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Evaluation of Inulin as a fat replacer in meat burger

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Abstract

The meat industry's challenge is developing healthful, low-fat meat products without affecting their textural properties. Inulin was used at different ratios as a fat replacer in the burger to reduce the probability of the fat risk on the consumer. Burger samples were prepared as a control sample containing 15% fat, low-fat beef burger containing 10% Inulin, 15% Inulin, and 15% Inulin + 5 % fat. All samples were evaluated chemically and physically. The obtained results showed slight differences in all the chemical components except fat, where the addition of inulin in beef burgers decreased the burger fat to reach 6.04, 4.74, and 7.50% in burgers of 10, 15% inulin, and 15% inulin + 5% fat, respectively. Also, Inulin in beef burger formulation caused higher water holding capacity, reaching 63 and 50% with 15% inulin or 15% inulin + 5% fat. The highest redness value (a*) was found in control samples of fresh or stored burgers compared to the burger of 15% inulin, while there was no significant difference in redness values between the control sample and the burger of 10% inulin. Texture profile analysis indicated that the maximum force required to compress the sample (hardness) was decreased as the addition of inulin to the burger increased after storage. Fat replacement with inulin in beef burgers showed no significant effect before or after storage in Deformation at Hardness, Adhesive Force, Resilience, Stringiness Length, Cohesiveness, and Springiness. Gumminess and chewiness declined as the addition of inulin increased. There was no significant effect on adhesiveness and stringiness Length in the formulated burger with inulin in cooked beef burger before or after storage.

Keywords: Inulin, Meat Burger, Low Fat Burger, Texture Profile Analysis, PhysicoChemical.

1. Introduction

Fast food has become a significant component of the food industry in recent years. Burgers are very well-liked; their quality varies depending on their recipe. Many meat products are heavy in saturated fat and cholesterol and low in protein (Campbell et al., 2017). There are numerous non-meat additives in use. The meat industry's most significant issue is how to create low-fat meat products without damaging their sensory and textural qualities (Barbut et al., 2016). Producing healthier beef products is challenging because they must be tasty and affordable (Decker & Park, 2010; Fernández-Ginéz et al., 2005

Chicory (*Cichorium intybus* L.) is the most widely utilized vegetable source for the industrial production of inulin and a natural source of inulin from fresh roots (Roberfroid, 2007). Chicory roots can be processed with water at high temperatures to extract inulin. In most cases, fresh roots are used to extract inulin because oven drying decreases the yield (Stökle et al., 2020). Nonetheless, the chicory roots and the specific feedstock surface have a significant impact on the extractability.

On the other hand, inulin was utilized as a novel component in the food processing industry because it had both technological and nutritional advantages (Tsokolar-Tsikopoulos et al., 2015). Inulin-type fructans, also known as ß-(2, 1)-fructans, are soluble dietary fiber and prebiotic food ingredients, according to Shoaib et al. (2016). Since inulin can bind water, create a gel, and mimic animal fat's sensory and technical qualities, it might be employed in various processed meat products. In a variety of processed meat products, such as scalded sausages (Garca et al., 2006; Tröger et al., 2005), canned meat products (Florowski & Adamczak, 2010), meatballs (Flaczyk et al., 2009), liver pâté (Florowski et al., 2008), and fermented sausages, several researchers have used rehydrated inulin (inulin gel) (Mendoza et al., 2001).

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Additionally, inulin was used as a practical supplement (dietary fiber or prebiotic ingredient) to enhance the nutritional content of meat products without impairing their sensory qualities (Beriain et al., 2011; Ergönül et al., 2009). Cegieka and Tambor (2012) assess the impact of inulin addition on the quality attributes of chicken meat burgers. Instead of replacing fat, they employed inulin as an addition with nutritional benefits.

Inulin has a wide range of applications in various meals, including confectionery, fruit preparations, milk desserts, yogurt, fresh cheese, baked products, chocolate, ice cream, and sauces because of its numerous health- promoting properties (Kaur & Gupta, 2002). According to experimental research, these substances can act as bifidogenic agents, boost the body's immune system, lower levels of pathogenic bacteria in the intestine, relieve constipation, lower the risk of osteoporosis by increasing mineral absorption, particularly of calcium, and lower the risk of atherosclerosis by reducing the production of triglycerides and fatty acids in the liver and their level in serum. Inulin also lowers the risk of developing several disorders. In this regard, consumer today needs producing tasty foods products as well as low in fat and calories to gain health benefits. To meet this need, this study aimed to produce low-fat beef burgers by using inulin in the formula of beef burgers without deteriorating the textural characteristics of burgers.

