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Qualitative improvement of low meat beef burger using *Aloe vera*

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ABSTRACT

Low meat beef burgers have found their niche in the food markets in developing countries because of their lower price. However, these burgers still lack an acceptable quality. This study investigates the effects of different concentrations of *Aloe vera* on the quality of this food product. For this purpose, beef burgers were produced with 0%, 1%, 3%, and 5% *Aloe vera* and the changes in their cooking parameters, lipid oxidation, texture, and appeal to consumers over 7 days of refrigerated storage were evaluated. Results indicate that *Aloe vera* contributed to some extent to decreased cooking loss and diameter reduction in the burgers. Increased concentrations of *Aloe vera* led to improvements in the water absorption and texture of the burgers as well as their lipid stability. However, a concentration level of 3% led to the most acceptability of the product to the panelists. Finally, it was found that *Aloe vera* acts as a hydrocolloid and improves the quality of burgers.

1. Introduction

The growing interest shown by the public in ready-made, fast, and easy foods stems from the busy life of modern consumers (Lawrie & Ledward, 2006). Hamburgers are among the attractive, ready-to-serve foods (Egbert, Huffman, Chen, & Dylewski, 1991) despite their failure to appear on everybody's plate due to their high fat and protein content. Over the last few years, a definite change in conceptual thinking stimulated by the need to satisfy regional preferences, optimization of food costs, and responsiveness to concerns about food safety has posed new challenges to food designers to address these needs (Modi, Mahendrakar, Narasimha Rao, & Sachindra, 2004). Meat processors should, therefore, be encouraged to provide a wider variety of products capable of winning consumer acceptance at affordable prices in order to increase the consumption of processed meats in developing nations. This necessitates a search for reduced formulation cost procedures while not compromising the quality and sensory attributes of the products (Akwetey & Knipe, 2012). Previous studies indicate that consumers are concerned about the high price and cholesterol content of beef burger (Menkhaus, Colin, Whipple, & Field, 1993). Moreover, beef burger contains about 20% fat which influences the quality perception of burgers (De Silva, Kalubowila, & Lalantha, 2011).

Partial substitution of meat with extenders/binders/fillers has been considered for improving the sensory quality and nutritional value of low meat burger at cheaper prices (Modi et al., 2004). Meat extenders are non-meat ingredients which are added to low quality meat products for economic reasons (Akwetey & Knipe, 2012). Up until now, different non-meat additives have been incorporated into meat products. For example, sodium caseinate and whey protein concentrate as dairy sources have been used in frankfurters (Atughonu, Zayas, Herald, & Harbers, 1998). Among the legumes, lupin, faba bean, chickpeas, and lentils in beef sausages (Bakr, Shekib, El-Iraqi, & Mohamed, 1986), soya beans in beef patties (Miles, Ziyad, Bodwell, & Steele, 1984), common bean flour in sausage (Dzudie, Scher, & Hardy, 2002), as well as cowpea and peanut flours in chicken nuggets (Prinyawiwatkul, Mcwatters, Beuchat, & Phillips, 1997) have been applied as extenders. Tubers and roots (Akwetey & Knipe, 2012; Kao & Lin, 2006), fruits and vegetables (Aleson-Carbonell, Fernández-López, Sayas-Barberá, Sendra, & Pérez-Alvarez, 2003), single-cell sources (Bruna, Fernández, Hierro, Ordóñez, & De La Hoz, 2000; Lin & Lin, 2004), and cereal grains (Beggs, Bowers, & Brown, 1997) are other extenders investigated for improving meat product quality.

Recently, *Aloe vera* has attracted attention in the food industry and used as a functional food ingredient in drinks, beverages, and ice cream and also as an edible coating to preserve grape fruit quality (Valverde et al., 2005). *Aloe barbadensis* belongs to the Liliaceae family with about 360 species. This cactus-like plant grows in hot and dry climates; however, it is cultivated in many areas of the world. The presence of 75 active components in *Aloe vera* meets the needs of the cosmetic and medicinal industries for the production of natural products (Vogler & Ernst, 1999). Anthrone, chromone, aloe verasin, hydroxyaloin, glycoprotein aloctin A, glucomannan, and acemannan are among the many active ingredients with wound healing, anti-inflammatory, anti-tumor, anti-ulcer, anti-neoplastic, and anti-viral effects (Hu, Xu, & Hu, 2003). A wide range of medical products made from *Aloe vera* are used for the treatment of diabetes, cancer, allergy, AIDS, and ulcer as well as gastrointestinal, kidney, and cardiovascular diseases (Valverde et al., 2005).

