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# The influence of cactus (*Opuntia ficus-indica* (L.) Mill) cladodes powder on improving the characteristics and shelf life of low-fat beef and chicken burgers

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**Abstract**

This research aims to investigate the influence of using cactus cladodes powder (CP) as a binder at three concentrations (1%, 3%, and 5%) on selected quality characteristics of low-fat beef and chicken burgers after formulation and during freeze storage (-18 °C) for 100 days, in comparison to control treatments without CP. Using CP at 3% and 5% influenced ($p < 0.05$) the proximate composition of the formulated burgers, while 1% CP did not influence the proximate composition significantly. Cooking loss was decreased ($p < 0.05$) by using CP at 3% and 5%. Oxidation stability of raw and cooked burgers formulated with 3% and 5% CP increased after formulation and during freezing storage for 100 days in comparison to control burger samples. Sensory preferences of color, tenderness, juiciness, taste, and overall acceptability were improved in samples with 3% and 5% CP in comparison to control and 1% CP burgers.

**Keywords:** cooking loss; meat binders; meat storage; oxidation; sensory evaluation.

**Practical Application:** The improvement of beef and chicken characteristics using cactus cladodes powder indicates the beneficial use of inclusion of this powder in the formulation of burgers in meat industries to manufacture meat patties with more palatable characteristics and a cheap source of the binder.

## 1 Introduction

A significant portion of the population's nutritional habits has changed largely as a result of the quickened urban pace and the necessity to cut meal preparation time (Kearney, 2010). However, this change in nutritional habits is associated with the increase in demand for healthier and functional diets (Prado et al., 2019). There is increased interest in foods for their bioactive components needed for the prevention of diseases (Silva et al., 2021).

Burgers are a prevalent product of processed meat in the world and consumed heavily (Mizi et al., 2019). About 47% of the adults in the United States eat one or more sandwiches on any given day where 17% of them are burgers (Sebastian et al., 2015). Burgers, convenience ready-to-eat food, can be made from different types of meat such as beef and chicken. They are highly accepted because of their low prices and fast preparation time and public demand (Carvalho et al., 2019; Oliveira, 2014).

Many studies were conducted to develop and enhance burger such as reduction of fat content to produce low-fat burgers. However, this reduction may be accompanied with adverse effects on the sensory attributes including texture, mouthfeel, and cooking yield (Ospina-Echeverri et al., 2012). A number of non-meat components have been added to meat products to enhance their qualities, as a part of consumer interest, and to produce natural, nutritional, and functional meat products (Longato et al., 2017; López-Vargas, et al., 2014; Xu, 2001). Using plant natural antioxidants in meat products has minimized lipid oxidation in many meat products (Mizi et al., 2019).

Numerous binding agents, or binders, are commonly used in processed meat products to increase moisture and fat binding capacity, enhance shelf stability due to antioxidant properties, and as a result enhance sensory preferences. Moreover, these additives improve the yield and minimize the product cost, which is economically viable for the burger industry (Colle et al., 2019).

Because of their natural origin, capacity to bind water, antioxidant impact, and presence of nutritional and functional components such as fibers and other substances, plant powders, which are high in carbohydrates and fiber, maybe the most accepted binders in meat products by customers (Mancini et al., 2017). The cactus (*Opuntia ficus-indica* (L.) Mill) plant belongs to the Cactaceae family and has four main segments: fruit, cladodes, flower, and seeds. It adapts easily to the environment in many geographic areas for instance; the Middle East, South Africa, North America, Central America, South America, Australia, and India (Loretta et al., 2019). It is used in diet and healthcare due to its high content of antioxidant and polyphenols, anxiolytic and anti-inflammatory properties (Akkol et al., 2020). Due to their hydrocolloid nature, the cladodes of the Opuntia species provide interesting perspectives as a food additive or component; it contains mucilage that is important to modify the texture of food products (Dick et al., 2019), dietary fibers and minerals. Cactus cladodes have bioactive compounds such as polyphenols (phenolic acids and flavonoids) and carotenoids with important antioxidant properties (Mena et al., 2018), which decrease the risk of several diseases related to oxidative stress. Cladodes

