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Comparison of Physicochemical Properties and Antioxidant Potential of Four Commercial Sauces

Hong Ahn[1], Il-Doo Kim[2]

[1]Department of Hotel & Food Service Industry, Daegu Health College, Daegu 41453, Korea
[2]International Institute of Research and Development, Kyungpook National University, Daegu 41566, Korea

Abstract: The sauce is a type of seasoning prepared in a liquid, semiliquid, or creamy form that blends various raw materials and makes it well suited to food, but the color, flavor, and texture vary depending on the composition of the ingredients. Due to the increasing eating out habit, consumption of Western-style diet has become more common in Korea. The objective of this study was to analyze the physicochemical and antioxidant potential of four commercial sauces. The pH value of oyster sauce (OSS) was significantly higher than the other three sauces, sweet chilli sauce (SCS), honey mustard sauce (HMS), and pork cutlet sauce (PCS). The soluble solid content was significantly highest in SCS and lowest in OSS. The lightness, redness, and yellowness values were in the order of SCS>HMS>PCS>OSS. The DPPH and superoxide anion scavenging potential were highest in SCS and HMS, respectively. However, the total flavonoid and polyphenol contents were significantly highest in PCS. The APX was significantly high in HMS followed by OSS. The other enzyme activities SOD, CAT, and PPO were significantly highest in OSS. Two sauces SCS and PCS had intermediate antioxidant enzymatic activities. Commercial sauces may vary in the physicochemical and antioxidant potential that could be considered while selecting them for consumption.

Keywords: Antioxidant Potential, Honey Mustard Sauce, Oyster Sauce, Physicochemical Property, Pork Cutlet Sauce, Sweet Chilli Sauce

Introduction

A sauce, generally, is a liquid, semiliquid, or creamy food material that is served on or used in preparing other dishes. It is a type of seasoning that blends various raw materials and makes it well suited to food, but the color, flavor, and texture vary depending on the composition of the ingredients. There are varieties of sauces that are not normally consumed by themselves but are used to add flavor, moisture, and appearance to a dish. Different types of sauces are specifically popular in certain parts of the world. Due to the increasing eating out habit, Western-style diet has become more common in Korea. Similarly, the consumption of Western-style sauces is also gradually increasing. In Korea, oyster sauce, sweet chill sauce, mustard sauce, and pork cutlet sauce are some of the common sauce products (Cho & Kang 2015; Hwang et al. 2015; Lee et al. 2018; Park et al. 2012). The commercial sauces found in the Korean market can be categorized into different groups, such as table sauce, cooking sauce, sauce for Korean foods, and sauce for non-Korean foods (Kang et al. 2014).

Oyster sauce is commonly used as a seasoning in Chinese cuisine that is prepared by mixing oyster boiled concentrate and other ingredients such as starch, sugar, various flavoring materials (Hwang et al. 2015). It is regarded as a healthy food item because it contains Angiotensin I converting enzyme (ACE) inhibitor (Je 2005; Matsui et al. 2004). ACE plays an important physiological role in regulating blood pressure (Skeggs et al. 1956). The availability of a wide range of phytochemicals such as vitamins, phenolics, and flavonoids in chilli (Ganguly et al. 2017; Howard et al. 2000) makes sweet chilli sauce a rich source of nutrients and functional materials which may reduce the risk of degenerative diseases. Mustard is a good source of various carotenoids, among which β-carotene is of great significance to human health because it possesses provitamin A activity and anticarcinogenic effects (Peto et al. 1981). Glucosinolates such as sinigrin, glucobarbarin, and gluconasturtiin are another type of phytochemical present in mustard (Kim et al. 2016). Mustard seeds contain a high concentration of glucosinolates, which is supposed to have a key role in cancer prevention, mainly in the initiation or promotion phases and in cell apoptosis (Szollosi 2011). The word pork cutlet comes from the French word Cottlet, which refers to a thin slice of meat from the legs or ribs of different animals such as veal, pork, chicken, or mutton. In Korea, the pork cutlet sauce was produced in the 1970s starting from mid-range restaurants which was spread to the general public since the 1990s (Han et al. 2002).

