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ARTICLE

The Effect of the Water Extracts of Digestive Medicinal Plants on the Shelf-life of Pork Patties

Kuk-Hwan Seol[1], Hyun-Chul Seol[2], Thirawong Prayad, Hyoun Wook Kim[1], Aera Jang[1], Jun-Sang Ham[1], Mi-Hwa Oh[1], Dong-Hun Kim[1], and Mooha Lee*

Department of Food and Animal Biotechnology, Research Institute for Agriculture and Life Science, Seoul National University, Seoul 151-921, Korea
[1]National Institute of Animal Science, Rural Development Administration, Suwon 441-706, Korea
[2]Byucksan Oriental Medicine Clinic, Seoul 153-035, Korea

Abstract

This study was performed to examine the possibility of water extracts of several digestive medicinal plants (DMPEs), such as *Amomum tasoko*, *Alpinia oxyphylla*, *Citrus unshiu*, and *Myristica fragrans*, as a natural antioxidant. Total phenol contents of each extract were expressed as gallic acid equibalents (GAE) and those were significantly different among *A. tasoko* (39.87±5.77 mg GAE/g), *A. oxyphylla* (30.28±3.36 mg GAE/g), *C. unshiu* (28.13±5.01 mg GAE/g) and *M. fragrans* (6.36±0.30 mg GAE/g) ($p<0.05$), and extract of *A. tasoko* showed significantly higher antioxidative effect than butylated hydroxyanisole (BHA) on linoleic acid peroxidation at 72 h after incubation ($p<0.05$). Addition of extracts in pork patties did not affect the pH value and total microbes during cold storage. However, thiobarbituric acid reative substances (TBARS) of treated patties were lower in dose dependant manner than that of control as storage period increased (except patties treated with *C. unshiu* extract), and patties treated with 0.5% *A. tasoko* extract showed no significant difference with patties treated with 0.5% BHA at day 7.

Key words: digestive medicinal plant extracts, antioxidative effect, pork patty, shelf-life

Introduction

Lipid peroxidation not only produces rancid odours and flavours, but also decreases safety and nutritional quality by destruction of essential fatty acids and vitamins in foods during cooking, processing and storage. Lipid peroxidation causes aging, heart disease and carcinogenesis (Edwin, 1996). Oxidation of foods can be retarded in several ways, such as conditions of vacuum, or air replaced by nitrogen or low temperature. In industrial processing, addition of highly effective antioxidants has become a popular and highly effective means to lengthen the shelf life of foods and to reduce nutritional losses and harmful substances formed (Kanner *et al*., 1991; Tsuda *et al*., 1994).

Synthetic antioxidants, such as butylated hydroxyanisole (BHA), butylated hydroxytoluen (BHT) and *tert*-butylhydro-quinone (TBHQ), are widely used in the food industry. However, animal test have demonstrated that BHA and BHT accumulate in the body and result in liver damage and carcinogenesis (Ames, 1983; Baardseth, 1989; Grice, 1986; Ito *et al.*, 1983; Ito *et al*., 1986; Wichi, 1988). Therefore, development and utilization of more effective and non-toxic antioxidants of natural origin are desired (Namiki, 1990).

Medicinal plants had traditionally played a major role in the management of human health and are still playing an active role in the health care in many countries. Particularly, digestive medicinal plants pharmacologically stimulate the exercise of stomach and secretion of digestive juice which helping digestion and absorption. Furthermore, they contain essential oils abundantly which have various biological activities. Most of antioxidant potentials in medicinal plants are due to the redox properties of phenolic compounds that allow them to act as reducing agents, hydrogen donators and free radicals quenchers (Shagidi and Wanasundara, 1992). A great number of natural medicinal plants have been tested for their antioxidant activities and results have shown that raw extracts or isolated pure compounds from them were more effective

*Corresponding author: Mooha Lee, Department of Food and Animal Biotechnology, Research Institute for Agriculture and Life Science, Seoul National University, Seoul 151-921, Korea. Tel: 82-2-880-4820, Fax: 82-2-873-4804, E-mail: moohalee@snu.ac.kr

antioxidants *in vitro* than BHT or vitamin E (Gordon and Weng, 1992; Gu and Weng, 2001; Pyo *et al.*, 2004). However, there were few reports about the application of medicinal plants extracts directly in foods, especially muscle originated foods.

