Optimization of low-fat meat hamburger formulation containing quince seed gum using response surface methodology

Negin Yousefi¹ · Fariba Zeynali¹ · Mohammad Alizadeh¹

Revised: 26 October 2017 / Accepted: 13 November 2017 / Published online: 24 November 2017
© Association of Food Scientists & Technologists (India) 2017

Abstract In the present study, feasibility of low-fat hamburger production by partial replacement with quince seed gum (QSG) was investigated. The effects of different QSG levels (1.2, 2.4, 3.6, and 4.8 wt%) on cooking loss, water holding capacity, lipid oxidation, antioxidant activity, and hardness of hamburger were investigated during a period of 9 days. The optimization was carried out based on minimum cooking loss, lipid oxidation, and maximum water holding capacity, antioxidant activity, and tissue hardness. Optimum conditions were achieved as 3.26% oil, 4.73% QSG, and 8.25th day of storability. According to the optimum conditions, values for cooking loss, water holding capacity, lipid oxidation, free radical scavenging, raw hamburger hardness, and fried hamburger hardness were as 13.80%, 55.61%, 0.59 mg MDA/Kg, 48.12%, 2.99 N, and 8.66 N, respectively. Overall acceptability of optimized hamburgers was better and more acceptable than control ones.

Keywords Antioxidant activity · Low-fat hamburger · Optimization · Quince seed gum (QSG) · RSM · Texture

Introduction

Hamburger is mainly comprised of beef meat, fat, soy protein, and certain amounts of water, fillers, flour, and spices. Scientific findings suggest a direct relation between high fat intake and the risk of heart diseases, hardening of

the arteries, obesity, high blood pressure, and cancer (Jenkins et al. 1998). Although fat plays an important role in creating a desirable texture, mouth feel, and flavor in hamburgers, high fat content (over 10%) in their formulation is considered as a negative factor. Thereby, reducing or completely eliminating fat content will cause much more deterioration in hamburgers. Therefore, to compensate these disadvantages, the use of fat alternatives could be an appropriate solution (Seydim et al. 2005).

Hydrocolloids are the main fat substitutes in low-fat meat products. The ability of these compounds in modifying the rheological and functional properties of food products makes them more preferable in food industries (Taherian et al. 2007). Different hydrocolloids have been incorporated in meat products as fat reducing agents till now. For example, carrageenan and guar gum have been used as fat replacers in meatballs (Ulu 2006). It was reported that partial replacement of fat with mixed konjac and gellan gum improved the overall sensory quality of reduced-fat frankfurters (Lin and Huang 2003). Quince belongs to the *Rosaceae* family and the subfamily *Pomoidae* (Patel et al. 2011). It has health promoting benefits, which are mainly associated with its antioxidant capacity, phenolic compounds, anti-cancer properties, antimicrobial, and hypoallergenic activities (Legua et al. 2013). Furthermore, it has low fat content and is an important source of organic acids, sugar, crude fiber, and minerals such as potassium, phosphorus and calcium (Rodríguez-Guisado et al. 2009). Acid hydrolysis of water-soluble polysaccharides generates D-arabinose and xylose production. The main water-soluble polysaccharide presents in mucilage of quince seeds is O-acetylated (4-O-methyl-D-glucurono)-D-Xylan, which contains large amounts of glucuronic acid residues (Lindberg et al. 1990). High accessibility to this fruit in Iran and high gum content of quince seed led us to

✉ Fariba Zeynali
f.zeynali@urmia.ac.ir

¹ Department of Food Science and Technology, Faculty of Agriculture, Urmia University, Urmia, Iran

use this gum as a food grade hydrocolloid and subsequently optimize different variables to make it sufficiently usable as a new source of fat replacers in the hamburgers.

Materials and methods

Materials

Quince seeds (*Cydonia oblonga*) were provided from Botanical Center of West-Azerbaijan, Iran. Ethanol (100%), n-hexane (95%), hydrochloric acid (HCL 37%), NaOH (98%), 2-tiobarbitoric acid (99%), trichloroacetic acid (TCA 99%), and DPPH (100%) were purchased from Merck Company (Darmstadt, Germany).