2. Materials and methods

2.1. Materials

All the ingredients needed to make the burgers, including raw beef, were bought from a nearby market (Dokki, Giza, Egypt). The Agricultural Research Center in Cairo, Egypt, provided the chicory roots and soy protein. Meanwhile, potato starch and sodium tri-polyphosphate ($Na_5P_3O_{10}$) were supplied from the Sigma-Aldrich Company (St. Louis, MO, USA).

2.2. Extraction of inulin from chicory roots

Inulin was extracted from chicory roots using the approach outlined by El-Kholy et al. (2020). In order to extract the inulin, water was added to the powdered root in a 1:10 (root powder: water, w/v) ratio and stirred continuously for 1 h at an average temperature of 80 °C 2 °C. Following the extraction procedure, the crude extract was filtered through cloth to get rid of the insoluble materials. To eliminate impurities like protein, pectin, etc., the crude concentrated extract was combined with 5% calcium hydroxide slurry and heated to between 50 and 60 °C for 30 min. After vacuum filtering using Whatman No. 4 filter paper, 10% phosphoric acid (H3PO4) was added to the filtrate extract while vigorously stirring continuously. The excess coagulate organic material and calcium was precipitated by adjusting the pH to 8–9. Prior to re-filtering using filter paper, the filtrate was allowed to rest at 60 °C 2–3 h. To get rid of the coloring agents, the charcoal powder was added to the filtrate and stirred with a glass rod for 15 to 30 minutes at 60 °C. The cleared extract was once again filtered using filter paper No. 1 before being further concentrated in a rotary evaporator at 60 °C. The concentrated sample gained after the evaporation procedure was combined with ethanol and kept at 20-25 °C for 4 days. After that, the supernatants have been discarded and the precipitates were washed with ethanol. Precipitated inulin was placed in an oven under vacuum at 40 °C for 1 h to eliminate the leftover solvent, lyophilized, and kept until the next assays.

2.3. Preparation of beef burgers

Samples of beef burgers were made using a modified version of the technique outlined by Aleson-Carbonell et al. (2005). 500 g of beef flesh was manually chopped with a JG-210 band saw before being minced on a 4 mm grinder plate. Minced beef (50g) was combined with salt (2% NaCl) for three minutes in a Hobart mixer. By a mixer, soy protein (50 g) and water were combined in a 1:5 (w/v) ratio and held between 2 and 5 °C. (1%) Tri-polyphosphate sodium (0.25 %) As stated in table 1, paprika, spices (1% black pepper, 1% garlic powder, and 2% onion powder), and 3% potato starch were combined with varying amounts of inulin and fat. According to the procedure outlined by Zhanc et al. (2004), the cooked burgers were made by grilling in a (Kenwood electric grill) at power 10 for 7-8 min until the interior temperature reached 74 ± 1 °C. The resulting mixture was formed into circular patties about 50 g in weight, 10 cm in diameter, and 0.5 cm thick. Before being packaged in polyethylene bags and stored, each item was isolated from the others using a polyethylene layer. The beef burger was divided into four equal portions for a different treatment as follows: T1: control beef burger sample (15% fat), T2: sample of 10 % Inulin (0 % Fat), T3: sample of 15 % Inulin (0 % Fat) and T4: sample of 15 % Inulin with 5 % fat. All treatments were packed in plastic bags and stored in a refrigerator at -20 ◦C for 90 days. Samples in three replicates from each batch were subjected to chemical and physical analysis initially and periodically after 3 months of frozen storage.

2.4. Physical tests

A Hanna pH 211 pH meter equipped with a Hanna FC 200B electrode was used to measure pH in each treatment (Hanna Instruments, Padova, Italy).

2.5. The water holding capacity
The water retention capacity was calculated as a percentage of the weight loss of a known-weight meat sample (Zaky et al., 2020).

Table 1: Gross chemical composition of low-fat beef burger at different replacing levels with inulin.

Chemical content (%)	Control 15% fat	Burger Zero % Fat 10% Inulin	Burger Zero % Fat 15% Inulin	Burger 5% Fat 15% Inulin
Moisture	65.50[c] ± 0.17	66.86 [a] ± 0.06	66.15[b] ± 0.06	67.11[a] ± 0.19
Protein	27.21[a] ± 0.135	24.65[b] ± 0.12	23.44[c] ± 0.23	20.22[d] ± 0.100
Fat	15.27[a] ± 0.482	6.04[c] ± 0.20	4.74[d] ± 0.07	7.50[b] ± 0.100
Fiber	1.57[a] ± 0.058	1.41[ab] ± 0.02	1.35[b] ± 0.01	1.30[b] ± 0.170
Ash	3.79[a] ± 0.039	3.42[bc] ± 0.12	3.47[b] ± 0.01	3.31[c] ± 0.001
pH	6.47[a] ± 0.006	6.43[b] ± 0.03	6.46[a] ± 0.01	6.47[a] ± 0.00

Results represented the mean values of three replicated samples. In the same row, different letters mean significant differences (P< 0.05).

