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ORIGINAL ARTICLE

Hawberry (*Crataegus monogyna* Jaqc.) extracts inhibit lipid oxidation and improve consumer liking of ready-to-eat (RTE) pork patties

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Abstract The objective of this work was to study the effectiveness of extracts from hawberry (*Crataegus monogyna* Jacq.) to inhibit lipid oxidation and odor deterioration during processing of ready-to-eat (RTE) pork patties subjected to roasting (180 °C/16 min), chilling (10 days/+3 °C) and reheating in microwave (600 mW/ 1 min). Acetone extracts of hawberry were chosen based on their total phenolic content (1281.1 ± 84.8 mg gallic acid equivalent (GAE)/100 g fruit) and in vitro antiradical activity (DPPH) (53.33 ± 15.40 g equivalent Trolox per g of fruits). Pork patties treated with increasing concentrations of hawberry extract, 200 and 800 ppm GAE (T2 and T8, respectively) and a control group (T0) of samples, were analyzed for TBARS, volatile carbonyls and odor liking in a consumer test. Hawberry extracts significantly improved the oxidative stability of cooked pork patties keeping TBARS and hexanal counts at basal levels during the whole process. The addition of hawberry phenolic-rich extracts significantly improved the degree of consumer satisfaction regarding the odor of patties. In conclusion, the hawberry extract displayed potential usage as an ingredient with antioxidant properties for the manufacture of high-quality RTE meat products.

Keywords Cooked pork patties · Hawberry · Lipid oxidation · Odor · Volatile compounds

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Introduction

In this contradictory world we are living, modern societies with high safety standards and overall well-being overlook fundamental aspects of human fulfilment such as the time to eat a balanced, healthy and appetizing diet. The socio-economical changes occurred in these societies have altered consumer trends shifting from traditional and freshly elaborated home-made foods to precooked commodities of indisputable lower nutritional and sensory quality. In this scenario, the demand for ready-to-eat (RTE) muscle foods has increased in modern societies owing to generally low prices and convenience consumption. The quality of these commodities varies considerably as it depends on the composition of the raw material, the recipe and the severity of the technologies applied during production and the subsequent storage. Ground meat is prone to become brown and rancid more rapidly than whole muscle retail cuts (Ho et al. 1996). In consequence of its relatively high content of unsaturated fatty acid, pork oxidizes more rapidly than either beef or lamb (Bekhit et al. 2013). Furthermore, thermal processes can promote lipid oxidation by disrupting cell membranes and releasing pro-oxidants (Soladoye et al. 2015). Lipid oxidation is recognized as one major threat to the safety and sensory quality of these pre-cooked meat products (Morrissey et al. 1998). While a certain extent of lipid oxidation is required for flavor development, an excess of oxidation products is a sign of nutritional loss, safety concerns and impaired sensory properties (Bekhit et al. 2013; Soladoye et al. 2015; Estévez and Luna 2017). Severe oxidative reactions may occur during manufacture of RTE muscle foods owing to the application of multiple processing steps typically involving pre-cooking, cold storage and reheating, prior to consumption (Ferreira et al.

2016). One major drawback of intense lipid oxidation in pre-cooked meat products is the onset of unpleasant off-flavours typically described as 'warmed-over flavor' (WOF). WOF in meat is mostly believed to be the result of oxidation of membrane phospholipids, a process triggered by hemoproteins and other iron species during cooking (Gray and Pearson 1987).

Many hawthorn species are grown for their edible fruits in Asia, Central America, and the Mediterranean area, with *Crataegus monogyna* Jacq. being the species commonly cultivated in Mediterranean countries (Caliskan 2015). The main classes of antioxidant compounds present in hawthorn (*C. monogyna*) are flavonoids, oligomeric, proanthocyanidins, triterpene acids, organic acids and sterols (Ganhão et al. 2010; Tadić et al. 2008). Many individual compounds identified in hawthorn extracts are reported to exhibit antioxidant properties including chlorogenic acid, epicatechin, quercetin, rutin, vitexin and procyanidins (Sokół-Łętowska et al. 2007; Tadić et al. 2008; Zhang et al. 2001). Nowadays there is a trend in applying natural antioxidants derived from plant materials in the food industry due to avoidance of toxicological effects of synthetic antioxidants such as butylated hydroxyanisole, butylated hydroxytoluene (BHT) and propyl gallate (Barlow 1990). While hawberry extracts contain polyphenolic compounds and exhibit antioxidant activity in raw meats (Ganhão et al. 2010) and bovine muscle homogenates (Shortle et al. 2014), their effectiveness as inhibitors of oxidative reactions in severely processed muscle foods (such as RTE meat products) is ignored.