Preparation and grinding the quince seeds

In order to increase the extraction rate, the grinding process was carried out. Quince seeds were dried and packaged at room temperature and stored at 8 °C until performing the grinding and extraction processes. The grist process was performed in electric mill (M30214, Moulinex, France) and obtained powders were screened by 300-micron mesh containing sieve.

Extraction of the quince seed gum (QSG)

The extraction process was performed using the previously described technique with some modifications (Abbastabar 2014). In brief, the extraction was performed in deionized water (pH = 6.6) at 60.77 °C using magnetic heater (RS3001 MLW hotplate Magnet, Germany) and different seed to water ratios of 96.2% (w/w). The extract was filtered by 180-micron sieve and then oven-dried (UT 5060E Heraeus, Germany) at 55 °C for 24 h.

Physicochemical analysis

The composition of QSG was analyzed according to the AOAC method [AOAC,1995]. The pH values of the QSG were determined using a pH-meter (pH 510, Eutech, Singapore), which was calibrated in buffer solutions at pH 4.0 and 7.0. All measurements were performed in triplicate.

Formulating hamburgers

Hamburger samples containing different amounts of QSG and oil were prepared according to Table 1. Hamburgers' formula was comprised of cow flank meat (30%), soy protein (12%), grated onion (12%), wheat flour (4%), gluten (1%), salt (1.1%), pepper (1.1%), hydrogenated oil (8%), and water (30.8%). All ingredients were mixed

together in a blender and the resulting paste was mixed with QSG in a separate blender. In each formula, the fat content was replaced by specific amounts of QSG. QSG was not added to the control sample. All formula batches were shaped as a flat burger in plates (radius = 6 cm) and stored at refrigerator (4 °C) for a period of 9 days. Further analyses were performed after 1, 3, 6, 7, 9 days of storage.

Cooking loss evaluations

To perform the cooking loss test, 15 g of hamburger samples were shaped to form a circular loop. Samples' weight was measured before and after frying in sunflower oil. Cooking loss percentage was calculated as described earlier (Akwetey and Knipe 2012).

Measuring water holding capacity (WHC)

To measure the WHC, three layers of Whatman paper filters were put in 2 ml vials. Weight of Whatman papers and vials were measured before centrifugation. Then, 0.2 g of samples were weighed into the vials. Vials were centrifuged (D-78532 Tuttlingen, Hettich, Germany) at 14,000 g for 10 min. After centrifugation, the meat pieces were removed from the vials, and the weight of vials and

Table 1 Quince seed gum (QSG) and oil contents in different formulations

Formulation	Time (day)	Oil (%)	QSG (%)
1	1	8	0
2	9	3.2	4.8
3	9	3.2	4.8
4	1	5.6	2.4
5	9	5.6	2.4
6	7	4.4	3.6
7	6	5.6	2.4
8	6	8	0
9	1	8	0
10	9	8	0
11	3	3.2	4.8
12	1	3.2	4.8
13	3	6.8	1.2
14	7	6.8	1.2
15	3	4.4	3.6
16	9	5.6	2.4
17	9	8	0
18	6	3.2	4.8
19	1	3.2	4.8
20	1	5.6	2.4
21	6	8	0

Whatman papers were measured. WHC was calculated as described earlier (Jauregui et al. 1981).

Lipid oxidation analysis

To measure secondary lipid oxidation compounds, thiobarbituric reactive material was analyzed previously reported method (Strange et al. 1977) with some modifications. For this purpose, 20 g of hamburgers were mixed with 50 ml trichloroacetic acid (TCA, 20% w/w) for 2 min. The blender content was washed with 50 ml of distilled water and then filtered through the Whatman paper using vacuum pump (5KH33GG-871T, General Electronic, USA) for faster filtration. Then, 5 ml of the filtrate was mixed with 5 ml of 2-thiobarbituric acid reagent (0.01 M) and kept in water bath at 100 °C for 1 h. The solution absorption was read at 532 nm using spectrophotometer (Novaspec II, Pharmacia LKB-Biochrom, England). Thiobarbituric acid content was reported by milligram of malondialdehyde (MDA) content per kilogram of samples (Strange et al. 1977).