2.6. Color measurement
The samples from both fresh and frozen storage underwent color measurement. X = 77.26, Y = -81.94, and Z = 88.14 (L* = 92.46, a* = -0.86, and b* = -0.16) were measured using a colorimeter (Lab. Scan XE, Hunter Lab., Murnau, Germany) and standardised with a white tile of Hunter Lab colour standard (LX No. 16379). L* (lightness), a* (redness), and b* (yellowness) were then measured as color parameters, and they were expressed as mean value standard deviation (El-Faham et al., 2016).

2.7. Texture analysis
Using a texture meter (Brookfield model-CT3-10 kg, USA) equipped with a cylinder Probe (TA-AACC36) for measuring burger firmness and carrying out texture profile analysis (TPA), the textural qualities of chilled (4 ± 1°C, 24 h) and grilled burger samples were assessed. TPA was used to measure various properties, including hardness, deformation at hardness, hardness work, adhesiveness, resilience, stringiness, cohesiveness, springiness, gumminess, and chewiness. The test speed was 2.00 mm sec, and the trigger load was 0.07 N. The analyzer was programmed to take two-cycle measurements to produce a two-bite texture profile curve. The tests were run on samples of hamburgers (10 mm x 90 mm depth x diameter). The results were reported as the averages of three burgers made in duplicate using each mixture.

2.8. Proximate Composition
Moisture, crude protein, fat, ash contents, and total carbohydrates were calculated by differences and estimated using the method described by A.O.A.C. (2005).

2.9. Lipid Oxidation
The 2-thiobarbituric acid (TBARS) assay was performed following Rowayshed' protocol (2015). For every treatment, two analyses were performed. A UV-VIS spectrophotometer was used to detect the absorbance at 538 nm. TBA was calculated as mg of malonaldehyde per kilogram of the burger.

2.10. Sensory Evaluation
According to Hussein et al. (2023), fifteen trained panelists from the National Research Center's Food Technology Department (Dokki, Giza, Egypt) performed the sensory evaluation. Panelists attended 1-h training sessions that researchers with commercial samples carried out over 1 week. Panelists identified, discussed, and determined sensory quality attributes and descriptive words. Burger samples were judged on their appearance, flavor, aroma, and texture using a seven-point hedonic scale (1= being severely disliked, 4= being neither liked nor disliked, and 7= being extremely liked). Unless otherwise stated, P<0.05 was used to determine significance.

2.11. Statistical Analysis
Using SPSS software, the study's data were subjected to a one-way analysis of variance (ANOVA) and significant differences (P <0.05) (2006). The results were calculated as the three duplicated samples' means.

3. Results and Discussion

Proximate Composition

Except for fat, all the chemical components in low-fat beef burgers had minor variations. According to Table 1, formula samples with higher inulin levels had higher moisture content and lower fat and protein content as compared to control samples. Burgers made using control ingredients, 10% inulin, and 15% inulin + 5%, had fat contents of 15.27, 6.04, 4.74, and 7.50%, respectively. Furthermore, compared to the control sample (27.21%), the protein content of burgers has decreased to 24.65, 23.44, and 20.22%. The findings corroborated those made by Beriain and colleagues (2011), who claimed that adding inulin to fermented sausage reduced fat and protein while increasing moisture. In various investigations replacing animal fat raw material with inulin gel in the formula of processed meat, a negative relationship between fat content and moisture was found (Flaczyk et al., 2009; Brauer, 2005; Garca et al., 2006; Nowak et al., 2007).

Table 2: Effect of frozen storage for three months at -20°C on water holding capacity (WHC), cooking loss, and TBA of a low-fat beef burger.

Properties	Control (15% fat)	10 % Inulin (0% Fat)	15 % Inulin (0% Fat)	15 % Inulin (5% fat)
WHC (%)				
Fresh	5.56 ± 0.012^{c}	6.47 ± 0.058^{a}	6.00 ± 0.058^{b}	5.06 ±0.055^{d}
Frozen	5.01 ± 0.021^{d}	8.62 ± 0.020^{c}	14.41 ±0.353^{a}	11.20 ±0.431^{b}
Cooking Loss (%)				
Fresh	8.28 ± 0.163^{d}	13.11 ± 0.100^{c}	20.12 ± 0.110^{b}	21.72 ± 0.629^{a}
Frozen	11.45 ± 0.308^{d}	23.95 ± 0.269^{c}	28.47 ± 0.203^{b}	34.967 ± 0.091^{a}
TBA (mg M.A./100g sample)				
Fresh	1.09 ± 0.082^{a}	1.08 ± 0.114^{a}	1.077 ± 0.139^{a}	1.163 ± 0.087^{a}
Frozen	1.570 ± 0.313^{a}	1.117 ± 0.040^{b}	1.133 ± 0.231^{b}	0.843 ± 0.652^{c}

Results represented the mean values of three replicated samples. In the same row, different letters mean significant differences (P< 0.05).

