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Oxidants and Antioxidants Associated with Commercial Pickle Products and Ingredients

Mi Jin Jang[2] · Il Young Cho[3] and Hyun Kyu Joo[1]*

[1]Department of Agricultural Chemistry, KonKuk University, Seoul, Korea 133-140,
[2]Perkin Elmer Korea, Seoul, Korea 137-044, [3]KJ Engineering, Seoul, Korea 150-093

Abstract : Investigations of the effects of pickle product ingredients on lipoxygenase (LOX) and methemoglobin (MHG, a nonenzymatic oxidant) catalyzing oxidation of linolenic acid were conducted. In addition, activities of LOX, peroxidase (POD) and catalase (CAT) in dry spices used in pickle products were determined. Some commercial pickle brines were observed to inhibit oxidation of linolenic acid by LOX and MHG. The ingredients in pickle products, such as dill oil emulsion, onion concentrate, oil cassia, polysorbate 80 and turmeric acid, reduced LOX and MHG catalyzed oxidation. Lipoxygenase activity was present in garlic, mustard seed and red pepper. Only in mustard seed, peroxidase activity was observed. Catalase activity was observed in garlic, black pepper, allspice and red pepper(Received April 29, 1995; accepted October 9, 1995).

Introduction

Almost all the common straight-chain volatile compounds produced either by enzymatic or nonenzymatic oxidation are derived from cleavage either at the hydroperoxy carbon or at another carbon after secondary reactions. There are similarities in the structures of the volatiles regardless of whether they originate from enzymatic or nonenzymatic oxidation. Enzymatic oxidation is more selective than nonenzymatic oxidation and results in a narrow range of volatiles, which is especially important in the production of typical cucumber flavor volatiles.

Endogenous enzyme, lipoxygenase (LOX), cause hydroperoxidation of unsaturated fatty acids to generate volatile compounds with characteristic flavor or off-flavor in cucumber upon physical disruption.[1] But the nonenzymatic decomposition of lipid hydroperoxide involves free radicals, and it is promoted by hemoproteins, α-tocopherol, lipid oxidation products, heat, photolysis and trace metals, especially copper, cobalt and iron.[2]

During food storage, the nonenzymatic decomposition of lipid hydroperoxides which causes off-rancid-flavor could have greater significance than decomposition by enzymes.[3] Enzyme activity is usually negligible, but the nonenzymatic lipid oxidation activity of hemoprotein increases with heat treatment.[2,3] The thermal increase of the nonenzymatic lipid oxidation activity occurred mainly at pH 5.5 to 6.5 due to heme migration to form the aggregated fractions. Therefore, nonenzymatic oxidation of unsaturated fatty acids causes off-flavor in pickle products, since pasteurization of products inactivates LOX activity which is heat labile.

To control development of off-flavor during storage and to generate flavor of pickle products, dry and oil emersion which also play a role as antioxidants have been used in pickle products. Most common spices were antioxidative, except ginger which was found to be slightly prooxidative.[1] However, ginger was antioxidative in lard bakery products and meat products. It was reported that most spices have shown varying antioxidative effects on lard in darkness, particularly allspice and cloves. Some of these spices acted more strongly with BHA. In addition, the extract of dry red pepper seed was found to have an inhibitory action on pure soybean LOX.[4,5]

Antioxidants and oxygen scavengers inhibit activity under certain circumstances. The most powerful antioxidants which inhibit the oxidation of substrates by LOX are α-tocopherol, hydroquinone, propyl gallate, butylate hydroxy toluene (BHT) and butylated hydroxy anisole (BHA).

However, the capacity of ingredients for antioxidation or peroxidation actions in pickle products is unknown. Therefore, investigations were carried out to examine the effects of pickle product ingredients on lipoxygenases and methamolglobin catalyzed oxidation of linolenic acid. Mixtures of components in commercial products and individual ingredients were used for these observations. Also, LOX, POD, POD and CAT activities in dry spices used in pickle products were determined.

Keywords : lipoxygenase, peroxidase, catalase, methemoglobin
*Corresponding Address

Materials and Methods

Source of pickles and ingredients

Samples of 8 different commercial pickle products were obtained from several pickling companies. The commercial products consisted of processed dill pickles (Nally), hamburger dill slices, relish (Cates), processed sweet pickles, fresh pack dills (Paramount), kosher spears (B & G), fresh pack chips (Vlasic) and peppers (Monarch). The first four products were processed pickles manufactured from fermented cucumbers, and the later four products were pasteurized fresh pack products. Samples of hamburger dill slices and sweet pickles were obtained from ten different pickling companies (refer Table 2 and 4).