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The aim of the present study was to investigate the feasibility of using *Aloe vera* as a functional extender for improving the quality of low meat burgers and extending their shelf-life during refrigerated storage.

2. Material and methods

2.1. Materials

All chemicals and solvents used in this study were analytical grade commercial products purchased from Merck Chemical Company, Germany. *Aloe vera* powder was obtained from Mexialoe Laboratorios S.A. de C.V., Mexico. The properties of *Aloe vera* declared by the supplier are listed in Table 1.

2.2. Production of beef burger

Frozen beef was allowed thawing before it was cut into chunks of 1–2 in. in size which were then passed through 8 mm plates. Beef burger was produced by mixing 30% lean beef meat with 12% grated onion, 12.5% texturized soy protein, 4% wheat flour, 1% gluten, 1% seasoning, 1.1% salt, 7.6% vegetable oil, and 30.8% water. The resulting mix was finally ground through a 5 mm plate and formed into burgers. Beef burgers were stored at 4 °C for one week and analyzed on days 1, 3, 5, and 7 of the storage period.

Three different treatments were prepared by adding 1%, 3%, and 5% *Aloe vera* to the formulation while an equivalent amount in each treatment was reduced from the texturized soy protein. No *Aloe vera* was added to the control treatment. Each of the four treatments was prepared in three separated batches.

2.3. Proximate analysis

The proximate composition of *Aloe vera* and raw beef burgers was determined according to the AOAC methods. Moisture content was determined in an oven at 105 °C until the weight became constant. Total crude protein was determined by the Kjeldahl method and lipid content was analyzed according to the Soxhlet method. Incineration in a muffle furnace at 550 °C was used for measuring the crude ash content of *Aloe vera* (AOAC, 1996). The available carbohydrate of *Aloe vera* was estimated by difference.

2.4. pH measurement

Using the IKA homogenizer (ULTRA-TURRAX, Germany), 5 g of raw burger was homogenized for 30 s with 45 mL of distilled water. A pH meter (JENWAY, USA) was used to measure the pH values of the samples.

Table 1
The declared and measured properties of *Aloe vera* obtained from Mexialoe Laboratorios, S.A. de C.V.

Property	Amounts (D.W.)
Moisture (%)	6.0
Protein (%)	0.92
Ash (%)	35.66
Fat (%)	0.65
Carbohydrate	56.77
Specific gravity at 25 °C (0.5% sol.)	1.0026
pH at 25 °C (0.5% sol.)	4.1
Solubility rate at 25 °C	15 seg.
Aloin solution 0.5%	Less than 1 ppm
Microbial count	<100 cfu/g
Pathogenic bacteria	<10 cfu/g

2.5. Water holding capacity (WHC)

Water holding capacity was expressed as expressible moisture according to method described by Jauregui and Regenstein (1981). The expressible moisture reported as percent weight lost from original samples.

2.6. Cooking loss

Three pieces 15 g in weight from each treatment was shaped to a circular disc and fried using a De'Longhi fryer (F38436, USA) in sunflower oil at 155 °C for 5 min. Cooking loss of the beef burgers was measured by weighing raw and fried burger according to the following formula (Akwetey & Knipe, 2012):

$$\text{Cooking loss}\ (\%) = [(\text{final weight-initial weight})/\text{initial weight}] \times 100.$$

2.7. Diameter reduction

The diameter of each beef burger was measured before and after frying with a digital caliper. Change in the beef burgers' diameter was determined using the following equation (Modi et al., 2004):

$$\text{Reduction in burger diameter}\ (\%) = [(\text{raw burger diameter} - \text{fried burger diameter})/\text{raw burger diameter}] \times 100.$$

2.8. Moisture retention

Moisture remaining in the products after frying was measured according to the following equation:

$$\text{Moisture retention}\ (\%) = (\text{moisture of raw beef burger}/\text{moisture of fried beef burger}) \times 100.$$

2.9. Fat absorption

Fat absorption was determined by calculating the difference between fat percentages in the raw and fried burgers.