Water holding capacity (WHC)

The beef burger's water holding capacity (WHC) is a crucial component that influences the burger's quality. It affects the burger's weight change during shipping and storage, drip loss after thawing, weight loss and shrinkage during cooking, and juiciness and tenderness (Mahmoud et al., 2017). According to Table 2, the inclusion of inulin in the formulation of beef burgers increased the water holding capacity (WHC), which reached 63 and 50%, respectively, in the burgers made with 15% inulin or 15% inulin + 5% fat. The WHC of some fibers is linked to the sort and quantity of their polysaccharides; large particles are associated with open structures that enhance the properties of hydration and fat absorption capacity. This could demonstrate the fact that the addition of inulin increased the WHC because of its ability to bind water molecules and retain fat. With regard to a boost in water-holding capacity, a similar outcome was stated by Furlán (2013) who added inulin to minced meat. The ability to hold more water could result in a meat structure that is harder and more compact (Youssef & Barbut, 2011). An ingredient's WHC is a crucial functional characteristic that can be used to compare the WHC of powders and the WHC of burgers made with various inulin fractions in the future.

Lipid oxidation

The cooking loss increased as the inulin content was raised to 15%, although the moisture released during cooking increased. However, the pH and TBA of the inulin-formulated hamburger were not significantly impacted. The literature on meat products does not support the pro-oxidant activity of inulin at the greatest addition levels, but there is also no evidence of an antioxidant impact. Therefore, taking into account the attributes of inulin, no mechanism is provided for the pro-oxidant impact found in cooked products. Overall, the increase in lipid oxidation of products made with inulin may be due to the presence of contaminants like transition metals in the inulin preparation.

Color

The effect of burger formulation with inulin on color parameters during storage for three months is clearly shown in Table 3. In fresh burgers, the highest lightness value (L*) was found in the burger of 15% inulin (48.12). The lowest lightness value (39.27) was recorded in the control sample. This was anticipated because the rise in the fat proportion caused an increase in L* value (Šoji´c et al. 2011), which was probably caused by a significant amount of light reflection.

Table 3: Effect of formulation burger with inulin on color parameters during storage at -20°C for three months.

Fresh Burger samples	L*	a*	b*
At zero time			
Control (15% fat)	39.27^{e} ± 0.084	15.89^{a} ± 0.321	23.41^{c} ± 0.397
10 % Inulin (0% Fat)	43.58^{d} ± 0.142	15.49^{ab} ± 0.225	25.07^{ab} ± 0.793
15 % Inulin (0% Fat)	48.12^{c} ± 1.342	13.74^{c} ± 0.511	24.60^{b} ± 0.308
15 % Inulin (5% fat)	47.55^{c} ± 0.231	14.81^{b} ± 0.095	25.55^{a} ± 0.323
After three months			
Control (15% fat)	43.59^{d} ± 1.670	8.27^{de} ± 0.200	18.27^{e} ± 0.266
10 % Inulin (0% Fat)	46.99^{c} ± 0.510	8.92^{d} ± 0.075	20.59^{d} ± 0.290
15 % Inulin (0% Fat)	50.31^{b} ± 0.235	8.89^{d} ± 0.266	20.60^{d} ± 0.065
15 % Inulin (5% fat)	52.19^{a} ± 0.235	7.60^{e} ± 0.965	20.67^{d} ± 0.285

*L**=lightness, *a**=redness, *b**=yellowness. Results represented the mean values of three replicated samples. In the same column, different letters mean significant differences (P< 0.05).

This behaviour was also noticed by Šoji´c et al. (2011) in cooked sausages prepared with 5% inulin, which had much lower L* values than the controls. Also, the highest yellowness value (b*) was observed in the formulated burger with 15% inulin + 5% fat (25.55), and the control sample recorded the lowest yellowness value (23.41). In contrast, other scientists have observed a reduction in b* after the addition of vegetable fibers (Egea et al., 2020; Riazi et al., 2016). The highest redness value (a*) was found in control samples (15.89) compared to the burger of 15% inulin. Furthermore, there was no significant difference in redness values between the control sample and the burger of 10% inulin. On the other hand, the highest lightness values and the lowest redness and yellowness were observed in stored burger samples compared to the same sample of the fresh burger. There were no significant differences between the redness values of all formulated samples after storage for three months compared to the control burger sample. Riazi et al. (2016) was assessed the colour of cooked beef sausages that were given a 2% treatment of nitrites from red grape pomace. When compared to the control, the product after this treatment had significantly lower L*, a*, and b* values.