So, this study was performed to examine the possibility of water extracts of several digestive medicinal plants, such as *Amomum tasoko*, *Alpinia oxyphylla*, *Citrus unshiu,* and *Myristica fragrans*, as a natural antioxidant. In this study we examined total phenol contents and inhibitory rate against linoleic acid peroxidation of selected digestive medicinal plant extracts (DMPEs) and we manufactured pork patties containing medicinal plant extracts, and then determined the shelf-life of those patties during cold storage.

Material and Methods

Materials

Dried *Alpinia oxyphylla* MIQ*, Amomum tasoko* CREVOST et LEM*, Citrus unshiu* MARCOR*, and Myristica fragrans* HOUTT were purchased from domestic oriental medicine clinic. Folin-Ciocalteau's phenol reagent, gallic acid, and thiobarbituric acid (TBA) were purchased from Sigma Chemical Co. (USA). All other chemicals and solvents used were analytical grade.

Preparation of extracts from digestive medicinal plants

Medicinal plants were extracted with 10 folds of distilled water in water bath (JEIO TECH CW-30G, Korea) at 100°C for 1 h, subsequently filtered with Wattman No.1 filterpaper and lyophilized (Ilshin FD8505, Korea).

Total phenol contents and antioxidative effect on linoleic acid emulsion peroxidation of extracts

The Folin-Ciocalteu method was used (Javanmardi *et al.*, 2003) and 1% concentration of each DMPE solution in DW was made to measure total phenol contents of the extracts. The aliquots (200 μL) of each extract were added to the test-tubes containing 1.0 mL of Folin-Ciocaltue's reagent and 800 μL of 7.5% sodium carbonate followed by voltexing. The absorption at 765 nm was measured by spectrophotometer (X-ma 1000, Human co., Korea) after standing for 30 min. The total phenol content was expressed as gallic acid equivalents (GAE) by reference to the gallic acid standard calibration curve.

Modified method of ferrithiocyanate of Haraguchi *et al.* (1992) was used to measure the antioxidative effect on linoleic acid emulsion peroxidation. 30 μL of the extract solutions of all medicinal plant extracts in concentrations of 25 μg/mL was mixed with 400 μL of 0.04 M phosphate buffer and 200 μL of 2.51% linoleic acid dissolved in ethanol. The reaction mixture was incubated at 37 for 60 min. Thereafter, 100 μL of reaction mixture was mixed with 2,700 μL of 75% ethanol and 100 μL of 30% ammonium thiocyanate. Subsequently 100 μL of 0.02 M ferrous chloride dissolved in 3.5% HCl was added and after 3 min the absorbance was read at 500 nm and the percentage of linoleic acid peroxidation inhibition was calculated. BHA and 0.04 M phosphate buffer were used as positive and negative control, respectively.

Effects of DMPEs on shelf-life of pork patties

Patties were prepared with trimmed pork ham grounded by 6 mm chopper plate. No additives were used to avoid interference with antioxidative activity. DMPEs were added to 100 g of patties at the level of 0.1, 0.3 or 0.5% before molding and then cooked by 80°C-water bath (JEIO TECH CW-30G, Korea) for 30 min. After cooling, patties were packed in LDPE bags and stored at 5°C refrigerator for 7 d. pH, TBARS and total microbes were measured at 0, 1, 4, and 7 d of storage. pH of cooked patties was determined with digital pH meter (4 Star, Orion, USA) equipped with a combined glass electrode. On 5 g of patty was homogenized with 20 mL distilled water using Ultra-Turrex T25 tissue homogenizer (Janke and Kenkel, IKA, Labor Tecnik, Germany) for 1 min. TBARS was analyzed by method of Witt *et al*. (1970) with slight modification and measured at 531 nm using spectrophotometer (X-ma 1000, Human Co., Korea). 5 g of patty was homogenized with 45 mL of buffered peptone water and serially diluted. Pour plate methods in duplicate were used to analyze the total microbes of patties. All experiments were repeated three times.