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powder was used to increase the concentration of beneficial compounds in bakery products and as an important ingredient in gluten-free baked products (Akkol et al., 2020). Furthermore, it was used as gelling, thickening, emulsifying and film-forming agents in food (Ayadi et al., 2009). It is a potential candidate to be incorporated food products not only because of it nutritional, nutraceutical, antioxidant, and functional properties but also for its low manufacturing cost (Ventura-Aguilar et al., 2017). Therefore, the purpose of this study was to assess the incorporation of cactus cladodes powder as a natural binder in the .production of low-fat beef and chicken burgers, and its influence on their characteristics after preparation and during frozen storage.

## 2 Materials and methods

### *2.1 Preparation and biochemical analysis of cactus cladodes powder*

Tender mature cactus cladodes (*Opuntia ficus-indica* (L.) Mill.) were randomly collected from different locations in the north of Jordan in March 2021, and transferred to the laboratory using polyethylene bags. Cladodes were washed using tap water, peeled, cut into small cubes, and dried to stable weight at 45 ± 1 °C for five days using a convection oven. After drying, cladodes were grounded, sieved using a wire sieve of 0.25 mm mesh, and the powder was kept in airtight polyethylene bags in the refrigerator at 5-7 °C until subsequent characterization and usage in burgers formulation.

The characterization of cladodes powder included moisture, crude protein, crude lipids, ash, total carbohydrates (by difference), and crude fiber, in addition to the tannins (mg/100 g D.M) according to Association of Official Analytical Chemists (2000). Total polyphenols (µmol of gallic acid (GA)/g sample) and flavonoids (µmol of quercetin (QE)/g of sample) were measured spectrophotometrically (Biotech Engineering Management CO. Ltd, UK) according to Guevara-Figueroa et al. (2010) methods. Total chlorophyll (mg/100 g D.M) content was measured as described by Mencarelli & Saltveit (1988) method. β-carotene (mg/100 g D.M) was measured as described by Rodriguez-Amaya (1999). Antioxidant activity using DPPH (µmol of Trolox/g of the sample) was measured according to Ozgen et al. (2006).

### *2.2 Preparation of burgers*

Fresh beef, fresh de-boned whole chicken meat, salt, and spices used in the preparation of burgers were purchased from the local market. Beef and chicken meat were grounded in a meat mincer using an 8 mm plate. Four batches of beef patties and four batches of chicken patties were made by dividing the ground beef and chicken meats into four portions of ten kg each resulting in 8 samples (four beef and four chicken burger treatments). Three beef and three chicken burger treatments were formulated by adding 1%, 3%, and 5% CP, followed by the addition of 1% salt, 1% spices, and 5% water for each treatment using Hobart (Hobart, London, UK) mixer. The fourth treatment (beef and chicken burgers) was a control treatment containing the same ingredients except for CP. All dry ingredients were first added and thoroughly mixed, followed the by addition of water. The prepared burger treatments were shaped into 100 g patties with 1 cm thickness using a household burger patty mold. Each treatment was performed in duplicate.

Some freshly prepared beef and chicken burger samples were taken and analyzed for physiochemical and sensory properties. The remaining samples were kept frozen in airtight polyethylene bags at -18 °C to be tested during storage for 100 days at four time points of 25, 50, 75, and 100 days.

### *2.3 Analyses of burgers*

*Proximate analysis*

The beef and chicken burgers were analyzed immediately after formulation for moisture, crude protein (Kjeldahl method), crude fat (Soxhlet method), ash, and total carbohydrates content as per AOAC (2000) protocol (in triplicates).

*Grilling and cooking loss*

The burgers in the frozen state were cooked on an electric grill (LT15, maker, Ankara, Turkey) preheated to 150 °C until the internal temperature reached 74 °C in the center. This was measured using a thermocouple thermometer (Digitec, Modena, Italy).

