syneresis rates of yogurts were determined by Dönmez et al. (2017) as the amount of spontaneous whey (mL/100 g) drained off after 2 h at 7°C when fresh and during storage in all yogurt treatments.

2.8 Sensory Evaluation

Scoring properties of yoghurt was done by ten stuff members at Desert Research Center, Samples were estimated for: flavour (50 points), body and texture (40 points) and appearance (10 points) according to the scheme of Keating and White (1990).

2.9 Statistical analysis

The results obtained were subjected to analysis of variance (ANOVA). Mean comparisons were carried out among yogurt products. Statistical analysis was carried out by Statistical Analysis System (SAS, 2012), utilizing the General Linear Model (GLM) with treatments as the main effect. Duncan's multiple ranges were employed at $p \leq 0.05$ to differentiate the means of three replicates.

3 Results and discussions

3.1 Chemical composition of yoghurt made fresh sheep, goat camel milk heat and laser treatments

Data in Table 3 showed that yogurt made from sheep, goat, and camel milk had a significant effect on the chemical composition. Laser treatment of the milk had a significant effect on the protein and total solids content. The slight changes in the total solids and protein values may be due to the effects of the laser treatment. The results also showed that it was clear there is low effect by laser exposure on yogurt constituents such as fat, protein, ash, Lactose, and total solids percentages for yogurt of sheep, goat, and camel, which were increased by lightly percentage in each constituent.

Table 3 Chemical composition of yoghurt was prepared using heat and with laser treatments

Yoghurt types	Yoghurt constituents				
	Fat %	Protein %	Ash %	Lactose %	Total solids %
			Heat treatment		
Sheep yoghurt	4.42^{a}	4.10 ^{Aa}	0.99^{a}	5.31^{a}	16.12 ^{Aa}
Goat yoghurt	3.44^{b}	3.67 ^{Ab}	0.97^{a}	4.92^{a}	14.21 ^{Ab}
Camel yoghurt	2.64^{c}	3.40 ^{Ab}	0.89^{b}	4.10^{b}	12.86 ^{Ab}
±SE	0.020	0.078	0.016	0.115	0.404
			Laser treatment		
Sheep yoghurt	4.42^{a}	4.28 ^{Ba}	1.03^{a}	5.56^{a}	17.46 ^{Ba}
Goat yoghurt	3.41^{b}	3.75 ^{Bb}	0.93^{ab}	5.07^{b}	14.50 ^{Bb}
Camel yoghurt	2.65^{c}	3.69 ^{Bc}	0.86^{b}	4.20^{c}	13.55 ^{Ba}
±SE	0.028	0.039	0.039	0.091	0.243

Note: $^{a-c}$ Superscript lowercase letters in each column indicate statistically significant difference by type of yoghurt (p< 0.05). $^{A-B}$ Superscript lowercase letters in each column indicate statistically significant difference by treatments (p< 0.05)

The results showed that the solids content of yogurt made from sheep milk was higher than that of goat milk and camel milk, respectively, when the milk was heat or laser treatments. While, the total solids content was higher in the laser treatment than in the heat treatment. These results were similar to those of Deeth and Tamine (1981). On the other hand, the composition of the yogurt in all treatments was almost identical to that of the milk, the raw material, with the differences being due to the fermentation process and the treatment used (Monteiro et al., 2019). Also, heat and laser-treatments yogurt made from goat and camel milk had lower protein content than yogurt made from sheep milk, possibly due to the breed (Pandya and Ghodke, 2007; Bano et al., 2011). However, there was a significant (p ≤0.05) improvement in protein content with laser treatment, which may be due to the laser treatment affecting the distribution of the casein micelles. Furthermore, ash content indicates the amount of minerals present, with sheep, goat, and camel milk being particularly high in these minerals (Jandal, 1996; Stelios and Emmanuel, 2004).

3.2 Effect of physiochemical and rheological of yoghurt made fresh sheep, goat camel milk heat and laser treatments

Table 4 shows the results of acidity and pH during storage and various treatments for three types of yoghurt. The analysis showed an increase in acidity and a decrease in pH during storage, whether by heat or laser treatments, for all types of yoghurt. This is due to the growth of lactic acid bacteria in yoghurt, which leads to the accumulation of organic acids, especially lactic acid, which causes an increase in lactic acid content and a gradual decrease in pH over storage. There were significant differences between yoghurt types and during storage for both acidity and pH. Heat and laser treatments also significantly (p≤ 0.05) affected acidity, while pH was non significantly (p>0.05). These results are consistent with the findings of Oliveira et al. (2001) and Dimitrellou et al. (2019), who reported that lactic acid bacteria, which produce lactic acid, become active during storage, leading to an increase in acidity and a decrease in pH.