Statistical analysis

Statistical analysis was performed with the SAS program for Windows V9.1 (SAS Institute, USA). ANOVA with Duncan's multiple range test was carried out to analyze the significant differences among the treatments ($p<0.05$).

Results and Discussion

Total phenol contents of DMPEs

The total phenol content of each DMPE was estimated, since phenolics may significantly contribute to its overall antioxidant activity. The total phenolic amounts of DMPEs

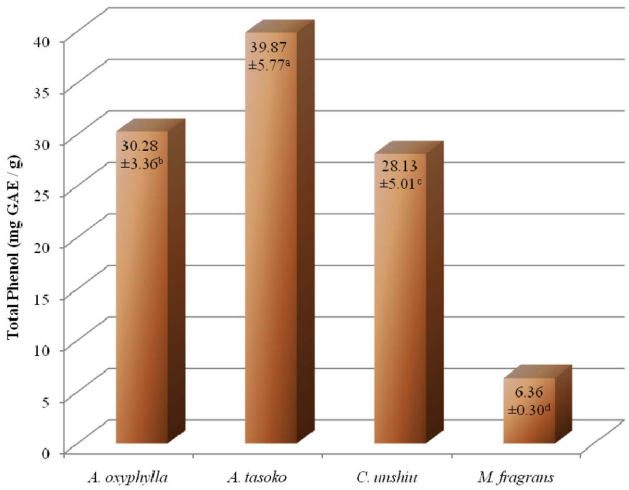

Fig. 1. Total phenol contents of medicinal plant extracts. *A. oxyphylla*, extract of *A. oxyphylla*; *A. tasoko*, extract of *A. tasoko*; *C. unshiu*, extract of *C. unshiu*; *M. fragrans*, extract of *M. fragrans*.

were significantly different among *A. tasoko* (39.87±5.77 mg GAE/g), *A. oxyphylla* (30.28±3.36 mg GAE/g), *C. unshiu* (28.13±5.01 mg GAE/g) and *M. fragrans* (6.36±0.30 mg GAE/g) ($p<0.05$) (Fig. 1).

Wong *et al*. (2006) reported the total phenol content of *A. oxyphylla* using boiling water extracts and 80% methanol extracts was 3.97±0.12 and 3.94±0.04 mg GAE/g, respectively, and in this study, *A. oxyphylla* extract showed 7 times higher amount of phenol, and it might be due to the different extraction method. Yoo *et al*. (2005) reported that total phenol contents of tangerine peel (*C. unshiu*) tea were 16.0, 18.9, and 20.9 mg% at 60, 80 and 100 water extracts, respectively. Son *et al.* (2007) reported the total phenol contents of water, ethanol extract and essential oil of nutmeg (*M. fragrans*) were 3.4, 16.9, and 3.2 mg%, respectively. And Su *et al*. (2007) also reported the total phenol content of nutmeg (*M. fragrans*) using 50% acetone and 80% methanol were 2.62±0.01 and 2.68±0.12 mg GAE/g, respectively. In this study, compared with previous reports, there are similar or higher amount of total phenol content in DMPEs.

Antioxidative effect on linoleic acid peroxidation of DMPEs

The inhibitory activities of DMPEs on linoleic acid emulsion peroxidation were similar or significantly higher than that of BHA at 24, 48, and 72 h after reaction except extracts of *C. unshiu* (Table 1). Though there was low total phenol content in extract of *M. fragrans*, it showed highest antioxidative activity of 66.77±13.94% at 48 h after reaction. Furthermore, the extracts of *A. tasoko* showed significantly higher antioxidative effect at 72 h after reaction (52.87±8.48%) than that of BHA (30.24±11.75%) ($p<0.05$). Inhibitory activities of medicinal plant extracts were impressively increased at 24 h of reaction and decreased at 72 h of reaction.