The cooking loss of burgers was determined as the difference between the weight of raw frozen and grilled patties after they were cooled to room temperature (21-22 °C) as follows (Equation 1):

$$\%\ cooking\ loss = Raw\ frozen\ burger\ weight\ (g) - \frac{Grilled\ burger\ weight\ (g) \times 100}{Raw\ frozen\ burger\ weight\ (g)} \quad (1)$$

*Thiobarbituric Acid Reactive Substances Values (TBARs)*

Lipid oxidation, in both raw and grilled beef and chicken burgers, was measured using the TBARs method using a double-beam UV-visible spectrophotometer as described by Bruna et al. (2001). The results were expressed as mg malonaldehyde (MDA)/kg sample, after the measurement of absorbance at 532 nm.

*Sensory evaluation*

Color, tenderness, juiciness, taste, and overall acceptability of beef and chicken burgers were assessed separately as described by Larmond (1991) using the 9-hedonic scale, ranging from 9 (like extremely) to 1 (dislike extremely). Thirty experienced panelists assessed the samples in three sessions. Water and bread were used between treatments to neutralize the palates.

### *2.4 Statistical analysis*

All treatments and analyses were carried out in duplicates. All data were expressed as means ± standard deviation (means ± SD). Data were subjected to analysis of variance (ANOVA) accompanied by the Duncan test using SAS software (version 9.1 for Windows, North Carolina, SAS Institute Inc, 2013), to identify the significance ($p < 0.05$) amongst the treatments.

## 3 Results and discussion

### 3.1 Characterization of cactus cladodes powder

The prepared CP had high carbohydrate content (70.1%) followed by ash (13.6%), protein (8.8%) and lipids (2.1%). Moreover, its content of functional components such as crude fiber (22.3%), tannins (40 mg/100 g D.M), polyphenols (62 µmol of gallic acid (GA)/g sample), carotene (0.95 mg/100 g D.M, and flavonoids (18 µmol of quercetin (QE)/g of sample) could be beneficial to be incorporated in different food items (Table 1).

### 3.2 Proximate composition of prepared burgers

The influence of cladodes powder addition on proximate composition for both beef and chicken burgers is shown in Tables 2 and 3, respectively. Moisture significantly decreased at 3% and 5% addition levels, protein, and lipids significantly ($P > 0.05$) decreased at 5% level, but were not affected at 1% and 3% levels. Ash contents significantly increased in burgers at a 5% level, while total carbohydrates and crude fiber significantly increased at all added three levels. It is a well-known fact that eating enough dietary fiber lowers the risk of degenerative illnesses including bowel cancer, diabetes, coronary heart disease, obesity, and gallstones (Ahmad, 1995; Horn, 1997). Dietary fibers also offer technical features that may be employed in food composition, resulting in texture changes and improved food stability throughout manufacture and storage (Thebaudin et al., 1997).

### 3.3 Cooking loss of burgers

Loss during burgers cooking has many negative effects on the economic, nutritional value, and sensorial attributes of these food products. It results in weight and diameter reduction, and loss of important nutrients including minerals, amino acids, and vitamins, moreover, produces products with bad texture and juiciness (López-Vargas et al., 2014).

As shown in Figure 1 of beef (A) and chicken (B) burgers cooking loss, the effect of CP at 3% and 5% in decreasing the cooking loss of beef and chicken burgers was evident at all storage times, while using 1% CP had no significant effect. This influence of CP in decreasing the cooking loss of beef and chicken burgers could be attributed to its components of high levels of carbohydrates, crude fiber, and protein. These components increase water retention and holding capacity. The results of this study are similar to that of Soltanizadeh & Ghiasi-Esfahani (2015) who found that using Aloe vera powder decreased the cooking loss of beef burgers. The polysaccharide content of Aloe