The results in Table 4 the viscosity. With the formation of curds, viscosity increases due to the strength of the protein network and the retention of fat globules and whey (Mok et al. 2008). The results indicated that viscosity has a significant effect on milk type, storage period, heat and laser treatments. In general, with heat treatment, yoghurt viscosity increased during storage up to day 14 for sheep, goat and camel milk yoghurts. These results are consistent with those of Denin-Djurdjević et al. (2002b) and Izadi et al. (2014), who demonstrated that yoghurt structure improves with prolonged storage and increased viscosity. Furthermore, the fermentation process and the type of starter culture used affect the viscosity of the product (Hoxha et al., 2023). However, the viscosity of camel milk decreased during storage, possibly due to its composition (Oselu et al. 2022). While laser treatment improved the viscosity of yogurt made from sheep, goat, and camel milk up to day 7, it decreased by day 14. This may be due to the laser treatment's effect on the distribution of protein micelles and lipid, and thus on viscosity.

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Table 4 Changes in physiochemical and rheological yoghurt samples with heat and laser treatments during storage

Group	Day	Acidity	pH	Viscosity	Syneresis	WHC
				Heat treatment		
	Fresh	0.61^{Cc}	4.84^{Ba}	342.50^{Ab}	18.13^{Ca}	81.64^{Cb}
Sheep milk	7	0.79^{Cb}	4.47^{Bb}	312.00^{Ac}	19.22^{Ca}	80.32^{Ab}
	14	0.91^{Ca}	4.03^{Bc}	464.00^{Aa}	19.46^{Cb}	80.69^{Aa}
	fresh	0.62^{Bc}	4.83^{Ba}	254.40^{Bb}	19.31^{Bb}	80.49^{Ba}
Goat milk	7	0.81^{Bb}	4.45^{Bb}	258.30^{Bc}	21.18^{Ba}	78.62^{Bb}
	14	0.99^{Ba}	3.96^{Bc}	262.40^{Ba}	22.30^{Ba}	77.70^{Bb}
	fresh	1.08^{Ac}	4.88^{Aa}	231.60^{Cb}	20.26^{Ab}	79.74^{Ca}
Camel milk	7	1.09^{Ab}	4.86^{Ab}	240.00^{Cc}	23.68^{Aa}	76.32^{Cb}
	14	1.11 ^{Aa}	4.85^{Ac}	235.33^{Ca}	25.00^{Aa}	74.90^{Cb}
±SE		0.02	0.05	0.210	0.436	0.355
				Laser treatment		
	fresh	0.65^{c}	4.88^{Ba}	363.00^{Ab}	18.03^{Ca}	81.67^{Ab}
Sheep milk	7	0.83^{b}	4.51^{Bb}	387.00^{Aa}	19.45^{Ca}	80.25^{Ab}
	14	0.95^{a}	4.07^{Bc}	323.00^{Ac}	18.03^{Cb}	81.57^{Aa}
	fresh	0.67^{c}	4.86^{Ba}	295.00^{Bb}	19.21^{Bb}	80.39^{Ba}
Goat milk	7	0.86^{b}	4.47^{Bb}	319.00^{Ba}	22.20^{Ba}	77.80^{Bb}
	14	1.05^{a}	3.98^{Bc}	287.00^{Bc}	21.08^{Ba}	78.12^{Bb}
	fresh	0.66^{c}	4.87^{Aa}	267.00^{Cb}	20.16^{Ab}	79.64^{Ca}
Camel milk	7	0.85^{b}	4.49^{Ab}	331.00^{Ca}	23.58^{Aa}	76.42^{Cba}
	14	1.03^{a}	4.00^{Ac}	245.00^{Cc}	24.90^{Aa}	75.20^{Cb}
±SE		0.03	0.08	1.075	0.393	0.360

Note: $^{A-C}$ Superscript uppercase letters indicate a statistically significant difference ($P < 0.05$) between yogurt samples in each column within the type of the product., $^{a-c}$ Superscript lowercase letters in each column indicate a statistically significant difference ($p < 0.05$) during storage

The water-holding capacity results are demonstrated in Table 4. There were statistical differences in water-holding capacity between yogurt types, during storage, and during heat and laser treatments. It was found that the water-holding capacity was higher in sheep and goat milk than in camel milk with heat treatment, unlike with laser treatment. Because there is an inverse relationship between water-holding capacity and syneresis, this was clearly evident in all treatments studied. This result is consistent with Kwasi Kpodo et al. (2014) and EL-Bannan et al. (2023).

It can be argued that upon heat and laser treatments, sheep milk has a high viscosity, which significantly affects the firmness of the product. This may be due to an increase in the protein content as well as the ability of milk proteins to bind water compared to goat and camel yoghurt.