Additionally, Table 4 clarifies the impacts of burger formulation with inulin on the cooked burger's color characteristic. The cooked hamburger from the control sample had the highest lightness (35.31), highest yellowness (16.64), and lowest redness (8.56) values. The cooked burger with 15% inulin and 5% fat had the most excellent redness value (9.59). However, Table 4 demonstrated no appreciable variations in the color characteristics (L*, a*, and b*) of stored cooked burger samples that were made with 10%, 15%, or 15% inulin plus 5% fat. Additionally, all inulin-containing samples had redness and yellowness values higher than the control samples' stored, cooked burgers.

Texture analysis

Before and after storage, a texture profile examination of formulated burger samples containing 10, 15%, and 15% Inulin plus 5% fat was conducted and compared with the control burger sample. Table 5 showed that as inulin addition to the burger increased, the maximum force needed to compress the sample (hardness) of cycles 1 or 2 reduced, whereas the hardness of the stored burger rose in comparison to the same formulation sample without inulin. Inulin replaced fat in beef burgers; however, there was no discernible difference in deformation at hardness, adhesive force, resilience, stringiness length, cohesiveness (a measure of how much the sample could be distorted before breaking), and springiness before or after storage (the ability of the sample to recover its original form after the deforming force was removed).

Table 4: Effect of storage cooked burger samples at -20°C for three months on color quality.

Cooked Burger	L*	a*	b*
At zero time			
Control (15% fat)	35.31^{a} ± 2.865	8.56^{c} ± 0.385	16.64^{a} ± 1.155
10 % Inulin (0% Fat)	30.34^{b} ± 0.995	8.89^{bc} ± 0.220	14.15^{bc} ± 0.185
15 % Inulin (0% Fat)	34.80^{a} ± 2.915	8.95^{bc} ± 0.685	16.34^{a} ± 0.965
15 % Inulin (5% Fat)	30.55^{b} ± 0.425	9.59^{ab} ± 0.010	14.55^{bc} ± 0.080
After three months			
Control (15% fat)	33.87^{ab} ± 3.335	7.85^{d} ± 0.650	13.35^{c} ± 1.655
10 % Inulin (0% Fat)	33.76^{ab} ± 1.235	9.97^{a} ± 0.080	15.62^{ab} ± 1.180
15 % Inulin (0% Fat)	32.60^{ab} ± 0.420	10.16^{a} ± 0.346	15.32^{ab} ± 0.325
15 % Inulin (5% fat)	33.82^{ab} ± 0.025	9.73^{a} ± 0.050	17.00^{a} ± 0.330

Results represented the mean values of three replicated samples. In the same column, different letters mean significant differences (P< 0.05).

According to Bourne (2002), as inulin was added, gumminess (stickiness) and chewiness (the effort to masticate the sample for swallowing) decreased in comparison to the control burger sample. However, compared to the identical sample made without inulin, the gumminess and chewiness of the preserved burger samples were not significantly altered. The findings corroborated those of Keenan et al. (2014), who claimed that adding fat to beef products could change certain tactile metrics compared to the control. Additionally, the type of fiber used significantly impacts the findings of textural parameters (López-Vargas et al., 2014). Additionally, Bos-Sduza (2018) discovered that soluble fibers derived from fructooligosaccharide and inulin reduced chewiness compared to the control samples.

Additionally, the impact of cooked, inulin-infused burgers on texture profile analyses before and after storage was assessed. Inulin was substituted for fat in Table 6's formulation, resulting in a substantial increase in cycles 1 and 2's hardness compared to the control sample. This outcome might result from replacing fat with inulin, which enhances moisture release during cooking and alters texture and hardness. Similarly, Garca et al. (2006) reported that adding powdered inulin to both full-fat and low-fat mortadella increased textural hardness. Chewiness and gumminess showed the same pattern. After storage, the hardness of the control sample was increased, while formulated burger with inulin was decreased compared to the same fresh cooked sample. This result could be due to some moisture released from the burger during storage for 3 months. Table 6 also indicated no significant effect on Adhesiveness and Stringiness Length from fat replacement with inulin in cooked beef burgers before or after storage.

Sensory evaluation

A significant predictor of potential consumer preferences is sensory evaluation. As demonstrated in the tables, sensory evaluation of cooked beef burger samples was done both before and after storage for three months (7 and 8). Table (7) demonstrated that, when compared to treated samples, the fresh beef burger from the control sample (15% fat) had the most excellent color and flavor (9.43), whereas the treated samples ranged from 8 to 8.43. The flavor of the control sample followed the same trend and was significantly higher at

9.71, whereas it varied between 7.71 and 8.43 in treated samples.

Table 5: Texture Profile Analysis (TPA) of fresh and stored Burger at -20° C for three months.