**Table 1**. Characterization of cactus cladodes powder.

| Content | Mean value |
|---|---|
| Moisture% | 5.4 ± 0.33 |
| Protein % | 8.8 ± 0.72 |
| Lipids % | 2.1 ± 0.15 |
| Ash % | 13.6 ± 0.87 |
| Total carbohydrates% | 70.1 ± 1.65 |
| Crude fiber % | 22.3 ± 1.28 |
| Tannins mg/100 g D.M | 40 ± 0.055 |
| Total polyphenols (µmol of gallic acid (GA)/g sample) | 62 ± 1.47 |
| Flavonoids (µmol of quercetin (QE)/g of sample) | 18 ± 0.44 |
| Total chlorophyll mg/100 g D.M | 50 ± 0.14 |
| β-carotene mg/100 g D.M | 0.95 ± 0.006 |
| DPPH (µmol of Trolox/g of the sample) | 582 ± 3.2 |

Values are means ± *SD* of duplicates.

**Table 2**. Proximate composition of beef burgers.

| Content (%) | B1 | B2 | B3 | B4 |
|---|---|---|---|---|
| Moisture | 67.3 ± 0.68a | 67 ± 0.55a | 65.8 ± 0.46b | 64.6 ± 0.58c |
| Protein | 16.8 ± 0.11a | 16.6 ± 0.15a | 16.4 ± 0.22ab | 16 ± 0.17b |
| Lipids | 13.4 ± 0.18a | 13.3 ± 0.13a | 13.1 ± 0.1ab | 12.7 ± 0.19b |
| Ash | 2.1 ± 0.08b | 2.2 ± 0.06b | 2.3 ± 0.07ab | 2.5 ± 0.09a |
| Total Carbohydrates | 0.4 ± 0.02d | 1 ± 0.09c | 2.4 ± 0.1b | 4.2 ± 0.12a |
| Crude fiber | 0d | 0.25 ± 0.07c | 0.43 ± ± 0.04b | 0.71 ± 0.03a |

B1: Beef burger without addition of cladodes powder (control); B2: Beef burger formulated with 1% cladodes powder; B3: Beef burger formulated with 3% cladodes powder; B4: Beef burger formulated with 5% cladodes powder. Values are means ± *SD* of duplicates. Values followed by various letters are significantly different ($p < 0.05$).

**Table 3**. Proximate composition of chicken burgers.

| Content (%) | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| Moisture | 67.8 ± 0.48a | 67.3 ± 0.34a | 66 ± 0.72b | 64.7 ± 0.85c |
| Protein | 17 ± 0.17a | 16.8 ± 0.18a | 16.6 ± 0.13ab | 16.3 ± 0.19b |
| Lipids | 12.7 ± 0.26a | 12.5 ± 0.28a | 12.3 ± 0.33ab | 12 ± 0.14b |
| Ash | 1.9 ± 0.05b | 2 ± 0.08b | 2.3 ± 0.07ab | 2.6 ± 0.12a |
| Total Carbohydrates | 0.6 ± 0.1d | 1.4 ± 0.15c | 2.8 ± 0.13b | 4.4 ± 0.21a |
| Crude fiber | 0d | 0.26 ± 0.08c | 0.46 ± 0.06b | 0.75 ± 0.07a |

C1: Chicken burger without addition of cladodes powder (control); C2: Chicken burger formulated with 1% cladodes powder; C3: Chicken burger formulated with 3% cladodes powder; C4: Chicken burger formulated with 5% cladodes powder. Values are means ± *SD* of duplicates. Values followed by various letters are significantly different ($p < 0.05$).