2.10. Thiobarbituric acid value

Twenty grams of meat was blended with 50 ml of 20% trichloroacetic acid (TCA) for 2 min. The blender content was rinsed with 50 ml of water, mixed together, and filtered through a Whatman # 1 filter. Subsequently, 5 ml aliquot of the TCA extract was mixed with 5 ml of 0.01 M 2-thiobarbitoric acid and held at 100 °C for 1 h. The absorbance of pink color solution was measured at 532 nm using a UV/vis spectrophotometer. TBA was reported as mg of malonaldehyde/kg of the sample (Strange, Benedict, Smith, & Swift, 1977).

2.11. Texture analysis

All mechanical properties were made using the Instron Universal Testing Machine (Model 4302) equipped with flat plate probe for compression and blade for cutting (with 500 g–5 Kg load cell). Texture properties were evaluated in raw and fried samples. Raw burgers 5 cm in diameter and 1 cm in thickness were compressed to 50% of their original height in a one-cycle compression test at a constant speed of 50 mm/min using a circular flat plate. The force corresponding to the maximum compression was reported as the maximum force. At least 3 measurements were taken for each test. The shear force of the cooked burgers was estimated with a blade attached to the texture analyzer

moving at a crosshead speed of 50 mm/min. Maximum force to cut the samples was recorded as the shear force.

2.12. Sensory evaluation

Burger samples were cooked according to the method described above. Twenty experienced panelists including 10 men and 10 women from Isfahan University of Technology (Isfahan, Iran) were requested to test the samples in three sessions. Each panelist compared four randomly coded samples for texture, flavor, color, and overall acceptability on a 9-point hedonic scale (9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely). Tap water was provided between samples to cleanse the palate.

2.13. Statistical analysis

All measurements were replicated three times for each batch and mean values ± standard errors were reported for each case. The split-plot analysis of variance, with confidence intervals set for a level of significance of $P < 0.05$ on Statistical Analysis System (SAS) to evaluate the significance of differences among TBARS and pH mean values. For other parameters, mean separation was accomplished by Least Significant Difference (LSD) Test. For sensory evaluation analysis of variance, the *Aloe vera* concentration, panelists and sessions were used as terms in the model while two last parameters were included as random effects.

3. Results and discussion

3.1. Proximate composition

Table 2 indicates moisture, protein, and fat content of the beef burgers containing different concentrations of *Aloe vera*. As can be seen, no significant effect was observed on the proximate composition of low meat beef burgers when compared with the control.

3.2. pH

pH profiles for the beef burgers are shown in Fig. 1. *Aloe vera* has an acidic pH of 4.1 and reduces the pH of beef burgers. Low meat beef burgers containing 5% *Aloe vera* exhibited the lowest pH value. This is because addition of *Aloe vera* to beef burgers reduced their pH value such that it declined to 4.6 in burgers containing 5% *Aloe vera*. At this pH level or lower, meat products are stable among most pathogenic bacteria, especially *Clostridium botulinum*. During the 7 days of storage, the pH values of the meat products containing 0%, 1%, and 3% *Aloe vera* decreased but it did not change significantly in the one containing 5% *Aloe vera*. The reduced pH during storage has been attributed to the microbial growth (Forrest, Alberle, Hedrick, Judge, & Merkel, 1975). It seems that acid producing bacteria grow in both beef burgers without *Aloe vera* and those containing 1% and 3% *Aloe vera*. Acid production was higher in burgers lacking *Aloe vera* that may be due to the higher growth rate of lactic acid bacteria. The antimicrobial effect of *Aloe vera* may be the cause of the lower acid production and less pH reduction with increasing *Aloe vera* concentration. The antimicrobial effect of *Aloe vera* has been proved in many previous studies (Cock, 2008; George, Bhat, & Antony, 2009; Gontijo, Gomes, Gala-García, Sinisterra, & Cortés, 2013) and Reynolds and Dweck (1999) found the dihydroxyanthraquinones and saponins in *Aloe vera* responsible for this antimicrobial effect.

Table 2
Proximate composition of raw burgers contain different percentage of *Aloe vera*.