Previous studies have found high significance, positive correlation between antioxidant capacity and phenolic content, indicating that phenolic compounds are a major contributor to antioxidant activity in the medicinal plants, herbs, vegetables and fruits (Velioglu *et al.*, 1998, Cai *et al.*, 2004; Dorman *et al.*, 2004; Surveswaran *et al.*, 2007). In contrast to those previous studies, the result of this study demonstrated that *C. unshiu* showed low antioxidative effect even though it has high phenol content, and *M. fragrans* showed high antioxidative effect although it has low phenol content.

Change of pH values of pork patties during cold storage

The pH values of *A. tasoko*, *A. oxyphylla*, *C. unshiu* and *M. fragrans* extract was 5.25±0.01, 5.12±0.02, 4.72±0.01, and 5.39±0.08, respectively (data not shown), and the effect of the addition of DMPEs on the pH value of pork patties held under chilled conditions is shown in Table 2. The pH values of several patties, such as patties treated with *M. fragrans* extract (FP) 0.1%, patties treated

Table 1. Antioxidative effect of medicinal plant extracts on linoleic acid peroxidation (Inhibition rate, %)

	Reaction time (h)			
	0	24	48	72
A. oxyphylla	5.56±3.41^{abC}	61.08±16.11^{A}	64.04±15.23^{aA}	39.25±12.75^{abB}
A. tasoko	10.50±0.78^{aB}	61.75±17.11^{A}	64.46±14.03^{aA}	52.87±8.48^{aA}
C. unshiu	0.25±9.74^{bB}	43.60±29.08^{A}	35.15±30.22^{bA}	11.59±32.23^{cAB}
M. fragrans	4.80±6.38^{abC}	60.47±14.90^{AB}	66.77±13.94^{aA}	50.55±4.05^{abAB}
BHA	−6.97±2.75^{cC}	64.26±11.06^{A}	56.41±21.96^{abA}	30.24±11.75^{bcB}

Values are Mean±SD.
$^{a-c}$Means in the same column with different letters are significantly different ($p<0.05$).
$^{A-C}$Means in the same row with different letters are significantly different ($p<0.05$).

Table 2. Change of pH of pork patties treated with various medicinal plant extracts during cold storage

%		Storage time (d)			
		0	1	4	7
FP	0.1	6.09±0.10^{abB}	6.13±0.08^{AB}	6.19±0.15^{aAB}	6.23±0.13^{A}
	0.3	6.07±0.09^{ab}	6.12±0.03	6.20±0.17^{a}	6.22±0.17
	0.5	6.08±0.12^{ab}	6.13±0.19	6.20±0.15^{a}	6.25±0.20
OP	0.1	6.04±0.06^{b}	6.12±0.02	6.15±0.16^{a}	6.15±0.16
	0.3	6.06±0.04^{b}	6.08±0.05	6.17±0.14^{a}	6.17±0.17
	0.5	6.04±0.05^{bB}	6.09±0.03^{AB}	6.18±0.12^{aA}	6.18±0.14^{A}
TP	0.1	6.14±0.13^{ab}	6.10±0.04	6.16±0.14^{a}	6.18±0.13
	0.3	6.10±0.11^{ab}	6.09±0.08	6.22±0.17^{a}	6.23±0.21
	0.5	6.07±0.06^{ab}	6.10±0.06	6.18±0.16^{a}	6.18±0.17
UP	0.1	6.18±0.12^{a}	6.18±0.10	6.27±0.10^{a}	6.27±0.12
	0.3	6.13±0.10^{abB}	6.15±0.13^{B}	6.28±0.11^{aA}	6.28±0.12^{A}
	0.5	6.09±0.07^{abB}	6.13±0.09^{B}	6.24±0.13^{aA}	6.25±0.10^{A}
BP	0.1	6.13±0.12^{ab}	6.14±0.15	6.17±0.14^{a}	6.23±0.17
	0.3	6.07±0.08^{abB}	6.15±0.11^{AB}	6.21±0.10^{aA}	6.19±0.19^{AB}
	0.5	6.13±0.14^{ab}	6.15±0.14	6.21±0.16^{a}	6.25±0.19
CP		6.07±0.09^{abAB}	6.09±0.13^{AB}	6.00±0.21^{bB}	6.20±0.16^{A}