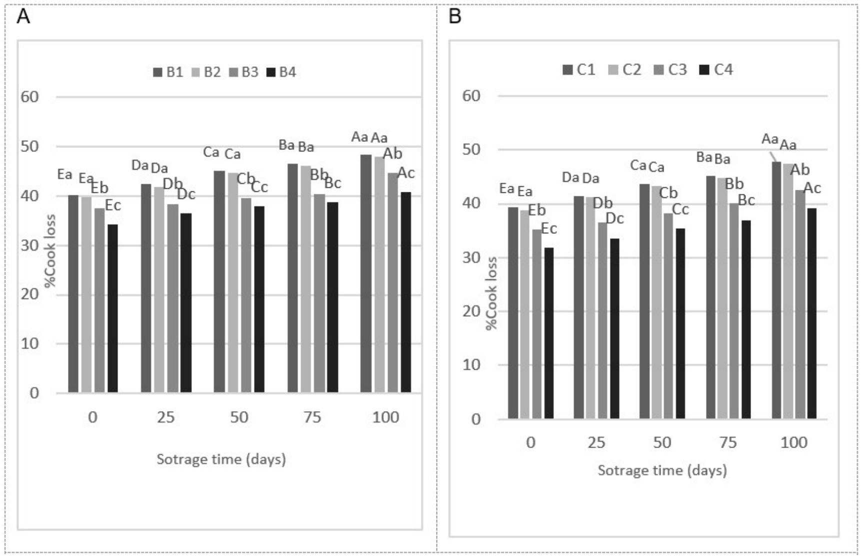


**Figure 1**. Cook loss values of beef (A) and chicken (B) burgers during storage for 100 days at -18 °C. Lower-case letters denote significant differences among treatments, whereas upper-case letters denote significant differences during storage (P < 0.05). B1 and C1: b=Beef and chicken burger (control) without the addition of cladodes powder; B2 and C2: beef and chicken burger formulated with 1% cladodes powder; B3 and C3: beef and chicken burger formulated with 3% cladodes powder; B4 and C4: beef and chicken burger formulated with 5% cladodes powder.

Vera retains water and forms a network with proteins to prevent water release. Crude fiber increases water and lipid retention during cooking and enhances emulsion stability. This results in decreased cooking loss and increased yield by strengthening the meat structure system favor in more binding between protein, water, and fat, and improving the technological characteristics of meat products (Mehta et al., 2015). Cactus cladodes powder studied by López-Cervantes et al. (2011) showed high water holding capacity, and they reported that this powder could be beneficial to use in food and food products to improve their texture and functional properties. Antioxidant activity is affected by cooking. A study conducted by Hwang et al. (2012) found that cooking significantly reduced antioxidant activity.

On the other hand, storage time at -18 °C increased significantly the cooking loss of all burger treatments as investigated at 25, 50, 75, and 100 days compared to cook loss at zero time. It also remained the lowest in burgers produced with CP which could be attributed to the antioxidant effect of this powder (Table 1) that protects the meat proteins against free radicals and reactive oxygen species. These results were confirmed by Mancini et al. (2017) who found that the addition of ginger powder increases water retention and decreases the cooking loss of the burgers.

### *3.4 TBARs values of burgers*

The oxidative stability of raw and grilled beef as well as chicken burgers after formulation and during storage, measured using the TBARs method is illustrated in Figure 2. Regarding raw burgers (Figure 2A and 2C), there was no significant difference at zero time between all burger treatments whether with or without CP. However, during storage for up to 100 days, the TBARs significantly increased for all treatments. Burgers formulated with 5% CP had significantly the lowest TBARs values followed by burgers formulated with 3% CP. Burgers made with 1% CP were not significantly different from the control treatment. TBARs of grilled control and 1% CP burger treatments were not significantly different at zero and during storage intervals, while grilled burgers with 5% CP had significantly the lowest TBARs values followed by grilled burgers with 3% CP at zero and during storage intervals (Figure 2B and 2D).

These results revealed the protective effect of cactus cladodes powder in the protection of meat lipids against oxidation in both raw and grilled burgers which could be attributed to the CP content of tannins, polyphenols, flavonoids, and carotene (Table 1). These compounds scavenge free radicals and protect the lipids from oxidation as indicated by. the DPPH parameters.