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Il-Doo Kim (Correspondence)
+82-53-950-5707; Fax: +82-53-950-6880

A number of studies on the sauces found in the Korean market have been carried out, for instance, potential hazard analysis by the physicochemical quality and microbiological safety (Kang et al. 2014), quality of pork cutlet sauce added with rice soybean paste powder (Yoon et al. 2006), and quality and antioxidant activity of pork cutlet sauce added with oyster mushroom (Park et al. 2010). To the best of our knowledge, reports on the comparative evaluation of the quality and antioxidant potential of commercial sauces found in the Korean market are lacking. The objective of this study was to assess the physicochemical properties and antioxidant potentials of commercially available oyster sauce, sweet chill sauce, mustard sauce, and pork cutlet sauces.

Materials and Methods

Chemicals and materials

Folin-Ciocalteu phenol reagent, DPPH (1,1-diphenyl-2-picryl-hydrazyl), quercetin, nitro blue tetrazolium, guaiacol, and pyrogallol were purchased from Sigma-Aldrich (Sigma-Aldrich Corp, St. Louis, MO, USA). All the chemicals and reagents used in this study were of analytical grade.

Four sauce products: oyster sauce (OSS), sweet chill sauce (SCS), honey mustard sauce (HMS), and pork cutlet sauce (PCS) produced by a Korean company (CJ Co.), were purchased from a local market in Daegu, Korea.

Measurement of pH and soluble solid content

The pH of sauces was measured using a pH Meter (Model 250, Beckman Coulter Inc, Fullerton, CA, USA). The soluble solid content was measured using a hand refractometer (RX-5000α, Atago, Tokyo, Japan).

Color measurement

L^* (lightness), a^* (redness, + or greenness, –), and b^* (yellowness, + or blueness, –) values of sauce samples were measured using a Chroma Meter (CR-300, Minolta Corp., Japan). A Minolta calibration plate (Y_{CIE} = 94.5, X_{CIE} = 0.3160, Y_{CIE} = 0.330) and a Hunter Lab standard plate (L^* = 82.13, a^* = – 5.24, b^* = – 0.55) were used to standardize the instrument with D65 illuminant. The color was measured directly on three zones of sauce samples and the average was calculated (Kim et al. 2014).

Determination of DPPH radical scavenging activity

The DPPH free-radical scavenging potential of sauce samples was determined according to a previously described method (Blois 1958) with some modifications. One gram sample was extracted with 10 mL methanol for 24 h at room temperature. The mixture was centrifuged (2,259×*g*, 15 min), and the supernatant was filtered through a 0.2 μm syringe filter (Waters Co., Milford, MA, USA). DPPH solution was prepared at the concentration of 4×10^{-4} M in methanol. A 0.1-mL aliquot of the extract was mixed with 2.9 mL of DPPH solution and the mixture was incubated at room temperature for 30 min. After standing for 30 min, absorbance was recorded at 516 nm by UV-VIS spectrophotometer (Opron 3000 Hanson Tech. Co. Ltd., Seoul, Korea). The inhibitory percentage of the DPPH radical by the samples was calculated according to the following equation:

$$\text{Scavenging effect (\%)} = [(A_0 - (A - A_b))/A_0] \times 100$$

where A_0 is the absorbance of DPPH without a sample (control), A is the absorbance of sample and DPPH, and A_0 is the absorbance of the sample without DPPH (blank).

Assessment of superoxide anion scavenging activity

Superoxide anion scavenging activity was determined by measuring the inhibition of the auto-oxidation of pyrogallol using a slightly modified method of Marklund and Marklund (1974). A sample solution (0.3 mL) and 2.61 mL of 50 mM phosphate buffer (pH 8.24) were added into freshly prepared 90 μL of 3 mM pyrogallol (dissolved in 10 mM HCl). The inhibition rate of pyrogallol auto-oxidation was measured at 325 nm. The absorbance of each extract was recorded at every 1 min interval for 10 min and the increment of absorbance was calculated by the difference (the absorbance at 10 min − the absorbance at the starting time).