The first aim of the present study was to determine the total phenolics content and antioxidant potential of different extracts (various ratios of water and acetone) from hawberry (Study 1). The most efficient materials and extracting conditions from Study 1 were selected to fulfil the second objective of the present paper: to evaluate the effectiveness of the selected hawberry extract as inhibitor of lipid oxidation and promoter of consumer liking in RTE pork patties (Study 2).

Materials and methods

Chemicals

All chemicals and reagents used for the present work were of ACS analytical grade and purchased from Panreac (Panreac Quimica, S.A., Barcelona, Spain), Merck (Merck, Darmstadt, Germany), Extrasynthese (Genay, France), and Sigma Chemicals (Sigma-Aldrich, Steinheim, Germany). The extraction solvents were compatible for industrial food use.

Fruits

Samples of hawberry (*C. monogyna* Jaqc.) cultivars were collected at the stage of full ripeness in the Caceres region, Spain (altitude = 450 m) during the summer and autumn of 2014. After hand-harvest, the samples were immediately transferred to the laboratory, cleaned and sorted to eliminate damaged and shrivelled fruits, and then frozen at −80 °C.

Physicochemical composition of hawberries (Study 1)

The fruits were air-dried at temperature room and ground through a 1 mm screen in preparation for chemical analysis. The proximate composition (moisture, crude protein, ashes) as well as pH and acidity of the selected fruits was analyzed according to AOAC methods (AOAC 2000). The method of Folch et al. (1957) was used for determining fat content in the hawberry fruits.

Preparation of hawberry extracts

For the preparation of hawberry extracts, fruits (2 g), including seed, peel and pulp, were finely ground, dispensed in a falcon tube, and homogenized for 1 min with 10 volumes (w/v) of distilled water:acetone using an Omni-mixer homogenizer (model 5100). Various ratios of distilled water:acetone were tested as follows: 100:0 v/v; 75:25 v/v, 50:50 v/v, 25:75 v/v and 0:100 v/v. The homogenates were centrifuged at 600*g* for 10 min at 4 °C using an Eppendorf centrifuge 5810 R (Eppendorf, Hamburg, Germany). The supernatants were collected and filtered through no. 54 Whatman paper while the residue was re-extracted once more following the procedure previously described. The two supernatants were combined and subsequently dried using rotary evaporator at 40 °C. Residues were brought to 10 mL volume with distilled water and immediately transferred to the laboratory for characterization (Study 1).

Total phenolic content (TPC) of hawberry extracts (Study 1)

Total phenolic content (TPC) of hawberry extracts was determined following the Folin–Ciocalteu method described by Singleton and Rossi (1965). An aliquot of 200 μL of the diluted extract was mixed with 1000 μL of 1:10 diluted Folin–Ciocalteu's phenol reagent, followed by 800 μL of 7.5% (w/v) sodium carbonate. The mixture was shaken and allowed to stand for 30 min at room temperature in the dark, after which the absorbance was measured at 765 nm using a spectrophotometer. Phenolic content was

calculated from a standard curve of gallic acid, and the results were expressed as milligram gallic acid equivalents (GAE) per 100 g of fresh fruit.

Antioxidant activity of hawberry extracts (Study 1)

The DPPH assay reported by Kähkönen and Heinonen (2003) was employed for the measurement of the antioxidant activity of extracts using the 2,2-diphenyl-1-picryl-hydrazyl (DPPH) radical. The extracts obtained from different mixtures of extracting solvents were subjected to dilutions using distilled water: 100% water extracts, 25 and 50% acetone extracts were diluted 1:1; 75% acetone extracts were diluted 1:10 and 100% acetone extracts were diluted 1:20. An aliquot of 33 μL of each diluted extract was mixed with 2000 μL of DPPH solution (6×10^{-5} M) in methanol. The reaction mixture was stirred and allowed to stand at room temperature in the dark for 6 min, and the absorbance at 517 nm was immediately recorded. A standard curve was obtained by using Trolox standard solution at various concentrations (ranging from 0.25 to 2 mM) in 80% methanol. The absorbance of the reaction samples was compared to that of the Trolox standard curve previously described, and the results were expressed as millimoles Trolox equivalents per gram of fresh fruit.