Properties	Fresh burger samples				Stored burger samples			
	T1	T2	T3	T4	T1	T2	T3	T4
Hardness cycle 1 (N)	14.347^{ab} ± 0.966	11.697^{bc} ± 0.878	7.983^{de} ± 1.061	6.087^{e} ± 1.195	17.035^{a} ± 4.179	13.155^{bc} ± 3.048	10.240^{cd} ± 0.523	13.545^{bc} ± 4.179
Deformation at hardness (mm)	2.993^{ab} ± 0.006	2.993^{ab} ± 0.006	2.997^{ab} ± 0.006	2.987^{b} ± 0.006	3.000^{a} ± 0.008	2.995^{ab} ± 0.007	3.000^{a} ± 0.008	2.995^{ab} ± 0.007
Hardness work cycle 1 (mJ)	19.233^{a} ± 1.644	16.767^{ab} ± 1.550	9.667^{c} ± 1.914	8.667^{c} ± 1.595	19.850^{a} ± 5.445	16.300^{ab} ± 6.223	11.500^{bc} ± 0.990	16.550^{ab} ± 6.293
Adhesive Force (N)	0.717^{a} ± 0.103	0.690^{a} ± 0.085	0.633^{a} ± 0.108	0.597^{a} ± 0.116	0.750^{a} ± 0.042	0.815^{a} ± 0.290	0.595^{a} ± 0.148	0.560^{a} ± 0.368
Adhesiveness (mJ)	2.600^{ab} ± 0.361	3.100^{a} ± 0.300	2.767^{a} ± 0.551	2.900^{a} ± 0.624	2.00^{bc} ± 0.707	1.500^{c} ± 0.424	1.400^{c} ± 0.283	1.400^{c} ± 0.141
Resilience	0.190^{b} ± 0.000	0.160^{b} ± 0.010	0.197^{b} ± 0.015	0.160^{b} ± 0.010	0.235^{b} ± 0.021	0.210^{b} ± 0.000	0.215^{b} ± 0.007	0.730^{a} ± 0.806
Stringiness Length (mm)	2.870^{ab} ± 0.755	6.457^{a} ± 5.798	2.890^{ab} ± 0.762	3.220^{ab} ± 0.743	0.525^{ab} ± 0.078	0.570^{b} ± 0.156	0.945^{b} ± 0.403	0.345^{b} ± 0.276
Stringiness work done (mJ)	1.600^{a} ± 0.265	1.667^{a} ± 0.289	1.467^{a} ± 0.513	1.633^{a} ± 0.777	0.250^{b} ± 0.071	0.350^{b} ± 0.212	0.350^{b} ± 0.071	0.450^{b} ± 0.212
Hardness cycle 2 (N)	13.217^{ab} ± 0.715	10.547^{bc} ± 0.742	7.277^{de} ± 0.951	5.533^{ef} ± 1.122	15.795^{a} ± 3.741	11.740^{bc} ± 2.432	9.245^{cd} ± 0.403	4.690^{f} ± 6.505
Hardness work cycle 2 (mJ)	14.900^{ab} ± 1.418	11.933^{ab} ± 1.328	7.467^{de} ± 2.259	5.933^{ef} ± 1.429	15.250^{a} ± 4.172	11.100^{bc} ± 3.677	8.150^{cd} ± 0.354	3.550^{f} ± 4.879
Cohesiveness	0.773^{a} ± 0.006	0.710^{a} ± 0.020	0.767^{a} ± 0.119	0.680^{a} ± 0.078	0.770^{a} ± 0.000	0.690^{a} ± 0.028	0.710^{a} ± 0.028	0.295^{b} ± 0.403
Springiness	2.623^{b} ± 0.074	2.533^{b} ± 0.021	26.677^{ab} ± 41.737	2.460^{b} ± 0.036	2.660^{b} ± 0.156	2.360^{b} ± 0.042	2.390^{b} ± 0.085	47.080^{a} ± 63.484
Gumminess (N)	11.100^{ab} ± 0.852	8.330^{bc} ± 0.777	6.150^{cd} ± 1.480	4.177^{de} ± 1.111	13.095^{a} ± 3.231	9.020^{bc} ± 1.640	7.280^{c} ± 0.042	3.130^{e} ± 4.285
Chewiness (mJ)	29.167^{a} ± 2.899	21.100^{b} ± 1.916	15.667^{bc} ± 5.216	10.267^{d} ± 2.754	35.100^{a} ± 10.607	21.300^{b} ± 4.243	17.400^{bc} ± 0.566	11.450^{cd} ± 2.899

T1 = Control (15% fat) T2 = 10 % Inulin (0% Fat)
T3 = 15 % Inulin (0% Fat) T4 = 15 % Inulin (5% Fat)
Values represented as means ± standard deviation. In the same raw, different letters mean significant differences (P< 0.05).