The oxidation in meat and meat products is accelerated by storage and/or heat. Lower TBARs values whether in stored or grilled burgers formulated with CP in comparison to freshly prepared and/or raw burgers without CP indicate retaining the antioxidant effect of this powder during storage and cooking. This is similar to the results of oxidation in pork burgers formulated with albedo-fiber powder from yellow passion fruit (López-Vargas et al., 2014). Mireles-Arriaga et al. (2017) reported that using plants as natural antioxidants could improve the nutritional value, overall quality parameters, and human health promotion of meat and meat products.

### *3.5 Sensory preferences of burgers*

Color is one of the main factors that affect consumers' acceptability of processed meat products. At zero time of preparation, the color evaluation showed that the addition of CP did not affect the preferences of beef burgers at all three added levels compared to the control treatment, but during storage from 25 to 100 days, treatments formulated with 3% and 5% CP were evaluated as the best compared to control and 1% CP treatments. On the other

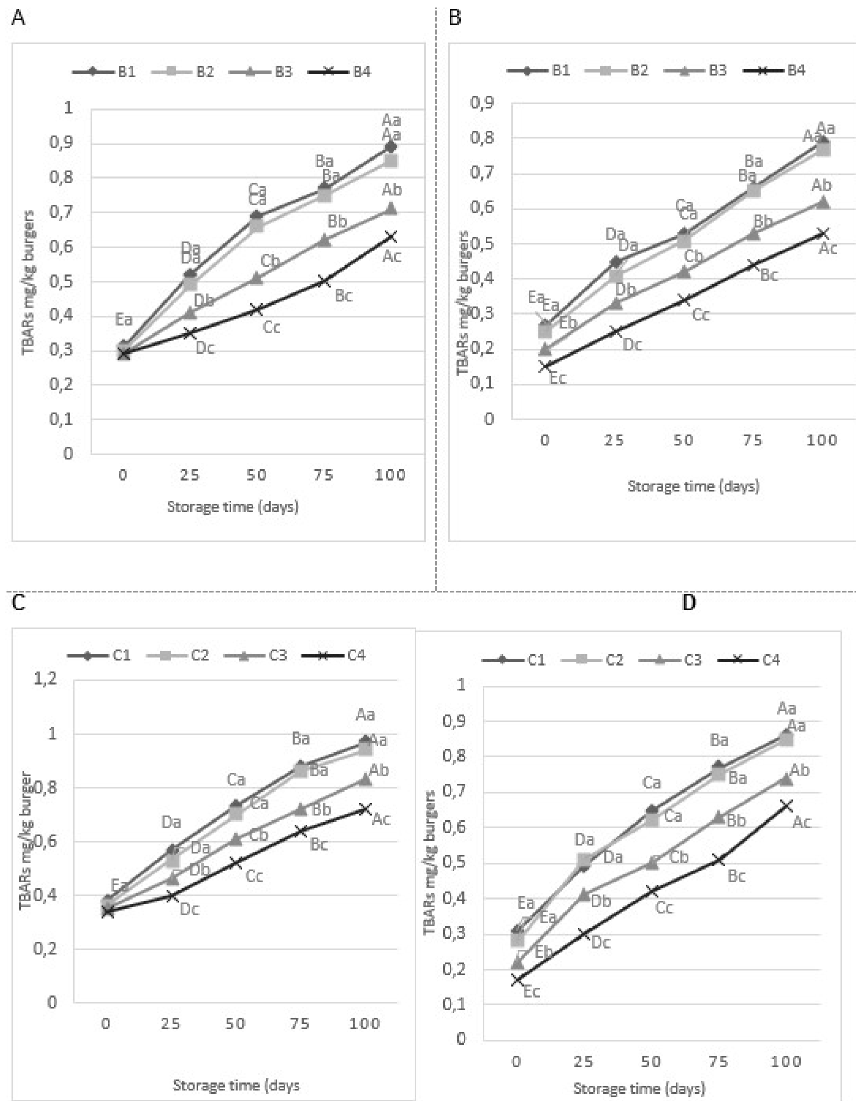


**Figure 2**. TBARs values of raw beef (A), grilled beef (B), raw chicken (C), and grilled chicken (D) burgers during storage for 100 days at -18 °C. Lower-case letters denote significant differences among treatments, whereas upper-case letters denote significant differences during storage ($P < 0.05$). B1 and C1: b = Beef and chicken burger (control) without the addition of cladodes powder; B2 and C2: beef and chicken burger formulated with 1% cladodes powder; B3 and C3: beef and chicken burger formulated with 3% cladodes powder; B4 and C4: beef and chicken burger formulated with 5% cladodes powder.