Hawberry extracts for pork patties (Study 2)

With the results from Study 1 taken into consideration, 100% acetone extracts from hawberry fruit were selected for Study 2. Two acetone extracts with TPC of 200 and 800 ppm GAE were manufactured following the procedure previously described. Acetone was evaporated using a rotary evaporator and the residue redissolved using 100 mg of distilled water. Water solutions were stored under refrigeration until used for the manufacture of pork burgers (<24 h) as described below (Study 2).

Preparation of porcine patties (Study 2)

The experimental patties were prepared in a pilot plant. Pork (m. longissimus dorsi et lumborum) was purchased from a local supermarket in Cáceres (Spain). In the basic formulation (control), the ingredients were as follows: 1076 g of pork, 100 g of distilled water and 24 g of sodium chloride. Three types of pork burger patties were prepared including the control (T0) and two groups treated with extracts from *C. monogyna* Jacq. at two TPC levels (T2: 200 ppm and T8: 800 ppm GAE). In the formulation of the patties treated with hawberry extracts, 100 g of the distilled water was replaced by 100 g of a water solution containing the corresponding hawberry extract. All ingredients were minced in a cutter until a homogeneous raw batter was

obtained. Emulsified burger patties were formed using a conventional patty-maker (∼100 g/patty), to give average dimensions of 10 cm diameter and 1 cm thickness.

After production, pork patties were subjected to 4 different manufacturing processes as follows: (1) raw patties: right after manufacture, raw patties were transferred to the laboratory for analyses; (2) cooked patties: patties were cooked in an oven (Unox®, Mod. GN2.1, Cadonegue, Italy) to an internal temperature of 70 °C for 16 min (8 min each side), allowed to cool down and immediately were transferred to the laboratory for analyses; (3) cooked and chilled patties: after cooking, patties were were placed in polystyrene trays, wrapped with oxygen-permeable PVC films (oxygen permeability: ∼17 cm³/m² day atm; moisture permeability: <5 g/m² day; Tecnodur S.L., Valencia, Spain) stored under refrigeration (+3 °C) for 10 days and finally transferred to laboratory for analyses; (4) cooked, chilled and reheated patties: At the end of the refrigeration, cooked and chilled samples were eventually reheated in a microwave (600 mW/1 min; Daewoo, Mod. KOR-6L75; Daewoo Electronics Sales UK Ltd) and subsequently transferred to laboratory for analyses. In total, four patties per group (treatment with hawberry extract and processing stage) were prepared in replicated and hence, independent manufacturing processes.

Determination of thiobarbituric-reactive substances (TBA-RS) numbers

Malondialdehyde (MDA) and other TBARS were quantified in all pork patties using the method described by Ganhão et al. (2010) with some modifications. Briefly, 2.5 g of patty were dispensed in cone plastic tubes and homogenized with 7.5 mL of perchloric acid (3.86%) and 0.25 mL of BHT (4.2% in ethanol). During homogenization, the plastic tubes were immersed in an ice bath to minimize the development of oxidative reactions during extraction of TBARS. The slurry was filtered and centrifuged (600*g* for 4 min), and 2 mL aliquots were mixed with 2 mL of thiobarbituric acid (0.02 M) in test tubes. The test tubes were placed in a boiling water bath (100 °C) for 30 min together with the tubes from the standard curve. After cooling, the absorbance was measured at 532 nm. The standard curve was prepared using a 1,1,3,3-tetraethoxypropane (TEP) solution in 3.86% perchloric acid. Results were calculated as mg of MDA per kilogram of patty.