The control sample (T1=15% fat) and T2 (10% inulin) had considerably higher tenderness than T3 (15%) and T4 (5% fat + 15% inulin), which had significantly lower tenderness at 7.86 and 7.43, respectively. In addition, there was no discernible change in terms of juiciness, chewiness, or off-flavor between the control sample and other treated samples. The acquired results were consistent with those made by Cegieka and Tambor (2012), who claimed that chicken burgers with varying levels of inulin substitution were approved sensory.

After three months of storage, the cooked burger's sensory qualities concerning fat replacement with inulin were assessed. The control sample (15%) and other treated samples did not differ significantly in color or chewiness, according to Table (8). In comparison to T3 (15% fat) and T4 (5% fat + 15% inulin), flavour and juiciness were considerably higher in the control (T1 = 15% fat) and T2 (10% inulin) samples. Chewiness, softness, and off-flavor were marginally different between the control and other treated samples. These findings supported the findings of Ergönül et al. (2009), who said that adding inulin did not reduce the overall sensory quality of turkey meatballs.

Table 6: Texture Profile Analysis (TPA) of fresh and stored Burger after cooking.

Properties	Fresh burger samples after cooking				Stored burger samples after cooking			
	T1	T2	T3	T4	T1	T2	T3	T4
Hardness cycle 1 (N)	$6.31^{d} \pm 1.711$	$40.377^{a} \pm 5.233$	$44.937^{a} \pm 10.129$	$37.700^{a} \pm 8.494$	$17.343^{bc} \pm 5.904$	$38.110^{a} \pm 8.697$	$22.035^{b} \pm 0.912$	$8.345^{cd} \pm 3.656$
Deformation at hardness (mm)	$2.995^{b} \pm 0.007$	$4.993^{a} \pm 6.085$	$4.997^{a} \pm 0.006$	$5.000^{a} \pm 0.000$	$2.993^{b} \pm 0.006$	$2.995^{b} \pm 0.007$	$3.000^{b} \pm 0.000$	$2.995^{b} \pm 0.007$
Hardness work cycle 1 (mJ)	$6.95^{c} \pm 1.768$	$74.300^{a} \pm 5.734$	$77.600^{a} \pm 24.171$	$68.700^{a} \pm 14.944$	$16.500^{bc} \pm 7.019$	$37.700^{b} \pm 8.485$	$21.200^{bc} \pm 2.687$	$10.000^{c} \pm 3.394$
Adhesive Force (N)	$0.125^{b} \pm 0.035$	$0.357^{a} \pm 0.006$	$0.177^{ab} \pm 0.112$	$0.373^{a} \pm 0.204$	$0.133^{b} \pm 0.050$	$0.175^{ab} \pm 0.078$	$0.255^{ab} \pm 0.049$	$0.175^{ab} \pm 0.120$
Adhesiveness (mJ)	$0.55^{a} \pm 0.778$	$0.533^{a} \pm 21.376$	$0.200^{a} \pm 0.000$	$0.533^{a} \pm 0.404$	$0.500^{a} \pm 0.608$	$-0.050^{a} \pm 0.071$	$0.250^{a} \pm 0.212$	$0.300^{a} \pm 0.424$
Resilience	$0.51^{a} \pm 0.014$	$0.253^{c} \pm 0.191$	$0.187^{d} \pm 0.025$	$0.203^{d} \pm 0.025$	$0.500^{a} \pm 0.053$	$0.365^{b} \pm 0.007$	$0.380^{b} \pm 0.014$	$0.355^{b} \pm 0.021$
Stringiness Length (mm)	$0.54^{ab} \pm 0.057$	$0.643^{ab} \pm 0.586$	$0.600^{ab} \pm 0.335$	$1.040^{a} \pm 0.040$	$0.433^{b} \pm 0.136$	$0.420^{b} \pm 0.141$	$0.520^{ab} \pm 0.141$	$0.690^{ab} \pm 0.438$
Stringiness work done (mJ)	$0.00^{b} \pm 0.000$	$0.200^{ab} \pm 0.029$	$0.067^{ab} \pm 0.115$	$0.267^{a} \pm 0.153$	$0.000^{b} \pm 0.000$	$0.050^{ab} \pm 0.071$	$0.100^{ab} \pm 0.000$	$0.050^{ab} \pm 0.071$
Hardness cycle 2 (N)	$6.16^{d} \pm 1.697$	$36.807^{a} \pm 0.659$	$39.577^{a} \pm 8.511$	$33.317^{a} \pm 7.253$	$17.033^{bc} \pm 5.661$	$36.410^{a} \pm 8.457$	$21.040^{b} \pm 0.806$	$8.150^{cd} \pm 3.818$
Hardness work cycle 2 (mJ)	$6.2^{c} \pm 1.527$	$49.133^{a} \pm 0.265$	$47.633^{a} \pm 12.926$	$43.000^{ab} \pm 10.124$	$14.367^{c} \pm 5.950$	$31.350^{b} \pm 8.132$	$17.200^{c} \pm 1.838$	$8.150^{c} \pm 3.606$
Cohesiveness	$0.9^{a} \pm 0.000$	$0.670^{c} \pm 4.386$	$0.617^{c} \pm 0.025$	$0.627^{c} \pm 0.065$	$0.873^{ab} \pm 0.049$	$0.830^{ab} \pm 0.028$	$0.815^{b} \pm 0.021$	$0.805^{b} \pm 0.078$
Springiness	$2.755^{b} \pm 0.177$	$7.683^{a} \pm 6.085$	$3.913^{ab} \pm 0.055$	$4.063^{ab} \pm 0.199$	$2.787^{b} \pm 0.057$	$2.740^{b} \pm 0.071$	$2.710^{b} \pm 0.057$	$2.725^{b} \pm 0.007$
Gumminess (N)	$5.65^{e} \pm 1.527$	$26.923^{ab} \pm 0.050$	$27.630^{ab} \pm 5.153$	$23.717^{bc} \pm 6.541$	$15.143^{d} \pm 5.185$	$31.680^{a} \pm 8.273$	$17.915^{cd} \pm 0.332$	$6.860^{e} \pm 3.635$
Chewiness (mJ)	$15.7^{b} \pm 5.233$	$198.533^{a} \pm 6.085$	$108.100^{b} \pm 20.1288$	$96.667^{b} \pm 29.344$	$42.033^{b} \pm 13.789$	$87.100^{b} \pm 24.890$	$48.550^{b} \pm 0.071$	$18.700^{b} \pm 9.899$