Antioxidant activity

Hamburgers' antioxidant activity was assessed using previously described method (Viuda-Martos et al. 2009) with some modifications. First, 0.1 g of samples and 4 ml of ethanol were mixed in tubes for 2 min. Then 2 ml of DPPH solution (250 mM) was mixed with 2 ml of the extracts for 1 min using vortex mixture and then they were kept in a dark place (at room temperature) for 30 min. The absorption was read at 515 nm using spectrophotometer. Antioxidant activity was assessed based on the inhibition percent during storage time at 4 °C (Eq. 1).

$$\% \text{inhibition} = [A_0 - A_1/A_0] \times 100 \quad (1)$$

where A_0 and A_1 represent the blank (2 ml of ethanol (99%, w/w) and 2 ml of the DPPH solution) and sample absorbance values, respectively.

Texture analysis

Texture profile analysis of samples was analyzed using TA.XT-PLUS Texture Analyzer (Stable Micro Systems, Surrey, UK). For this purpose, 15 g of hamburger samples were formed as a flat circle (diameter = 5 cm) with a thickness of 1 cm. Raw and fried samples were compressed at room temperature with a two-step mechanism (TPA) (with 5000 g load cells up to 50% of their heights).

The general speed of 2 mm per second was applied for analyzing firmness of textures and the maximum compression force was reported (Soltanizadeh and Ghiasi-Esfahani 2015).

Optimization process using response surface methodology (RSM)

Central square design was used for optimization of different levels of QSG. The concentration of oil (A) and quince seed gum (B), and time of storage (C) were selected as independent variables and the values for each test were reported as a response.

Sensory evaluations

Evaluating sensory properties of optimum hamburger formulations were conducted by 15 panelists using 5-point hedonic scale (5 = excellent, 4 = good, 3 = average, 2 = poor, 1 = bad). For this purpose, the control sample and fried optimum hamburger were placed in odor and taste less randomly numbered disposal plates. Pre-trained panelists evaluated the samples at room temperature under fluorescent light. Providing optimum and control samples for each panelist were different from one another. Appearance, flavor, texture, and overall acceptability of samples were evaluated (Riazi et al. 2016).

Statistical analysis

The combined design was used as a statistical analysis. In formulations the oil and QSG were considered as variables and processing time was considered as a processing factor. Scheffe model was used to simulate the responses and type I error level (α) was considered as 0.05.

Results and discussion

Physicochemical analysis of quince seed gum (QSG)

Chemical composition of quince seed powders were as 6.5 ± 0.09 , $4.21 \pm 0.07\%$, 8.84 ± 0.44 , $24.5 \pm 1.23\%$, and $3.16 \pm 0.05\%$ for pH, moisture, ash, protein, and fat, respectively. Moisture, ash, protein, and fat contents of QSG were 4.21, 8.84, 24.5, and 3.16% (wet-weight), respectively. The results were similar to the values reported by other researchers (Fekri et al. 2008). However, the protein and ash values were higher than the reported ones. Moisture content was lower in comparison with these researches, which can be caused by environmental conditions such as growing conditions, type, and fertility of the soil.

Effects of QSG on the cooking loss rate

Figure 1a depicts the cooking loss of the hamburgers during a period of 9 days storage at 4 °C. As it shows,

Fig. 1 Effects of different quince seed gum (QSG) amounts on the **a** cooking loss (CL %), **b** water holding capacity (WHC), **c** oxidative stability (mg of Malondialdehyde), **d** oxidative capacity (DPPH

assay), **e** firmness in raw and **f** fried hamburgers during the storage time (A Oil, B QSM, and C Time (day))

decreasing the oil content and increasing the QSG in the formulation of hamburgers reduced the cooking loss ($p < 0.05$). In samples with more QSG and less oil, cooking loss was not influenced by the time. But, in samples with more oil and lower QSG, cooking loss increased with time increment. This increase was remarkably observed in control sample once they were reaching to the end of the storage time (45%). These results were highly attributed to the WHC of the QSG. QSG has a mucilaginous jelly texture and structure, which makes it able to hold and involve the water in its structure and keep more moisture during cooking (Gowda et al. 1979). In general, gums show barrier abilities against moisture removal during the frying process due to making hydrogen bonds with water molecules, which then makes them more powerful to prevent weight loss in the final product.