Lipid-derived volatiles (Study 2)

Volatiles were analyzed in reheated samples by headspace/solid-phase microextraction (HS/SPME) and gas chromatography/mass spectrometry (GC/MS) following

the method described by Estévez et al. (2003). A gas chromatograph Hewlett-Packard 5890 series II coupled to a mass selective detector Hewlett-Packard HHP-5791A was used. One gram of minced sample was weighed into a 4 mL vial, which were closed with a Teflon/silicone septum (National Scientific) and preconditioned for 10 min at 37 °C. An SPME fibre (50/30 μm divinylbenzene-carboxen-polydimethylsiloxane coating) was preconditioned prior analysis at 220 °C during 45 min and then inserted through the septum and exposed to the headspace of the vial. After extraction, the SPME fiber was immediately transferred to the injector of the chromatograph (splitless mode). The separation of volatile compounds was performed on a 5% phenyl–methyl silicone (HHP-5)-bonded-phase fused-silica capillary column (Hewlett-Packard, 50 m × 0.32 mm id, film thickness 1.05 m). The carrier gas was helium at 18.5 psi (flow rate of 1.6 mL min^{-1}) at 40 °C. The SPME fiber was desorbed and maintained in the injection port at 220 °C during the whole chromatography run. The temperature program was isothermal for 10 min at 40 °C and then increased at the rate of 7 °C min^{-1} to 250 °C and held for 5 min. The GC–MS transfer line temperature was 270 °C. The mass spectrometer operated in the electron impact mode with an electron energy of 70 eV and a multiplier voltage of 1650 V and collected data at a rate of 1 scan s^{-1} over a range of m/z 40–300. Selected lipid-derived volatiles were positively identified by comparing its linear retention indexes/mass spectra (LRI/MS) with that from standard compound (Sigma-Aldrich, Steinheim, Germany). Results are provided in arbitrary area units (AU × 10^6).

Sensory analysis (Study 2)

The odor liking assessment of RTE pork patties was performed in samples right after reheating by 52 semi-trained panelists (staff and students from the Veterinary Faculty in Caceres, Spain, who frequently participate of sensory assessments in meat and meat products). A 7 cm linear non-structured quantitative scale from extremely disliked to extremely liked was used. Five grams of each sample were finely minced, dispensed in falcon tubes, sealed and wrapped with aluminum foil and offered to the panelists after being warmed up to 37 °C for 10 min in an electric oven.

Statistical analysis

The whole experiment was replicated four times and all analysis in each experimental unit (=patty from a replicated batch) was made in duplicate. A one-way analysis of variance (ANOVA) followed by Tukey's test was used to analyze the influence of extracting solvent on the TPC and antioxidant capacity of hawberry extracts and also to assess the effect of the hawberry extract on the volatiles of pork patties. A two-way ANOVA was performed to evaluate the effects of hawberry extract, the processing stage and the interaction on the TBARS of pork patties. A Kruskal–Wallis analysis was applied to sensory data. A significance level of $p < 0.05$ was applied.

Results and discussion

General composition, TFC and anti-radical activity of hawberry fruit (Study 1)

The TPC and anti-radical activity of extracts from Hawberry fruits are shown in Table 1. TPC ranged from 499.7 to 1282 mg of GAE/100 g of fruit. The highest TPC was found in the 75% acetone and 25% water extracts (1282 mg of GAE/100 g of fruit) followed by 100% acetone extracts (1281.1 mg of GAE/100 g of fruit) ($p < 0.05$). The lowest TPC was observed in the 100% water extracts (499.7 mg of GAE/100 g of fruit) ($p < 0.05$). In a previous study by Ganhão et al. (2010), the TPC of water, methanol and ethanol extracts from hawberry were 450, 600 and 2068 mg of GAE/100 g of fruit, respectively. In general, we can consider that our results are compatible with those reported by others authors (Ganhão et al. 2010; Shortle et al. 2014). However, it is necessary to state that environmental factors (Heinonen 2007) greatly influence the chemical characteristics of fruits and consequently their antioxidant potential (Goli et al. 2005).