Measurement of total flavonoid content

The total flavonoid content in the sauce was determined following the method described by Zhishen et al. (1999) with some modifications. The methanolic sample extract that was used in the DPPH assay was used in this assay. Sample extract (100 μL), methanol (500 μL), 10% $AlCl_3$ (50 μL), 1 M hydrochloric acid (50 μL), and distilled water (300 μL) were mixed and incubated in dark for 30 min. The absorbance value of the reaction mixtures was measured at 510 nm using a microplate spectrophotometer (Multiskan GO; Thermo Fisher Scientific Oy, Vantaa, Finland). The standard calibration curve was plotted using quercetin (QE).

Measurement of total polyphenol content

The total polyphenol content of sauce samples was assayed according to the Folin-Ciocalteau method (Singleton et al. 1999) as described by Dhungana et al. (2015). The methanolic sample extract that was used in total flavonoid determination was used in this assay. Fifty microliters of the methanolic extract and 1000 μL of 2% (w/v) aqueous sodium carbonate were thoroughly mixed using a vortexer and allowed to react for 3 min at room temperature. After 3 min, 50 μL of 1 N Folin-Ciocalteau reagent was put into the mixture and allowed to react at room temperature for 30 min under dark conditions. The absorbance value of the mixture was read at 750 nm using a Microplate

Spectrophotometer (Multiskan GO; Thermo Fisher Scientific Oy, Vantaa, Finland). The calibration curve was plotted using gallic acid (GA) as a standard. Total polyphenols contents in the samples were estimated as GA equivalents (μg GAE/g sample).

Determination of antioxidant-related enzymatic activity

The catalase (CAT) activity was measured using a previously described method (Halo et al. 2015) which involved the calculation of H_2O_2 absorption reduction at 240 nm. The reaction buffer contained 15 mM hydrogen peroxide and 50 mM potassium phosphate buffer at a pH of 7.0. Then, 100 μL of the enzyme extract was added to the reaction mixture to initiate the reaction. The H_2O_2 level in the reaction mixture was measured after 1 min using the extinction coefficient of 40 mM^{-1} cm^{-1}, which indicated CAT enzyme activity.

The superoxide (SOD) activity was determined using a previously described method (Giannopolitis & Ries 1977), which consisted of evaluating the SOD inhibitory ability to photochemically decrease nitro blue tetrazolium (NBT). The SOD activity units were determined as the amount of enzyme required to cause 50% inhibition of the reduction of NBT, as monitored at 560 nm.

The polyphenol oxidase (PPO) activity was determined using the guaiacol method (Zhang & Kirkham 1994), which was performed by adding 0.1 mL of the supernatant to the reaction mixture containing 1.0 mL of 2% H_2O_2, 2.9 mL of 50 nM phosphate buffer (pH 5.5) and 1.0 mL of 50 mM guaiacol. Phosphate buffer was used as control without enzyme. Absorbance was read at 470 nm for 3 min, and POD activity was calculated as a unit change per minute.

For the measurement of the ascorbate peroxidase (APX) activity, 100 mg of sample was extracted with 1 mL of 50 mM phosphate buffer (pH 7.0) containing 1 mM ascorbic acid and 1 mM EDTA. The homogenates were centrifuged at 4830×g (4°C) for 15 min. The supernatant was mixed with phosphate buffer solution (pH 7.0), 15 mM ascorbic acid, and 0.3 mM H_2O_2, then, the reaction mixture was read at 290 nm (Gara et al. 1997).

Statistical analysis

Analysis of variance was conducted using SAS 9.4 (SAS Institute, Cary, NC, USA) and the significant differences between sample means were determined using the Tukey test at 5% probability. Average values of three replications are reported unless otherwise mentioned.

Results and Discussion

pH and soluble solid content

The pH value of OSS (4.39) was significantly high compared to other sauces (Table 1). The lowest pH was measured in SCS (3.38). On the contrary, the soluble solid content was significantly highest and lowest in SCS (52.4°Brix) and OSS (34.0°Brix), respectively.