hand, Sensory evaluation of chicken burgers showed that color preferences of chicken burgers at zero time of preparation were evaluated as the best for control and 1% CP treatments, while lowest for 5% then 3% burgers with CP. Then as the storage time progressed from 25 to 100 days, the preferences shifted toward the treatments with 3% and 5% CP. The variations in color acceptability between beef and chicken burgers formulated with CP could be attributed to the difference in muscle type, the red muscle pigment could mask the color of CP that contains chlorophyll (Table 1), while white muscles in chicken burgers; could have less ability to mask the color of CP. At the storage time of both beef and chicken burgers, the antioxidant effect of CP, as shown from its component in Table 1 and TBARs results in Figure 2, could delay the oxidation of myoglobin which enhanced the color preferences of these burgers in comparison to burgers without CP. The oxidative process during the storage of meat contributes to the deterioration of the color. Synthetic antioxidants have been used to slow the oxidation process and extend the shelf life of meat but they have limited applications because their safety is questionable (El-Din Ahmed Bekhit et al., 2019) (Table 4).

Tenderness, juiciness, taste, and overall acceptability of beef burgers were evaluated as the best for treatment made with 5% CP followed by treatment with 3% CP, indicating that formulation of beef burgers with CP at 3% up to 5% enhanced the sensory characteristics of the made beef burgers. On the other hand, tenderness and juiciness parameters of chicken burgers were higher for treatment with 5% followed by 3% CP, while there was no significant difference between control and 1% cactus burger treatments. The taste and overall acceptability of chicken burgers were evaluated as the best for treatment with 3% CP followed by treatment with 5%, while

**Table 4**. Sensory evaluation of beef burgers.

| Characteristic | Storage time (day) | B1 | B2 | B3 | B4 |
|---|---|---|---|---|---|
| Color | 0 | A7.3a | A7.5a | A7.6a | A7.7a |
| | 25 | B6.5b | B6.3b | A7.4a | A7.3a |
| | 50 | C5.2b | C5.5b | B6.5a | B6.7a |
| | 75 | D4.6b | D4.7b | C5.8a | C6.0a |
| | 100 | E3.7b | E3.9b | D5.1a | D5.5a |
| Tenderness | 0 | A6.5c | A6.8c | A7.8b | A8.7a |
| | 25 | B6c | B6.2c | B7.2b | B8a |
| | 50 | C5.4c | C5.5c | C6.5b | C7.5a |
| | 75 | D4.7c | D4.9c | D5.6b | D6.7a |
| | 100 | E4c | E4.3c | E5b | E6a |
| Juiciness | 0 | A6.2c | A6.4c | A7.6b | A8.8a |
| | 25 | B5.6c | B5.8c | B6.9b | B8.2a |
| | 50 | C5c | C5.2c | C6.3b | C7.4a |
| | 75 | D4.3c | D4.6c | D5.7b | D6.8a |
| | 100 | E3.7c | E4c | E5b | E6.1a |
| Taste | 0 | A5.8c | A6.2c | A7.1b | A8.2a |
| | 25 | B5.2c | B5.5c | B6.5b | B7.5a |
| | 50 | C4.5c | C4.8c | C5.9b | C6.7a |
| | 75 | D4c | D4.2c | D5.1b | D6a |
| | 100 | E3.3c | E3.6c | E4.2b | E5.5a |
| Overall acceptability | 0 | A6.5c | A6.3c | A7.5b | A8.5a |
| | 25 | B6c | B5.6c | B6.8b | B7.8a |
| | 50 | C5.5c | C5.1c | C6b | C7a |
| | 75 | D4.9c | D4.6c | D5.4b | D6.5a |
| | 100 | E4c | E4.1c | E4.9b | E6a |