The antioxidant activity of hawthorn berry extracts has previously been reported in the scientific literature (Froehlicher et al. 2009; Ganhão et al. 2010; Shortle et al. 2014). In the present study, the in vitro antioxidant activity of water and acetone extracts of hawberry fruit was determined using the DPPH method. In all cases, significant differences were found among the extracts (Table 1). The acetone extracts of hawberry fruit were the most

Table 1 TPC and anti-radical activity of extracts from hawberry fruits

Extracts	μM Trolox/g of fruits	mg GAE/100 g fruit
Water 100%	13.32[c] ± 4.72	499.7[c] ± 25.8
Acetone 25%	20.69[bc] ± 4.29	818.9[b] ± 124.4
Acetone 50%	41.21[ab] ± 6.97	1139.3[a] ± 155.2
Acetone 75%	48.27[a] ± 12.78	1282.0[a] ± 50.0
Acetone 100%	53.33[a] ± 15.40	1281.1[a] ± 84.8

Mean ± standard error. Means with different letters (a–c) from different extracting solvents are significantly different in ANOVA ($p < 0.05$)

efficient in DPPH assay. DPPH results ranged from 13.32 to 53.33 μM Trolox/g of fruits. Correlated to our TPC results, the highest antioxidant activity was found for the 100% acetone extracts (53.33 μM Trolox/g of fruits) followed by 75% acetone and 25% water extracts (48.27 μM Trolox/g of fruits) ($p < 0.05$). The lowest antioxidant activity was found for the 100% water extracts (13.32 μM Trolox/g of fruits) ($p < 0.05$). These results are consistent with those reported by Ganhão et al. (2010), who described weak antioxidant activity of water extracts of hawberry fruit against DPPH radical. Taking into account these results, the 100% acetone extract was used for testing the ability of hawberry to control oxidative reactions in RTE porcine patties (Study 2).

TBARS (Study 2)

Lipid oxidation, assessed as TBARS, increased rapidly after cooking and during succeeding storage and reheating of control cooked pork patties. This trend was previously reported by Ferreira et al. (2016) in RTE chicken patties and hence, expected in the present samples. The effect of different concentrations of hawberry phenolics on TBARS values of raw, cooked, cooked-chilled and cooked-chilled-reheated pork patties is shown in Fig. 1. TBARS values for all treatments were significantly lower than those in the control counterparts ($p < 0.05$). Quantitatively, the effect of the hawberry extract was considerably remarkable as the TBARS numbers in the most oxidized control samples surpassed 4 mg MDA/kg patty and the hawberry extract kept TBARS values below 0.5 mg MDA/kg patty. The antioxidant effect was so intense that the significant dose effect (200 vs 800 ppm GAE) of the hawberry extract at several stages was eclipsed by the quantitative differences

between the two treated samples and the control. This result suggests that the bioactive compounds from hawberry extracts efficiently controlled lipid oxidation during cooking and the following processing stages. This finding agrees with that reported by Juntachote et al. (2007) and Kong et al. (2010) who tested assorted natural extracts in cooked ground pork. Iron has been reported to be a major catalyst of lipid oxidation in cooked meats as it is released from the heme molecule upon heating (Han et al. 1993). In contrast to many other previous works, the present study covers several succeeding processing stages which highlight the effectiveness of our extract in severe pro-oxidant conditions.

The antioxidant effects of these extracts may be related to the ability of their phenolic components to quench reactive oxygen species. Estévez et al. (2007) highlighted the possibility of replacing synthetic antioxidants such as BHT in meat products by natural plant extracts. TBARS involve a heterogeneous collection of carbonyl compounds that promote the deterioration of the organoleptic properties of muscle foods in terms of meat odor, flavor, and color (Morrissey et al. 1998). As discussed above, lipid oxidation is a major cause of the onset of rancidity during frozen storage of meat and meat products. The threshold of TBARS values for the perception oxidized flavor in cooked beef was set between 0.5 and 1.0 and perceived by trained panelists (Tarladgis et al. 1960) and between 0.6 and 2.0 by inexperienced panelists (Greene and Cumuze 1982). Therefore, the detection WOF in the present samples by consumers is plausible. Using this threshold as indicator, hawberry extract is able to retard the sensory noticeable development of oxidation products in cooked pork patties for more than 10 days.