Proximate composition	Control	1% *Aloe vera*	3% *Aloe vera*	5% *Aloe vera*
Moisture (%)	62.23 ± 1.28	61.4 ± 1.47	62.49 ± 1.35	59.99 ± 1.11
Protein (%)	9.02 ± 0.96	10.23 ± 0.58	9.07 ± 1.04	10.93 ± 2.61
Fat (%)	13.08 ± 0.60	10.79 ± 1.33	12.14 ± 3.12	9.97 ± 1.84

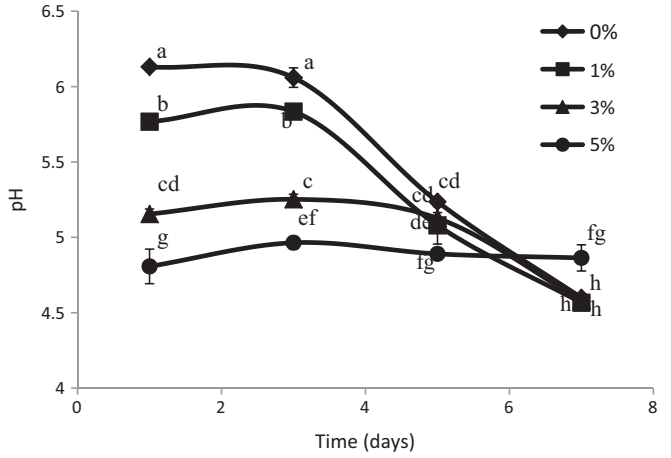

Fig. 1. Changes in pH values of burger samples containing different concentrations of *Aloe vera* during cold storage.

3.3. Water holding capacity

Aloe vera, at all its concentrations, increased the water holding capacity (WHC) of the beef burgers (Fig. 2). This increase was found to depend on the *Aloe vera* concentration, rising about 8% with increasing *Aloe vera* content to the highest level. Beef burgers containing 3% and 5% *Aloe vera* had the highest WHC while burgers without *Aloe vera* and those containing 1% *Aloe vera* showed no significant differences. WHC is the ability of meat to hold its own or added water during processing. Scala et al. (2013) maintained that *Aloe vera* has a WHC of about 78%. This high water holding capacity helps to retain the water released from meat while it also increases the WHC of low meat burgers with increasing *Aloe vera* concentration. Polysaccharides account for the greatest portion of the dry matter of *Aloe vera* parenchyma (Femenia, García-Pascual, Simal, & Rosselló, 2003). Our findings also indicate that the carbohydrate content of *Aloe vera* is high (Table 1). The polysaccharides of *Aloe vera*, either alone or in interaction with proteins, may form a network that traps water and prevents its release.

3.4. Cooking loss

Addition of *Aloe vera* to low meat beef burgers at all levels improved cooking yield. Cooking losses significantly decreased with increasing

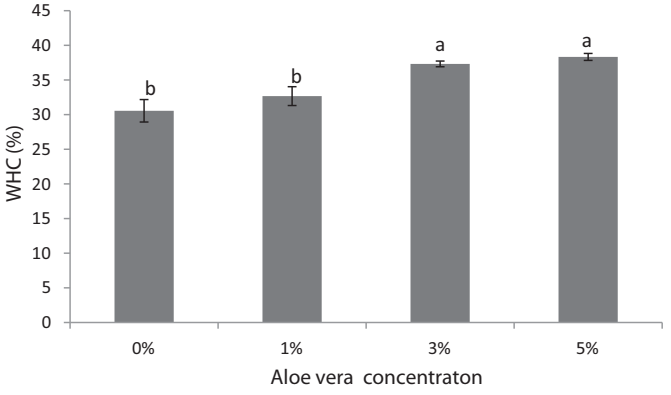

Fig. 2. Water holding capacity of low meat beef burgers containing different concentrations of *Aloe vera*.

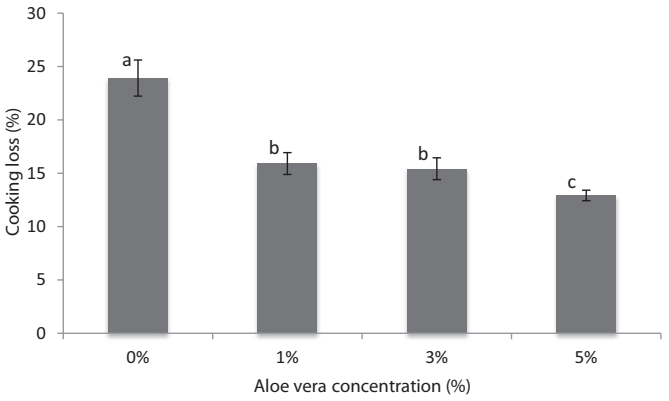

Fig. 3. Cooking loss of low meat beef burgers containing different concentrations of *Aloe vera*.