Lower-case letters denote significant differences among treatments, whereas upper-case letters denote significant differences during storage ($P < 0.05$). B1: Beef burger without addition of cladodes powder (control); B2: Beef burger formulated with 1% cladodes powder; B3: Beef burger formulated with 3% cladodes powder; B4: Beef burger formulated with 5% cladodes powder. Values followed by various letters are significantly different ($p < 0.05$).

**Table 5**. Sensory evaluation of chicken burgers.

| Characteristic | Storage time (day) | C1 | C2 | C3 | C4 |
|---|---|---|---|---|---|
| Color | 0 | A8.5a | A8.3a | A7.5b | A7.0c |
| | 25 | B7.5a | B7.2a | A7.1ab | A6.7b |
| | 50 | C6.6a | C6.5a | B6.3a | B6.2a |
| | 75 | D4.5b | D4.7b | C5.6a | C5.4a |
| | 100 | E3.2b | E3.5b | D4.3a | D4.6a |
| Tenderness | 0 | A6.7c | A7c | A7.9b | A8.8a |
| | 25 | B6c | B6.3c | B7.3b | B8.1a |
| | 50 | C5.5c | C5.6c | C6.5b | C7.4a |
| | 75 | D4.9c | D5c | D6b | D6.8a |
| | 100 | E4.2c | E4.4c | E5.2b | E6.1a |
| Juiciness | 0 | A6.5c | A6.9c | A8b | A8.7a |
| | 25 | B5.8c | B6.2c | B7.2b | B8a |
| | 50 | C5.2c | C5.5c | C6.3b | C7.5a |
| | 75 | D4.6c | D4.7c | D5.5b | D6.9a |
| | 100 | E3.9c | E4.1c | E5b | E6.3a |
| Taste | 0 | A6.2c | A6.5c | A8.5a | A7.6b |
| | 25 | B5.5c | B5.8c | B7.9a | B7b |
| | 50 | C4.8c | C5c | C7a | C6.4b |
| | 75 | D4c | D4.3c | D6.5a | D5.5b |
| | 100 | E3.2c | E3.5c | E5.8a | E4.8b |
| Overall acceptability | 0 | A6.4c | A6.7c | A8.3a | A7.5b |
| | 25 | B5.6c | B6c | B7.5a | B7b |
| | 50 | C5c | C5.3c | C6.8a | C6b |
| | 75 | D4.3c | D4.6c | D6a | D5.5b |
| | 100 | E3.5c | E3.8c | E5.5a | E4.6b |

Lower-case letters denote significant differences among treatments, whereas upper-case letters denote significant differences during storage ($P < 0.05$). C1: Chicken burger without addition of cladodes powder (control); C2: Chicken burger formulated with 1% cladodes powder; C3: Chicken burger formulated with 3% cladodes powder; C4: Chicken burger formulated with 5% cladodes powder. Values followed by various letters are significantly different ($p < 0.05$).

control and 1% CP treatments were the lowest. Decreasing the cooking loss (Figure 1) and the oxidation of burgers (Figure 2) could enhance their tenderness, juiciness, and taste. The difference between taste preferences between beef and chicken burgers at 5% could be attributed to the differences between white and red muscle. The overall acceptability of the chicken burgers formulated with 5% CP could be affected also by the taste that was lower for this treatment in comparison to the chicken burger with 3% CP (Table 5).

## 4 Conclusion

Inclusion of cactus cladodes powder at 3% and 5% in the formulation of beef and chicken burgers could be beneficial from both the food technology and nutrition point of view since both the cooking loss and the oxidation are decreased, while sensory quality and dietary fiber increased. On the other hand, the polyphenols, flavonoids, and β-carotene contents of cactus cladodes powder could add another nutritional value to the produced burgers.

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