Fig. 1 TBARS during processing of RTE porcine burger patties. *Different letters* (*a–c*) above columns denote statistical differences between means from different fruit groups at the same processing stage ($p < 0.05$)
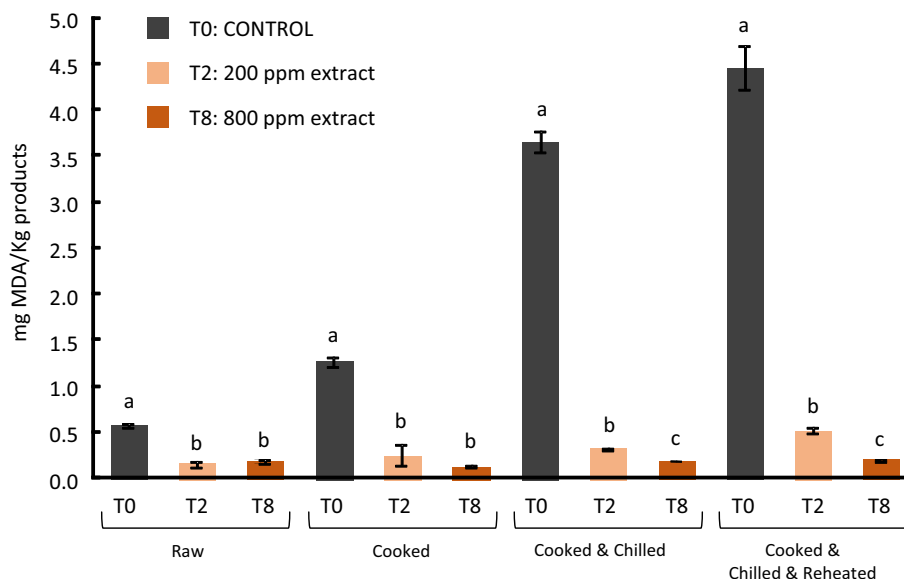
Lipid-derived volatiles (Study 2)

The assessment of volatile compounds in meat and meat products has received great attention because of the variety of information provided by this type of analysis. For instance, the evaluation of lipid oxidation in a meat product through the analysis of volatile compounds provides information on the convenience of processing and/or storage and the aromatic profile of the product (Estévez et al. 2003, 2004). Since RTE meat products are destined for consumption only after a proper reheating, volatiles were only analyzed in the headspace of cooked-chilled-reheated samples (Table 2). Aldehydes were the major volatile components in RTE pork patties and their proportion to total volatiles increased gradually in samples with higher oxidation rates. From the total volatiles found in the headspace of the samples, 6 aldehydes and one ketone were selected for their suitability as markers of lipid oxidation and key odorants in cooked meat products (Estévez et al. 2003). Hexanal is the main volatile compound, formed from omega 6-fatty acids in an oxidizing meat system (Frankel 1998). Hexanal has been typically used to follow the course of lipid oxidation and off-flavor development in meat products (Shahidi and Pegg 1994). The amount of hexanal was significantly higher in T0 group than in the treated samples T2 and T8 ($p < 0.05$). A significant dose–effect of the hawberry extract was observed. The addition of the extract significantly inhibited the formation of all other volatile compounds. It is worth mentioning that some of volatile compounds such as non-2-(E)-enal, dec-2-(Z)-enal, dec-2-(E)-enal and deca-2,4-(E,E)-dienal were not even detected in T2 and T8 groups. These unsaturated aldehydes are regarded as odor-active compounds and the alkadienals, in particular, are known for having a low odor-threshold and imparting rancid and off-flavors to cooked meats (Estévez et al. 2003). By contributing rancid and other off-odors, these lipid-derived volatiles may worsen the overall quality of meat commodities (Frankel 1998; Shahidi and Pegg 1994) such as the RTE pork product under study. Thus, the addition of fruit extracts in burger patties would preserve the sensory quality of the product by efficiently reducing the generation of volatiles responsible for off-odors during chilled storage and also after the reheating. Similar to our results, the addition of 0.05, 0.10 and 0.15% (w/w) ethanolic extracts of dried galangal in cooked ground pork had lower hexanal values as compared with controls during 14 day storage at 5 °C (Juntachote et al. 2007). Ahn et al. (2002) reported that hexanal values of cooked ground beef treated with 0.02% rosemary oleoresin were significantly lower than those of the control during 3 day storage at 4 °C.