Lower pH value is an important attribute to improve the shelf-life and resistance to microbial contaminations during storage (He et al. 2014). Although the association of soluble solid content with the quality loss of sauce is not reported, higher storage temperature may increase the soluble solid content of tomato-mushroom mixed ketchup (Kumar & Barman Ray 2016).

Table 1. pH and soluble solid content of four commercial sauces

Properties	Sample[1)]			
	OSS	SCS	HMS	PCS
pH	4.39±0.02[a]	3.38±0.03[d]	3.59±0.02[c]	3.68±0.02[b]
Soluble solid content (°Brix)	34.0±0.10[d]	52.4±0.20[a]	48.7±0.30[b]	46.5±0.10[c]

[1)] OSS: Oyster sauce, SCS: Sweet chill sauce, HMS: Honey mustard sauce, PCS: Pork cutlet sauce.
[2)] Quoted values are means±SD of triplicate measurements. Values followed by different superscripts in the same row are significantly different (p<0.05).

Color value

The color values of sauce samples were significantly different (Table 2). All three parameters, lightness, redness, and yellowness values were significantly highest in SCS (13.72, 37.44, and 23.26) and lowest in OSS (0.62, 2.76, and 0.82, respectively). The values were in the order of SCS>HMS>PCS>OSS.

The color of a food product is one of the major decisive factors influencing the willingness of consumers to accept the product (Udomkun et al. 2018). The variation in natural colorants like anthocyanins, betalains, chlorophylls, carotenoids in the sauces might be the reason for the significant difference in the color values of the sauce samples (Francis & Markakis 1989).

Table 2. Hunter's color values of four commercial sauce

Sample[1)]	Color value[2)]		
	L*	a*	b*
OSS	0.62±0.02[d]	2.76±0.03[d]	0.82±0.12[d]
SCS	13.72±1.21[a]	37.44±0.25[a]	23.26±1.73[a]
HMS	3.03±0.21[b]	10.71±0.15[b]	4.98±0.17[b]
PCS	1.27±0.05[c]	5.99±0.31[c]	2.02±0.02[c]

[1)] OSS: Oyster sauce, SCS: Sweet chill sauce, HMS: Honey mustard sauce, PCS: Pork cutlet sauce.
[2)] L*, lightness (100, white; 0, black); a*, redness (-, green; +, red); b*, yellowness (-, blue; +, yellow).
[3)] Data are means±SD of triplicate measurements. Values followed by different superscripts in the same column are significantly different (p<0.05).

DPPH free-radical and superoxide anion scavenging activities and total flavonoid and polyphenol contents

The antioxidant potential of sauce samples was significantly different (Table 3). The DPPH and superoxide anion scavenging potential were highest in SCS (96.08%) and HMS (0.93%), respectively. However, the total flavonoid and polyphenol contents were significantly highest in PCS (149.07 mg QE/g and 71.26 mg GAE/g, respectively) among four samples.

Free radicals are highly reactive species and are detrimental, if available in high concentration, to biologically important molecules such as DNA, proteins, carbohydrates, and lipids (Young & Woodside 2001). Substantial modification and impairment to lipids, proteins, and DNA by free radicals may lead to various health problems (Lobo et al. 2010). The damaging effects of free radicals can be amended by supplying antioxidants. Intake of synthetic antioxidants like butylated hydroxytoluene and butylated hydroxyanisole, however, is not considered good for human health (Lobo et al. 2010). The higher DPPH free-radical scavenging potential of SCS might be due to the availability of a wide range of phytochemicals such as vitamins, phenolics, and flavonoids in chilli (Ganguly et al. 2017; Howard et al. 2000). Therefore, there is an ever-increasing interest in natural dietary antioxidants. The results may provide useful information for the consumers to select antioxidant-rich sauces.