3.3 Effect of heat and laser treatments on the sensory evaluation of sheep, goat camel yoghurt:

Sensory evaluation is performed to compare products and during storage conditions based on properties such as texture, flavour, appearance, and overall acceptability. The results of the sensory evaluation are given in Table 5. There were significant ($p \le 0.05$) effect of heat and laser treatment on the yoghurt, yoghurt type, and storage period. Laser treatment had a positive effect on the texture, flavour, appearance, and overall acceptability of all yoghurt types during storage compared to heat treatment. Sheep yoghurt performed higher in all evaluations than goat and camel yoghurts, whether heat or laser treatments. Laser treatment improved the acceptability of all yoghurt types. These results are attributed to the effect of laser treatment on casein micelles, which affected texture and viscosity. These results are consistent with Park (2007), who demonstrated that casein content and percentage influence the hardness and viscosity of yoghurt.

From the previous results, it was clear there is lightly increase effect in organoleptic characteristics of yoghurts (texture, flavour, appearance and overall acceptability) for storage time for sheep, goat, and camel yoghurts. Meanwhile, constituents of yoghurt samples with laser exposure have improved yoghurt constituents' quality (texture, flavour, appearance and overall acceptability) for storage time for sheep, goat, and camel yoghurt.

Table 5 Changes in sensory evaluation of yoghurts with and without laser treatments

Yoghurt types	Storage time, days	Texture	Flavor	Appearance	overall acceptability
			Heat treatment		
	fresh	33^{Ab}	43^{Ab}	8.55^{Aa}	84.55^{Aa}
Sheep milk	7	34^{Ac}	46^{Ab}	8.00^{Ab}	88.00^{Aa}
	14	37^{Aa}	48^{Aa}	8.00^{Ab}	93.00^{Ab}
	fresh	32^{Ab}	42^{Bb}	8.50^{Aa}	82.50^{Ba}
Goat milk	7	34^{Ac}	44^{Bb}	8.00^{Ab}	$86.00^{\mathbf{Ba}}$
	14	36^{Aa}	46^{Ba}	8.00^{Ab}	$90.00^{\mathbf{Bb}}$
	fresh	32^{Bb}	42^{Cb}	7.50^{Ba}	81.50^{Ca}
Camel milk	7	30^{Bc}	40^{Cb}	7.00^{Bb}	77.00^{Ca}
	14	26^{Ba}	37^{Ca}	5.00^{Bb}	68.00^{Cb}
±SE		0.544	0.544	0.278	1.360
				Laser treatment	
	fresh	35^{Ab}	45^{Ab}	9.50^{Aa}	89.50^{Ab}
Sheep milk	7	36^{Ac}	48^{Aa}	9.50^{Aa}	93.50^{Ab}
	14	39^{Aa}	50^{Aa}	9.50^{Ab}	98.50^{Aa}
	fresh	34^{Ab}	44^{Bb}	9.33^{Aa}	87.33^{Bb}
Goat milk	7	36^{Ac}	46^{Ba}	9.27^{Aa}	91.27^{Bb}
	14	38^{Aa}	48^{Ba}	9.50^{Ab}	95.50^{Ba}
	fresh	34^{Bb}	44^{Cb}	8.50^{Ba}	86.50^{Cb}
Camel milk	7	32^{Bc}	42^{Ca}	8.50^{Ba}	82.50^{Cb}
	14	28^{Ba}	39^{Ca}	6.50^{Bb}	73.50^{Ca}
±SE		0.54	0.58	0.228	1.256

Note: $^{A\text{-}C}$ Superscript uppercase letters indicate statistically significant difference ($P < 0.05$) between yogurt samples in each column within the type of the product., $^{a\text{-}c}$ Superscript lowercase letters in each column indicate a statistically significant difference ($p < 0.05$) during storage

4 Conclusion

Current study was designed to evaluate the effects of heat and laser treatment on the chemical, physical, and rheological properties of yoghurt made from sheep, goat, and camel milk during storage. The results showed that laser treatment of milk had a significant effect on protein and total solids content, which was evident for yoghurt made from sheep, camel, and goat milk, respectively. There was an increase in acidity and a decrease in pH during storage, whether heat or laser treatment, for all yogurt types. The results also indicated that viscosity was significantly affected by milk type, storage period, heat and laser treatments. Heat treatment increased yoghurt viscosity during storage up to day 14 for both sheep and goat milk yoghurts. While laser treatment improved the viscosity of sheep, goat, and camel milk yoghurts up to day 7, it decreased by day 14. Syneresis and water-holding capacity was significantly higher in heat and laser treated sheep, goat and camel yoghurts. Sensory analyses indicated a significant effect ($p \leq 0.05$) of heat and laser treatment on yoghurt, yoghurt type, and storage period. The components of the yoghurt samples exposed to the laser showed an improvement in the quality of the yoghurt components (texture, flavor, appearance, and overall acceptability) during the storage period of sheep, goat, and camel yoghurt.

The results showed that laser-treated yogurt did not differ from heat-treated yogurt, while the properties of yogurt produced by laser-treated yogurt were slightly better than those produced by heat-treated yogurt. Yoghurt made from sheep, goat and camel, respectively, had better properties in laser than heat treatment, respectively.

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