Odor liking (Study 2)

Cooked-chilled-reheated samples were also analyzed by consumers for their odor profile (Table 2). The panelists scored the samples according to their odor liking and found significant differences between treatments. The addition of phenolic-rich hawberry extracts significantly improved the degree of consumer satisfaction regarding the odor of patties. According to their quantitative assessment, consumers 'slightly disliked' control samples and 'slightly/moderately liked' treated ones. Taking into account the clear consistency between results from sensory test with the TBARS and the analysis of lipid-derived volatiles, it is plausible to hypothesize that hawberry extract improved the odor liking of the RTE pork patties by inhibiting the formation of relevant oxidation products. The correlation coefficients shown in Table 3 support the reasonable connection between lipid oxidation and the deterioration of the odor in control patties compared to the treated ones. In fact, most consumers referred to 'rancidity' and other unpleasant odors when explained the reasons for disliking control samples while were driven by the pleasant

Table 2 Lipid-derived volatiles (Aux 10^6) and odor liking (9-points scale) of cooked-chilled-reheated pork patties

	Groups		
	T0 (control)	T2	T8
Hexanal	$149.77^a \pm 24.11$	$46.56^b \pm 17.35$	$16.49^c \pm 0.73$
Octan-2-(E)-al	$13.32^a \pm 1.96$	$0.46^c \pm 0.17$	$1.93^b \pm 0.56$
Octane-2,3-diona	$6.46^a \pm 1.85$	$2.51^b \pm 0.65$	ND
Non-2-(E)-enal	15.05 ± 3.59	ND	ND
Dec-2-(Z)-enal	43.00 ± 7.59	ND	ND
Dec-2-(E)-enal	48.26 ± 9.71	ND	ND
Deca-2,4-(E,E)-dienal	7.88 ± 1.30	ND	ND
Odor liking	$4.19^b \pm 1.72$	$5.62^a \pm 1.51$	$5.81^a \pm 1.80$

Mean ± standard error. Different letters (a–c) in means from different treatments denote significant differences ($p < 0.05$)

Table 3 Pearson correlations between chemical markers of lipid oxidation and odor liking in cooked-chilled-reheated RTE pork patties

	Odor-liking	
	Correlation coefficient	Significance level
TBA-RS	0.74	***
Hexanal	0.81	***
Octan-2-(E)-al	0.68	**
Octane-2,3-diona	0.59	*
Non-2-(E)-enal	0.58	*
Dec-2-(Z)-enal	0.59	*
Dec-2-(E)-enal	0.61	*
Deca-2,4-(E,E)-dienal	0.58	*

$* \ p < 0.05$; $** \ p < 0.01$; $*** \ p < 0.001$

'roasted' and 'meaty' odor notes when scoring the treated ones.

Ahn et al. (2002) reported high and significant correlation coefficients between WOF scores and TBARS values, and between WOF scores and hexanal content in cooked ground beef treated with natural plant extracts containing polyphenolic compounds. These results indicate that TBARS values and hexanal contents can be used as reliable indicators of WOF in RTE meats. Rojas and Brewer (2007) also found significant correlations between TBARS and 'grassy' odor in cooked pork samples with this descriptor being a reliable descriptor of WOF. Thereby it can be stated that hawberry extracts increased the satisfaction of consumers for RTE pork patties by inhibiting the odor deterioration upon cooking and hence, preserving the typical odor of freshly cooked meats. Moreover, in contrast to chemical markers of oxidation (hexanal, TBARS), consumers found no significant difference in the degree of satisfaction among the T2 and T8 groups ($p > 0.05$).

Conclusion

Results of the present study indicate that pure acetone extracts of hawberry had higher extraction yield, total phenolic content, and antioxidant activity against a DPPH scavenging activity than extracts obtained using assorted ratios with water. The addition of the crude extract redissolved in water to RTE pork patties efficiently controlled lipid oxidation in a severely processed meat product. We may also conclude that the addition of the more diluted extract (200 ppm) would be sufficient to maintain basal levels of oxidation and improve odor perception by consumers. These data strongly suggest that using these hawberry extracts as ingredients in pork patties can be an effective strategy for improving the nutritional value, safety and sensory characteristics of these meat commodities.

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