Effects of QSG on the WHC

Figure 1b shows the effects of adding different amounts of QSG on the WHC during storage time. As it depicts, WHC was reduced ($p < 0.05$) with the QSG decrement and oil content increment. Higher oil and lower QSG percentages didn't show a large impact on WHC over the time. While, it was decreased in lower QSG and higher oil contents

(Filgueras et al. 2010). The highest and lowest WHC values were observed in hamburgers containing 4.8% QSG (59.62%) and the control ones (39.94%), respectively. High WHC feature of QSG caused it to maintain and involve drip loss water in its structure and prevents the water to be removed from products.

On the other hand, the oxidation of protein provokes covalent changes in the protein structures that can directly occur by reactive oxygen species (Davies 2005). Protein oxidation might be increased during the storage time (Mercier et al. 1998). This phenomenon is responsible for many physiological changes such as fragmentation and agglutination (Promeyrat et al. 2010), which subsequently can decrease the solubility of protein and bioavailability of amino acids. Protein oxidation reduces its WHC properties (Decker et al. 1993). In fact, the process of oxidation reduces the ability of proteins to form hydrogen and electrostatically bonds with water molecules and subsequently increases drip loss. Generally, in meats, fat and myoglobin oxidation occur together, which influences the functional properties of each other (Han et al. 1994). As a result, occurrence of the oxidation in control hamburgers and the hamburgers with less QSG, was reduced the WHC during the storage time (Fig. 1c).

Effects of QSG on the oxidative stability of hamburgers

The main reason for quality degradation of meat products is lipid oxidation, which promotes rancidity and destruction of color and texture (Pfalzgraf et al. 1995). Thiobarbituric acid reactive substances, as an indicator of oxidation level, were reported based on milligrams of malondialdehyde (MDA) content. According to Fig. 1c, by increasing oil and decreasing the QSG percentage, MDA content of samples was increased over the time. The maximum and minimum levels of MDA were detected in control samples (at the end of storage time – 0.8 mg/kg) and the samples containing 4.8% QSG (at the beginning of the storage time – 0.4 mg/kg), respectively.

The oxidation was remarkably reduced when the QSG was applied ($p < 0.05$). In red meats, myoglobin and other heme compounds act as prooxidant agents (Han et al. 1994). During the oxidation of oxy-myoglobin to met-myoglobin, O_2 and H_2O_2 are produced, which subsequently react and facilitate the oxidation of Fe^{3+} (Chan et al. 1997). QSG is an excellent source of caffeoylquinic acid, which is the main reason for its high antioxidant activities (Magalhães et al. 2009). Antioxidant capacity of phenolic compounds are due to their important role in adsorption and neutralization of free radicals and singlet oxygen generated during processes (Costa et al. 2009). The reason for increased TBARS index over time, might be due to the oxidation of lipids and phospholipids in respect to oxidative stability reduction in meat, which consequently breakdown the hydro-peroxides and lipid oxidation secondary compounds. MDA is also one of the end products of lipid oxidation that can be increased during process and storage (Thomas et al. 2006).

Antioxidant activity (DPPH assay)

Antioxidant activity of QSG was over 80%, which is mainly attributed to the 3-O and 5-O-Caffeoylquinic Acids, Iso Schaftoside, Stellarin-2, Vicenin-2, Lucenin-2, A6-C-Pentoyl-8-C-Glucosyl Chrysoeriol SchaFtoside, and A6-C-Glucosyl-8-C-Pentoyl Chrysoeriol. C-glycosyl flavones and Stellarin-2 are the main phenolic compounds (Magalhães et al. 2009). The antioxidant activity of QSG could be attributed to the presence of these phenolic compounds and flavonoids in its structure (Viuda-Martos et al. 2009). As it can be seen in Fig. 1d, an increase in oil content reduced free radical scavenging activity during the storage time.