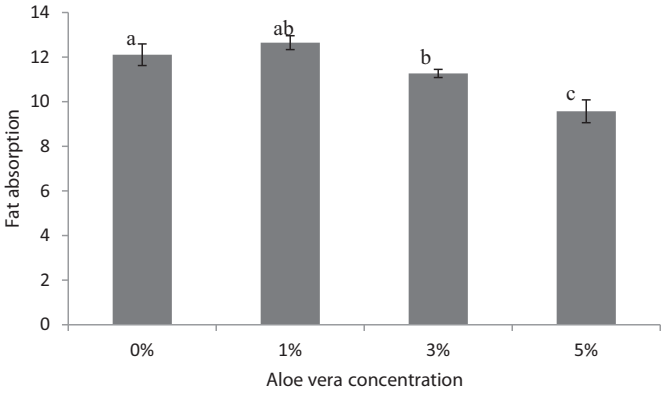

Fig. 5. Fat absorption of low meat beef burgers containing different concentrations of *Aloe vera*.

Aloe vera levels in beef burgers compared to the control (Fig. 3). The losses of burgers containing 1% and 3% *Aloe vera* decreased by about 8%, reducing further by 11% when 5% *Aloe vera* was added. This could be attributed to the high water holding capacity and moisture retention of *Aloe vera* during cooking. *Aloe vera* has a mucilaginous jelly texture that is composed of at least four different glucomannans which are partially acetylated and have different acetyl contents and glucose-to-mannose ratios (Channe Gowda, Neelisiddaiah, & Anjaneyalu, 1979). These mucilaginous compounds sequester high amounts of water in their structure and retain moisture during cooking.

3.5. Moisture retention

Based on the results obtained on WHC and cooking losses, it is obvious that moisture retention of beef burger samples increases with *Aloe vera* incorporation (Fig. 4). In the present study, moisture retention values were observed to increase with increasing *Aloe vera* in beef burger (from 63% in control samples to 68% in burgers contacting 5% *Aloe vera*), which could be attributed to the high water binding capacity of *Aloe vera*. The lower moisture retention of beef burgers lacking *Aloe vera* or containing 1% *Aloe vera* (about 63 and 65%, respectively) must be the consequence of their lower water holding capacity.

3.6. Fat absorption

Addition of *Aloe vera* to beef burgers resulted in reducing fat absorption on frying (Fig. 5). As can be seen in Fig. 5, increasing *Aloe vera* concentration led to 2.5% reduction of fat absorption. During deep-fat frying, water will evaporate out of the food being fried. The vapor escaping from the burgers leaves behind voids which will be occupied by fat. Thus, foods with a higher moisture loss will absorb more fat during frying (Mellema, 2003). The low meat burger produced with 5% *Aloe vera* had the highest water holding capacity and moisture retention which reduced vapor production and fat absorption. Fat absorption was observed to reduce to the interestingly low level of 9.5%, which could possibly be attributed to the mucilaginous compounds of *Aloe vera*.

3.7. Cooking shrinkage

Cooking shrinkage is an important quality factor in the production of burgers (Ammar, 2012). The diameter of the control sample used in this study was observed to shrink by approximately 16% during frying; however, this reduction in diameter significantly decreased with increasing amounts of *Aloe vera* added (Fig. 6) so that it reached to 2% in burgers having 5% *Aloe vera*. Fat and water release as well as muscle protein denaturation are the main causes of the reducing diameter during cooking of beef burgers. Since the ability of burger extenders to form a gel and to retain moisture and fat determines the level of shrinkage in meat products (Alakali, Irtwange, & Mzer, 2010), the high moisture retention of beef burgers containing 5% *Aloe vera* seems to have prevented the reduction in diameter.