Values are mean±SD.
FP, Patties treated with *M. fragrans* extract; OP, Patties treated with *A. oxyphylla* extract; TP, Patties treated with *A. tasoko* extract; UP, Patties treated with *C. unshiu* extract; BP, Patties treated with BHA; CP, Control patties.
^{a,b}Means in the same column with different letters are significantly different (p<0.05).
^{A,B}Means in the same row with different letters are significantly different (p<0.05).

with *A. oxyphylla* extract (OP) 0.5%, patties treated with *C. unshiu* extract (UP) 0.3 and 0.5%, patties treated with BHA (BP) 0.3% and control patties (CP), increased significantly during storage period (p<0.05). The increase in pH is due to the accumulation of metabolites by bacterial action in meat and deaminations of proteins (Jay, 1996). The pH values of patties incorporated with *A. oxyphylla* (OP) were significantly lower than others at day 0 (p<0.05), and the pH values of all tested patties were significantly higher than that of control patty at 4 d of storage (p<0.05). However, the concentration and the species of medicinal plant extract did not affect consistently the pH values of patties overall storage period, and it might be caused by the amount of added extracts was not enough to bring differences between the concentration and the species.

Mansour and Khalil (2000) reported that there was no difference in pH between controls and antioxidants added samples over 35 d of chilled storage, however, the pH values of all patties increased significantly during storage. McCarthy *et al.* (2001) and Sahoo (1995) reported similar findings in pork patties and in ground buffalo meat containing BHA/BHT antioxidants during refrigerated and frozen storage, respectively. In our study, the difference between control and treatments was might be caused by the low pH of added DMPEs.

TBARS of pork patties with DMPEs

The chemical analysis of TBARS is widely used as indicator of lipid oxidation in meat studies and it has repeatedly been demonstrated the relationship of sensory terms versus log TBARS (Nissen *et al*., 2000; Poste *et al.*, 1986; Stapelfeldt *et al*., 1992).

The effect of the addition of DMPEs on TBARS development during refrigerated storage of cooked pork patties is shown in Table 3. In general, the TBARS values of all patties were increased significantly during chilled storage (p < 0.05). However, the TBARS values of patties with DMPEs (except UP) were significantly lower than that of control patty at 7 d of storage, and as the amount of added extract increased, such tendency was distinct. The TBARS values of patties with TP were lower than others, and those of patties with OP, FP and UP were in the increasing order. Especially, patties with 0.5% *A. tasoko* extract (TP 0.5%) showed no significant difference from the patties with 0.5% of BHA (BP 0.5%) at 7 d of storage (p>0.05). However, in contrast with the strong inhibition on linoleic acid peroxidation, the extract of *M. fragrans* did not showed strong inhibition activity on lipid oxidation in pork patty. Patties with *C. unshiu* extract did not show significant difference with control patties (p>0.05) and that coincide with the previous result of antioxidative effect on linoleic acid peroxidation which showed the

Table 3. Change of TBARS (mg malonaldehyde/kg) of pork patties treated with medicinal plant extracts during cold storage