Texture analysis

Firmness of meat products is one of the most important factors affecting the consumers' willingness to eat (Huang

et al. 2011). This parameter shows the maximum force needed to compress the sample. As shown in Fig. 1e, reducing the QSG caused a decrement in the required force to compress hamburgers ($p < 0.05$), which consequently reduced the firmness. Raw hamburgers containing 4.8% QSG showed the highest compression (4 N) force on the first day of production, which came down to 2 N at the end of the storage time. In raw hamburgers with lower amounts of QSG, the compression force was reduced to the 1 N at the end of the storage time. As a result, reducing the amounts of QSG in the raw hamburgers' formula reduced the degree of firmness. This reduction was more evident in control samples. It can be concluded that the reduction of gum in the formulation and raw burgers and long storage times reduced the degree of firmness. According to Fig. 1f, by lowering the amounts of QSG, the compressing force of fried hamburgers was reduced. The maximum force needed to compress the fried hamburgers was achieved in samples containing 4.8% of QSG on the first day of production (12 N), which was reduced gradually to 8 N. At the QSG concentrations of 2.4%, the force reduction was continued and at the end of the storage time it reached to 4 N. QSG have fibers and polysaccharides in its structure (Forni et al. 1994). Increasing in fiber content can cause an increment in firmness of meat products (Thebaudin et al. 1997). Fibers can increase consistency of meat products through the formation of an insoluble three-dimensional network due to their water binding and swelling abilities, which can then enhance rheological properties of the continuous phase of hamburgers emulsion (Shan et al. 2015).

Optimization of the variables

Optimization was conducted based on minimum cooking loss, fat oxidation, maximum WHC, free radical scavenging, and firmness in constant range (Table 2). Optimized conditions for 100 g hamburger were as 3.26 g of oil (3.26%), 4.73 g of QSG (4.73%), and the storage time of 8.25 days. In these circumstances, the optimized values (Table 3) showed that there weren't any significance differences in parameters when comparing the predicted and the measured values. These approaches indicate that the optimization process could successfully be applied for the predicting different formulation parameters.

Sensory evaluation

Flavor, appearance, texture, and overall acceptability scores for the optimum and the control sample were presented in Fig. 2. As previously mentioned, QSG increased the WHC and firmness, which were reported by the panellists. As shown in Fig. 2, optimum hamburger formulations were remarkably better than the control ones in all

Table 2 Regression coefficients of the response surface model for the response variable (analysis was performed using coded unit)

Factors ^a	CL%	WHC%	DPPH%	MDA $\left(\frac{\text{mg}}{\text{kg sample}}\right)$	Max force raw (N)	Max force friend (N)
A	39.77	38.71	32.24	0.70	1.75	3.62
B	13.80	61.45	61.44	0.51	1.81	8.23
A*B	− 31.58*	—	—	—	—	—
A*C	4.68	− 3.69***	− 15.70**	0.16*	− 4.63**	0.57
B*C	—	−3.09	− 16.00**	0.15*	1.90	− 1.68*
A*C ²	—	—	—	—	0.03	6.75**
B*C ²	—	—	—	—	1.53**	2.73**
A*C ³	—	—	—	—	4.51**	—
B*C ³	—	—	—	—	− 2.61***	—
R ²	0.91	0.88	0.69	0.88	0.83	0.86
R ² _{adj}	0.81	0.86	0.64	0.86	0.73	0.79
F	60.09	44.24	13.07	43.24	8.57	13.86
Probability of F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0007	0.0002

^aFactors: A, oil Concentration(g); B, gum concentration(g); C, Time of maintenance (days)

* $p \leq 0.001$, ** $p \leq 0.01$, *** $p \leq 0.05$

Table 3 The predicted and measured values for different parameters in optimum formulation

	Cooking loss (%)	Water holding capacity (%)	DPPH assay (%)	malondialdehyde (mg MDA/kg sample)	Max force raw (N)	Max force friend (N)
Predicted values	13.80 ± 0.08 ^{a*}	58.61 ± 0.78 ^b	48.12 ± 5.47 ^c	0.59 ± 0.02 ^d	2.99 ± 0.47 ^e	8.66 ± 0.37 ^f
Measured values	13.68 ± 0.06 ^a	59.70 ± 0.60 ^b	47.72 ± 6.02 ^c	0.62 ± 0.01 ^d	2.60 ± 0.32 ^e	9.24 ± 0.29 ^f