3.8. Texture

The use of *Aloe vera* in beef burger formulations influenced textural properties significantly. The force required for 50% compression of the raw beef burgers is shown in Table 3. With increasing *Aloe vera* concentration to 3%, the force needed for compression increased but no significant differences were observed between beef burgers

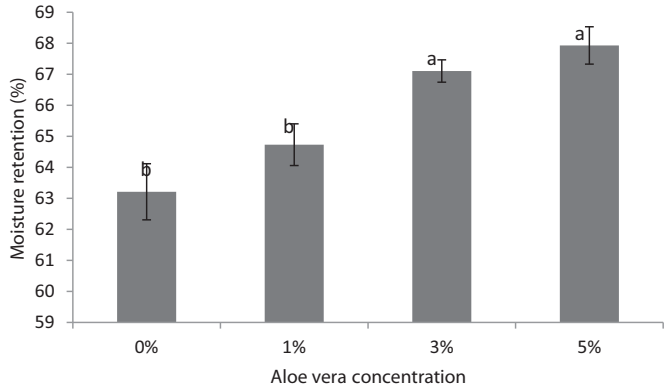

Fig. 4. Moisture retention of low meat beef burgers containing different concentrations of *Aloe vera*.

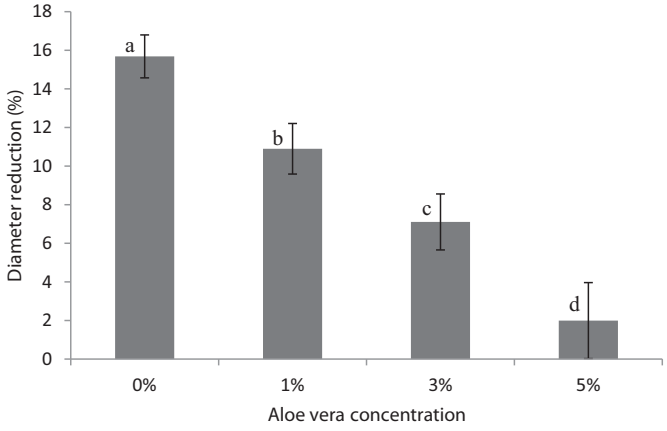

Fig. 6. Diameter reduction of low meat beef burgers containing different concentrations of *Aloe vera*.

Table 3
Force for compression and cutting of raw and fried beef burgers containing different amounts of Aloe vera.

Textural characteristics	control	1%	3%	5%
Compression of raw burgers (N)	$14.84^{c} \pm 037$	$20.13^{b} \pm 1.15$	$23.82^{a} \pm 0$	$23.82^{a} \pm 0$
Shear force of cooked burgers (N)	$5.13^{a} \pm 0.24$	$4.98^{a} \pm 0.13$	$4.25^{b} \pm 0.26$	$3.21^{c} \pm 0.42$

Means in a same row with different letters are significantly different ($P < 0.05$).

containing 3% and 5% *Aloe vera*. Polysaccharides have meat-binding and hydration properties which enhance the hardness of beef burgers (Gnanasambandam & Zayas, 1994). *Aloe vera* with its high content of polysaccharides forms a weak gel and increases the force required for compression of the samples. Harder beef burgers are preferred for easier handling and processing. Sharoba (2009) found the same results when a part of meat was replaced with the whole amaranth meal.

Table 3 shows the force required for cutting beef burgers with different amounts of *Aloe vera*. Clearly, the shear force for cutting of beef burgers decreased after cooking with increasing *Aloe vera* levels. It seems that myofibrillar proteins and *Aloe vera* may compete for adsorption of water needed for gel formation; hence, this competition interferes with the gel structure and formation of the gel matrix. This characteristic is partially appropriate because of easier mastication during eating. However, panelists were not able to detect any differences among the beef burgers produced (Table 4).

3.9. TBARS

Fig. 7 shows lipid oxidation in different burger samples during the 7 days of storage. Thiobarbituric acid reactive substances (TBARS) as an indicator of lipid oxidation were measured based on mg of malondialdehyde per kg of the sample. The initial amount of malonaldehyde on day 0 varied in the range of 0.52–0.55 mg/kg of the sample and no significant differences were observed among the burger samples. During the 7 days of storage, lipid oxidation proceeded in the control sample and reached 0.74 mg malonaldehyde/kg burger. The increase of TBARS value in beef burgers containing 1% *Aloe vera* was also significant; however, lipid oxidation in samples with 3% and 5% *Aloe vera* was retarded. In beef burgers produced with 3% and 5% *Aloe vera*, the increase observed in their malonaldehyde content was only 0.05 and 0.02 mg malonaldehyde in kg burgers during the 7 days of storage. Evaluating the antioxidant potential of *Aloe vera* at different growth stages, Hu et al. (2003) found that *Aloe vera* had a strong antioxidant activity equal or even superior to such synthetic antioxidant compounds as BHT and α-tocopherol. Previous studies have indicated that *Aloe vera* contains tannin and flavonoids (Arunkumar & Muthuselvam, 2009) and large amounts of ascorbic acid and vitamin E which can scavenge free radicals and prevent propagation of lipid oxidation (Zapata et al., 2013).