%		Storage time (d)			
		0	1	4	7
FP	0.1	0.17 ± 0.09^{bcdC}	1.12 ± 0.33^{abB}	2.23 ± 0.59^{abA}	2.73 ± 0.51^{bA}
	0.3	0.06 ± 0.02^{efD}	0.34 ± 0.03^{defC}	0.79 ± 0.35^{defB}	1.49 ± 0.23^{cdA}
	0.5	0.06 ± 0.01^{efC}	0.15 ± 0.07^{efC}	0.65 ± 0.16^{efgB}	1.02 ± 0.25^{dA}
OP	0.1	0.08 ± 0.03^{defC}	0.62 ± 0.15^{cdB}	1.74 ± 0.32^{bcA}	1.97 ± 0.38^{cA}
	0.3	0.07 ± 0.01^{efC}	0.22 ± 0.02^{efC}	0.92 ± 0.37^{deB}	1.42 ± 0.36^{dA}
	0.5	0.07 ± 0.01^{efC}	0.11 ± 0.01^{efC}	0.27 ± 0.04^{fgB}	0.42 ± 0.09^{eA}
TP	0.1	0.07 ± 0.03^{efB}	0.39 ± 0.18^{deB}	1.33 ± 0.47^{cdA}	1.45 ± 0.54^{dA}
	0.3	0.06 ± 0.03^{efB}	0.07 ± 0.01^{efB}	0.19 ± 0.12^{gA}	0.26 ± 0.13^{eA}
	0.5	0.06 ± 0.01^{ef}	0.07 ± 0.00^{ef}	0.07 ± 0.01^{g}	0.07 ± 0.02^{e}
UP	0.1	0.34 ± 0.18^{aD}	1.29 ± 0.17^{aC}	2.80 ± 0.71^{aB}	3.45 ± 0.55^{aA}
	0.3	0.22 ± 0.19^{bcC}	1.00 ± 0.61^{abC}	2.58 ± 0.87^{aB}	3.41 ± 0.81^{aA}
	0.5	0.15 ± 0.07^{cdeD}	0.88 ± 0.24^{bcC}	2.44 ± 0.49^{aB}	3.16 ± 0.80^{abA}
BP	0.1	0.03 ± 0.01^{fB}	0.17 ± 0.03^{efB}	0.46 ± 0.17^{efgA}	0.40 ± 0.27^{eA}
	0.3	0.03 ± 0.01^{fC}	0.05 ± 0.02^{efBC}	0.06 ± 0.01^{gAB}	0.09 ± 0.04^{eA}
	0.5	0.02 ± 0.01^{fB}	0.03 ± 0.01^{fB}	0.07 ± 0.01^{gA}	0.04 ± 0.02^{eA}
CP		0.25 ± 0.07^{bD}	1.12 ± 0.63^{abC}	2.26 ± 0.75^{abB}	3.41 ± 0.38^{aA}

Values are mean±SD.

FP, Patties treated with *M. fragrans* extract; OP, Patties treated with *A. oxyphylla* extract; TP, Patties treated with *A. tasoko* extract; UP, Patties treated with *C. unshiu* extract; BP, Patties treated with BHA; CP, Control patties.

[a-g]Means in the same column with different letters are significantly different ($p<0.05$).

[A-D]Means in the same row with different letters are significantly different ($p<0.05$).

lowest effect, however, that does not coincide with the previous study of Min *et al.* (2002) which showed high (80.93-83.27%) electron donating abilities. These results coincide with the report of Park *et al*. (2005) that the TBARS of marinated beef incorporated with medicinal plant mixture extract such as *S. miltiorrhiza*, *G. uralensis*, *S. chinesis* Bacillon, *C. sappan* L., and *L. erythrorhizon* was lower increase rate than that of control beef, and as the amount of added extract increased that tendency was distinct.

Hernández-Hernández *et al*. (2009) reported rosemary extract added raw pork batter showed the lowest TBARS. Nissen *et al*. (2004) reported that rosemary, green tea and grape skin extracts showed significantly low TBARS in chilled-stored precooked pork patties and Rey *et al*. (2005) reported that cloudberry extract and quercetin showed most effective in preventing lipid oxidation in cooked pork patties after 3 d of refrigerated storage.

Phenols stabilized hydroperoxides preventing further degradation to more active oxidizing forms, such as malonaldehyde (Wellwood and Cole, 2004). Phenol compounds complex with Fe^{2+} preventing hydroxyl radical formation. According to other authors (Frankel and Huang, 1996; Frankel *et al*., 1994) the antioxidant effect of carnosic acid is due to its lipophilic characteristics. Kilic and Richards (2003) reported that lipid oxidation in an oil-in-water emulsion increases with decreasing antioxidant polarity; antioxidant compounds were located at the interface where hydroperoxides were in contact with prooxidants.

Change of total microbes of pork patties with DMPEs

The effect of the addition of DMPEs on total microbes during chilled storage of cooked pork patties is shown in Table 4. In general, patties significantly increased in total plate counts (TPC) as the storage period increased. Park *et al*. (2005) reported that the addition of medicinal plant mixture extract to marinated beef inhibited the microbial growth during chilled storage. Mansour and Khalil (2000) reported that beef patties without antioxidant increased in TPC at the 28th in chilled and 45th day in frozen samples, and this might be due to cooking which drastically injured and/or killed the microbial population (Jay, 1996). However, in this study, at 7 d of storage, there was no significant difference between medicinal plant extract treated and control patties ($p>0.05$).