* Results are expressed as mean ± SD of three experiments (Same superscript letters show nonsignificant difference at the 5% level in *t* test)

Fig. 2 Sensory evaluations of control and quince seed gum containing optimum hamburger formulations using five hedonic scale

sensory parameters especially from the aspect of texture and overall acceptability. These outstanding results illustrated that the QSG not only enhanced the texture but also had positive effects on the other sensory parameters. These findings introduce that the QSG could act as a good fat replacer representative in hamburgers.

Conclusion

The results showed that incorporation of QSG in hamburger formulations, a significantly improved the texture of low-fat hamburgers due to its high water-holding capacity. QSG successfully reduced the negative effects associated with lowering fat content of hamburgers, which indicated that QSG has a more potential ability in acting as an appropriate fat replacer. Sensory and textural analysis indicated that the QSG could be regarded as a novel textural enhancer in hamburger formulations, which needs to be investigated in detail in future.

Acknowledgement This research was supported by Urmia University.

References

- Abbastabar B (2014) Optimization of extraction yield of quince seed gum and rheological characteristics under the optimum extraction conditions. Iran J Nutr Sci Food Tech 9:29–38

- Akwetey W, Knipe C (2012) Sensory attributes and texture profile of beef burgers with gari. *Meat Sci* 92:745–748
- Chan W, Faustman C, Yin M, Decker E (1997) Lipid oxidation induced by oxymyoglobin and metmyoglobin with involvement of H₂O₂ and superoxide anion. *Meat Sci* 46:181–190
- Costa RM, Magalhães AS, Pereira JA, Andrade PB, Valentão P, Carvalho M, Silva BM (2009) Evaluation of free radical-scavenging and antihemolytic activities of quince (*Cydonia oblonga*) leaf: a comparative study with green tea (*Camellia sinensis*). *Food Chem Toxicol* 47:860–865
- Davies MJ (2005) The oxidative environment and protein damage. *BBA Protein Proteom* 1703:93–109
- Decker EA, Xiong YL, Calvert JT, Crum AD, Blanchard SP (1993) Chemical, physical, and functional properties of oxidized turkey white muscle myofibrillar proteins. *J Agric Food Chem* 41:186–189
- Fekri N, Khayami M, Heidari R, Jamee R (2008) Chemical analysis of flaxseed, sweet basil, dragon head and quince seed mucilages. *Res J Bio Sci* 3:166–170
- Filgueras R et al (2010) Colour, lipid and protein stability of Rhea americana meat during air- and vacuum-packaged storage: influence of muscle on oxidative processes. *Meat Sci* 86:665–673
- Forni E, Penci M, Polesello A (1994) A preliminary characterization of some pectins from quince fruit (*Cydonia oblonga* Mill.) and prickly pear (*Opuntia ficus indica*) peel. *Carbohydr Polym* 23:231–234
- Gowda DC, Neelisiddaiah B, Anjaneyalu YV (1979) Structural studies of polysaccharides from Aloe vera. *Carbohydr Res* 72:201–205
- Han D, McMillin K, Godber J (1994) Hemoglobin, myoglobin, and total pigments in beef and chicken muscles: chromatographic determination. *J Food Sci* 59:1279–1282
- Huang S, Tsai Y, Chen C (2011) Effects of wheat fiber, oat fiber, and inulin on sensory and physico-chemical properties of Chinese-style sausages. *Asian Australas J Anim Sci* 24:875–880
- Jauregui C, Regenstein J, Baker R (1981) A simple centrifugal method for measuring expressible moisture, a water-binding property of muscle foods. *J Food Sci* 46:1271