T1 = Control (15% fat)　　T2 = 10 % Inulin (0% Fat)
T3 = 15 % Inulin (0% Fat)　　T4 = 15 % Inulin (5% Fat)

Values are represented as means ± standard deviation.
In the same row, different letters mean significant differences (P< 0.05).

Table (7): Effect of replacing fat with inulin in sensory properties of cooked burger.

Properties	Fresh burger samples after cooking			
	T1	T2	T3	T4
Color	9.43[a]	8.43[b]	8.00[b]	8.00[b]
Flavor	9.71[a]	8.43[b]	7.71[b]	8.00[b]
Juiciness	9.14[a]	8.29[ab]	7.57[b]	8.29[ab]
Chewiness	9.00[a]	8.57[a]	8.14[ab]	7.43[b]
Tenderness	9.43[a]	8.56[a]	7.86[b]	7.43[b]
Off Flavor	9.00[a]	8.29[ab]	7.43[b]	8.29[ab]

T1 = Control (15% fat) T2 = 10 % Inulin (0% Fat)
T3 = 15 % Inulin (0% Fat) T4 = 15 % Inulin (5% Fat)
Results represented the mean values of three replicated samples. In the same row, different letters mean significant differences ($P < 0.05$).

Table (8): Effect of replacing fat with inulin on sensory properties of the cooked burger after storage for three months.

Properties	burger samples after storage and cooking			
	T1	T2	T3	T4
Color	8.57[a]	8.14[a]	8.07[a]	8.64[a]
Flavor	8.29[a]	7.93[ab]	6.29[c]	7.00[bc]
Juiciness	8.14[a]	7.71[a]	6.43[b]	6.57[b]
Chewiness	8.14[a]	7.57[ab]	7.43[ab]	6.86[b]
Tenderness	8.50[a]	7.86[ab]	7.50[b]	7.57[ab]
Off flavor	8.14[a]	7.57[ab]	7.21[b]	7.86[ab]

T1 = Control (15% fat) T2 = 10 % Inulin (0% Fat)
T3 = 15 % Inulin (0% Fat) T4 = 15 % Inulin (5% Fat)
Results represented the mean values of three replicated samples. In the same row, different letters mean significant differences ($P < 0.05$).

4. Conclusion

The consumer needs tasty foods low in fat and calories to gain health benefits. Inulin was used in the formula of beef burgers to meet this need. The obtained results showed that were no significant differences between the redness values of all formulated samples after storage for three months compared to the control burger sample. The highest redness value was observed in a cooked burger of 15% inulin + 5% fat (9.59). Also, the effect of cooked formulated burgers with inulin before and after storage on texture profile analysis was evaluated. Adding inulin to the formula significantly increased hardness compared to the control sample. After storage, the hardness of the control sample was increased, while formulated burger with inulin was decreased compared to the same fresh cooked sample. The obtained findings confirmed the ability to replace fat (15%) with 10 or 15% inulin, or 15% inulin + 5% fat, where inulin in all samples did not cause a significant effect on sensory or texture properties and at the same time reduced fat content in meat burger.

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