Though extracts from tested digestive medicinal plants did not show significant antimicrobial effect, extract of A. *tasoko* showed as strong antioxidative effect as chemical

Table 4. Change of total microbes (log CFU/g) of pork patties treated with medicinal plant extracts during cold storage

	%	Storage time (d)			
		0	1	4	7
FP	0.1	2.05 ± 0.77^{abcB}	1.26 ± 0.35^{C}	2.05 ± 0.67^{abAB}	4.12 ± 0.86^{A}
	0.3	1.87 ± 0.44^{abcdB}	1.87 ± 0.41^{B}	1.86 ± 0.31^{bB}	3.20 ± 1.65^{A}
	0.5	1.80 ± 0.45^{abcdB}	1.93 ± 0.44^{B}	2.69 ± 0.90^{abA}	2.86 ± 0.92^{B}
OP	0.1	1.70 ± 0.55^{abcdB}	1.98 ± 0.31^{B}	2.50 ± 0.95^{abB}	3.40 ± 1.32^{A}
	0.3	1.64 ± 0.61^{bcdeB}	2.03 ± 0.35^{B}	2.10 ± 1.01^{abB}	2.92 ± 0.79^{A}
	0.5	2.21 ± 0.72^{ab}	2.16 ± 0.62	2.37 ± 0.47^{ab}	2.74 ± 0.71
TP	0.1	1.88 ± 0.43^{abcdB}	2.19 ± 0.26^{B}	2.27 ± 0.39^{abB}	3.20 ± 1.52^{A}
	0.3	1.79 ± 0.18^{abcdC}	1.93 ± 0.46^{C}	2.75 ± 0.28^{abB}	3.38 ± 0.86^{A}
	0.5	2.29 ± 0.53^{aB}	2.04 ± 0.39^{AB}	2.42 ± 0.89^{abAB}	3.23 ± 1.45^{A}
UP	0.1	1.87 ± 0.60^{abcdC}	2.26 ± 0.83^{BC}	2.85 ± 0.52^{aAB}	3.23 ± 0.07^{A}
	0.3	1.92 ± 0.50^{abcdB}	1.92 ± 0.78^{B}	2.98 ± 0.58^{aA}	3.23 ± 0.68^{A}
	0.5	1.48 ± 0.59^{cdeC}	2.01 ± 0.33^{BC}	2.79 ± 1.13^{abAB}	3.03 ± 0.21^{A}
BP	0.1	1.13 ± 0.16^{eC}	1.97 ± 0.35^{B}	2.53 ± 0.71^{abAB}	2.91 ± 0.64^{A}
	0.3	1.77 ± 0.57^{abcdB}	1.75 ± 0.39^{B}	2.50 ± 1.00^{abAB}	2.71 ± 0.28^{A}
	0.5	2.25 ± 0.36^{aB}	1.73 ± 0.40^{C}	2.31 ± 0.41^{abB}	3.29 ± 0.51^{A}
CP		1.39 ± 0.37^{deB}	2.07 ± 0.43^{B}	2.77 ± 0.72^{abA}	3.27 ± 0.98^{A}

Values are mean±SD.

FP, Patties treated with *M. fragrans* extract; OP, Patties treated with *A. oxyphylla* extract; TP, Patties treated with *A. tasoko* extract; UP, Patties treated with *C. unshiu* extract; BP, Patties treated with BHA; CP, Control patties.

[a-e]Means in the same column with different letters are significantly different ($p<0.05$).

[A-C]Means in the same row with different letters are significantly different ($p<0.05$).

antioxidant, BHA.

Digestive medicinal plant extracts tested in this study were containing sufficient phenolic compounds to inhibit linoleic acid peroxidation and lipid oxidation in cooked pork patties during cold storage. Therefore, there is possibility to develop the natural antioxidant with those medicinal plants as an alternative of synthetic antioxidants, and need to study more about the functionality of phytochemicals derived from various kinds of medicinal plants and herbs.

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