- Jenkins DJ, Kendall CW, Ransom TP (1998) Dietary fiber, the evolution of the human diet and coronary heart disease. *Nutr Res* 18:633–652
- Legua P, Serrano M, Melgarejo P, Valero D, Martínez JJ, Martínez R, Hernández F (2013) Quality parameters, biocompounds and antioxidant activity in fruits of nine quince (*Cydonia oblonga* Miller) accessions. *Scientia Horticult* 154:61–65
- Lin K-W, Huang H-Y (2003) Konjac/gellan gum mixed gels improve the quality of reduced-fat frankfurters. *Meat Sci* 65:749–755
- Lindberg B, Mosihuzzaman M, Nahar N, Abeysekera RM, Brown RG, Willison JM (1990) An unusual (4-O-methyl-D-glucurono)-D-xylan isolated from the mucilage of seeds of the quince tree (*Cydonia oblonga*). *Carbohydr Res* 207:307–310
- Magalhães AS, Silva BM, Pereira JA, Andrade PB, Valentão P, Carvalho M (2009) Protective effect of quince (*Cydonia oblonga* Miller) fruit against oxidative hemolysis of human erythrocytes. *Food Chem Toxicol* 47:1372–1377
- Mercier Y, Gatellier P, Viau M, Remignon H, Renner M (1998) Effect of dietary fat and vitamin E on colour stability and on lipid and protein oxidation in turkey meat during storage. *Meat Sci* 48:301–318
- Patel N, Rathod B, Shah V, Mahajan A (2011) *Cydonia vulgaris* Pers.: a review on diversity, cultivation, chemistry and utilization. *Pharmacia Lett* 3:51–61
- Pfalzgraf A, Frigg M, Steinhart H (1995) alpha-tocopherol contents and lipid oxidation in pork muscle and adipose tissue during storage. *J Agric Food Chem* 43:1339–1342
- Promeyrat A, Gatellier P, Lebre B, Kajak-Siemaszko K, Aubry L, Santé-Lhoutellier V (2010) Evaluation of protein aggregation in cooked meat. *Food Chem* 121:412–417
- Riazi F, Zeynali F, Hoseini E, Behmadi H, Savadkoobi S (2016) Oxidation phenomena and color properties of grape pomace on nitrite-reduced meat emulsion systems. *Meat Sci* 121:350–358
- Rodríguez-Guisado I, Hernández F, Melgarejo P, Legua P, Martínez R, Martínez J (2009) Chemical, morphological and organoleptical characterisation of five Spanish quince tree clones (*Cydonia oblonga* Miller). *Sci Hortic* 122:491–496
- Seydim ZB, Sarikus G, Okur O (2005) Effect of inulin and Dairy-Lo[®] as fat replacers on the quality of set type yogurt. *Milchwissenschaft* 60:51–55
- Shan B et al (2015) Effect of shaddock albedo addition on the properties of frankfurters. *J Food Sci Tech* 52:4572–4578
- Soltanizadeh N, Ghiasi-Esfahani H (2015) Qualitative improvement of low meat beef burger using Aloe vera. *Meat Sci* 99:75–80
- Strange E, Benedict R, Smith J, Swift C (1977) Evaluation of rapid tests for monitoring alterations in meat quality during storage: intact meat. *J Food Prot* 40:843–847
- Taherian AR, Fustier P, Ramaswamy HS (2007) Effects of added weighting agent and xanthan gum on stability and rheological properties of beverage cloud emulsions formulated using modified starch. *J Food Process Eng* 30:204–224
- Thebaudin J, Lefebvre A, Harrington M, Bourgeois C (1997) Dietary fibres: nutritional and technological interest. *Trend Food Sci Tech* 8:41–48
- Thomas R, Anjaneyulu A, Kondaiah N (2006) Quality and shelf life evaluation of emulsion and restructured buffalo meat nuggets at cold storage (4 ± 1 °C). *Meat Sci* 72:373–379
- Ulu H (2006) Effects of carrageenan and guar gum on the cooking and textural properties of low fat meatballs. *Food Chem* 95:600–605
- Viuda-Martos M, Ruiz-Navajas Y, Fernández-López J, Pérez-Álvarez J (2009) Effect of adding citrus waste water, thyme and oregano essential oil on the chemical, physical and sensory characteristics of a bologna sausage. *Innov Food Sci Emerg Technol* 10:655–660