Table 3. DPPH free-radical and superoxide anion scavenging activities and content of total flavonoid and polyphenol in four commercial sauces

Sample[1)]	% Inhibition		Total flavonoid (mg QE/g)	Total polyphenol (mg GAE[4)]/g)
	DPPH[2)]	O_2^{-} [3)]		
OSS	34.52±0.32[d 5)]	0.49±0.04[b]	125.11±2.31[b]	61.21±1.32[b]
SCS	96.08±1.21[a]	0.26±0.03[c]	40.35±0.96[d]	26.18±0.90[d]
HMS	88.82±0.98[b]	0.93±0.06[a]	118.92±1.31[c]	51.32±1.12[c]
PCS	51.65±1.11[c]	0.40±0.06[b]	149.07±2.00[a]	71.26±2.31[a]

[1)] OSS: Oyster sauce, SCS: Sweet chill sauce, HMS: Honey mustard sauce, PCS: Pork cutlet sauce.
[2)] DPPH: DPPH free radical scavenging activity.
[3)] O_2^{-}: superoxide anion scavenging activity.
[4)] GAE: garlic acid equivalent.
[5)] Quoted values are means±SD of triplicate measurements. Values followed by different superscripts in the same column are significantly different (p<0.05).

Antioxidant-related enzymatic activity

The antioxidant-related enzymatic activities were also significantly varied with the type of sauce (Table 4). The APX was significantly high in HMS (19.48 µmol/mg protein/g) followed by OSS (14.33 µmol/mg protein/g). The other activities SOD, CAT, and PPO were significantly highest in OSS (60.30, 97.45, and 21.76 µmol/mg protein/g, respectively). Two sauces SCS and PCS had intermediate antioxidant enzymatic activities.

Antioxidants like APX, SOD, CAT, and PPO help maintain a balance between reactive oxygen species production and antioxidant defense (Gill & Tuteja 2010). For instance, superoxide dismutase (SOD) acts as a catalyst to convert superoxide radicals into oxygen and hydrogen peroxide (Fridovich 1997). The hydrogen peroxide converts into water and oxygen by catalase to protect the cells from the accumulation of H_2O_2 (Halliwell 1999). APX and POD play roles in H_2O_2 scavenging during oxidative stress (Mondal et al. 2004). The loss of such balance creates oxidative stress, resulting in a series of deregulation of cellular functions that may lead to disease development, including cancer, cardiovascular disease, cataract, and aging (Poljsak et al. 2013).

Table 4. Ascorbate peroxidase (APX), superoxide dismutase (SOD), catalase (CAT), and polyphenol oxidase (PPO) of four commercial sauces

Sample[1)]	Enzyme (μmol/mg protein/g)			
	APX	SOD	CAT	PPO
OSS	14.33±1.17^{b} [2)]	60.30±2.61^{a}	97.45±1.21^{a}	21.76±2.31^{a}
SCS	11.04±0.69^{c}	14.91±0.12^{d}	67.45±4.71^{c}	7.28±0.29^{c}
HMS	19.48±1.31^{a}	38.80±1.21^{b}	84.79±5.12^{d}	15.34±1.22^{b}
PCS	8.14±1.11^{d}	24.99±1.00^{c}	96.67±0.23^{b}	13.09±1.06^{b}

[1)] OSS: Oyster sauce, SCS: Sweet chill sauce, HMS: Honey mustard sauce, PCS: Pork cutlet sauce.
[2)] Quoted values are means±SD of triplicate measurements. Values followed by different superscript in the same column are significantly different (p<0.05).

Conclusion

The pH, soluble solid content, color value, and antioxidant potential of four commercial sauces, oyster sauce (OSS), sweet chill sauce (SCS), honey mustard sauce (HMS), and pork cutlet sauce (PCS), were evaluated. The pH value of OSS was significantly higher than other sauces. The soluble solid content was significantly highest in SCS and lowest in OSS. The lightness, redness, and yellowness values were in the order of SCS>HMS>PCS>OSS. The DPPH and superoxide anion scavenging potential were highest in SCS and HMS, respectively. However, the total flavonoid and polyphenol contents were significantly highest in PCS. The APX was significantly high in HMS followed by OSS. The other enzyme activities SOD, CAT, and PPO were significantly highest in OSS. Two sauces SCS and PCS had intermediate antioxidant enzymatic activities. The results suggested that commercial sauces may have different properties that could be considered while selecting them for consumption.

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