3.10. Sensory evaluation

Evaluation of the effects of *Aloe vera* addition on the sensory quality of beef burgers revealed a significant change in the overall acceptability and flavor of the product (Table 4). The control sample and the product containing 1% *Aloe vera* were equally acceptable to the panel members; however, taste panels detected a sour taste in the sample containing 3% *Aloe vera* and a bitter taste in the 5% *Aloe vera* burgers. Unfortunately, the presence of aloin with a bitter taste in *Aloe vera* renders it unacceptable for human nutrition (Tumlinson, 1985) while increasing *Aloe vera* concentration makes the bitter taste more recognizable. Filtration of the *Aloe vera* gel is one method of removing aloin and the bitter taste for application in foods (Ramachandra & Rao, 2008). It is interesting that the overall acceptability scores of the beef burgers followed the same trend as their flavor acceptability scores, reflecting the major influence of flavor on overall acceptance.

The color and texture of the beef burgers were not significantly influenced by different percentages of *Aloe vera* added. Some panel members stated that texture was improved by increasing the *Aloe vera* percentage; however, these differences were not significantly different ($P > 0.05$) compared to the control (Table 4). According to the taste panel results, it seems that 1% *Aloe vera* concentration is the threshold level which has no significant effects on the sensory quality of the product; however, panel members were still satisfied with burgers containing 3% added *Aloe vera*.

Table 4
Sensory properties of low meat beef burgers containing different amounts of *Aloe vera*.

Sensory characteristics	Control	1%	3%	5%
Flavor	2.43^{a}	2.28^{a}	0.66^{b}	-0.61^{c}
Color	2.19	2.14	1.43	1.95
Texture	2.28	2.38	1.67	1.48
Overall acceptability	2.43^{a}	2.24^{a}	1^{b}	-0.05^{c}

Means in a same row with different letters are significantly different ($P < 0.05$).

4. Conclusion

The results of this study indicated that substitution of texturized soy protein with *Aloe vera* in low meat beef burger has a significant effect on the quality of the samples. Although burgers containing 1% *Aloe vera* were similar to the control samples in most respects, addition of 3% and 5% *Aloe vera* improved most quality characteristics of the burgers. Addition of 5% *Aloe vera* reduced cooking loss, cooking shrinkage, fat absorption, and lipid oxidation while water holding capacity, moisture retention, and textural properties also improved. Samples with these properties have a good quality for production of low meat beef burgers; however, the bitter taste of *Aloe vera* is a big obstacle for addition of 5% *Aloe vera* to beef burgers. Based on the results, it may be claimed that burgers containing 3% *Aloe vera* enjoy not only a good quality but also a satisfactory consumers' acceptability.

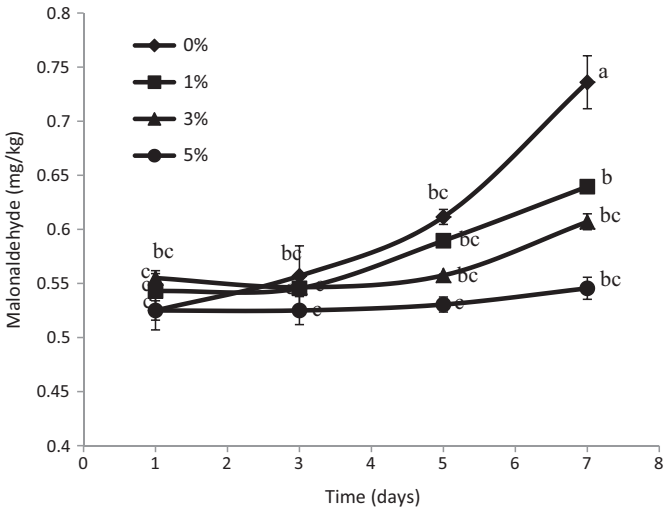

Fig. 7. Lipid oxidation of burger samples containing different concentrations of *Aloe vera* during cold storage.

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