Dry spices such as garlic, mustard seed, black pepper, allspice, red pepper, ginger, cinnamon, fennel and clove were obtained from Vlasic Food, Inc. (West Bloomfield, MI, USA).

Lipoxygenase assay

General extractions and assays involving LOX were conducted as described previously.[1)]

Effect of pickle product brine

Pickle brine (0.2 m*l*) was added to 2.8 m*l* of linolenic acids substrate solution, and O_2 consumption was monitored for 5 min at 30℃. Then enzyme lipoxygenase extract (0.1 m*l*) or methemoglobin (MHG, 0.1 m*l* containing 0.1 mg MHG as a nonenzymatic oxidant) was added to the above solution and O_2 consumption was monitored to measure linolenic acid oxidation. Deionized water was added instead of brine to serve as the control treatment.

A solution containing 2.5% NaCl in 0.1 M acetate at pH 3.5 was prepared to serve as brine treatment without the influence of other ingredients. This solution would be typical of salt and acid levels in commercial pickle brine but without flavoring or color ingredients.

A study was designed to determine the effect of brine concentration on oxidation by LOX or MHG. In this study, 0, 0.1, 0.2, 0.3, 0.4 or 0.6 m*l* of brine from Vlasic's dill slices was added to the assay solution. Oxidation induced by the brine alone and by LOX or MHG was measured. In addition, the brine samples (pH 3.5) were adjusted to pH 5.5 and incubated for 2 days at 40℃ to study the effect of incubation on subsequent antioxidant activity.

Effect of individual ingredients

This study was conducted to determine if certain ingredients were capable of being oxidized by LOX or MHG. One m*l* of garlic emulsion, dill oil emulsion, onion concentrate, polysorbate 80, oil cassia or oleoresin turmeric acid was added to 19 m*l* of assay buffer (0.05 M MES containing 16 mM $CaCl_2$, pH 5.5). The above solution (2.9 m*l*) was used for observing oxidation by LOX (0.1 m*l*) or MHG (0.1 mg) in the absence of linolenic acid. The oxidation of ingredients was monitored by the amount of O_2 consumption as used for measuring LOX or MHG activity.

To determine the effect of ingredients on LOX or MHG catalyzed oxidation of linolenic acid, 0.1 m*l* of stock solution (1 : 19 dilution) of each ingredient was added to the 11 m*l* of LOX assay solution and monitored for O_2 consumption after the addition of 0.1 m*l* of LOX extract or 0.1 mg of MHG to the above solution.

Another study was conducted to examine the effect of polysorbate 80 and turmeric acid concentration on linolenic acid oxidation by LOX and MHG. One m*l* of stock solution (1 : 19 dilution) of polysorbate 80 or turmeric acid was diluted with 9 m*l* of deionized water. Then 0, 0.1, 0.5 or 1.0 m*l* of the diluted polysorbate 80 or turmeric acid was added to 11 m*l* of the LOX assay solution. LOX extract (0.1 m*l*) or MHG (0.1 mg) was added to 2.9 m*l* of the above solutions and assayed for oxygen consumption as previously described.[1)]

Oxidases in dry spices

Garlic, mustard seed, black pepper and allspice from spice mixtures used for manufacturing both zesty and deli dill pickles were used. The spices used for deli dills, a refrigerated product, had been disinfected with ethylene oxide, while the spiced used for zesty pickles, a pasteurized product had not been disinfected. Also red pepper, ginger, cinnamon, fennel and clove were used. Dry spice (1.0 g) was homogenized with a Tissumizer for 20 sec in 10 m*l* of citrate-phosphate buffer, pH 6.5, (a mixture of 0.05 M citric acid and 0.1 M Na_2HPO_4) which contained 4 mM DTT and 0.2% triton X-100.

The homogenate was filtered through miracloth and centrifuged at 10,000×g for 10 min. The supernatant was used as the enzyme source. Dry spice extract (0.1 m*l*) was assayed for LOX, POD or CAT activity.

CAT activity was determined by the following assay procedures. Hydrogen peroxide (0.6 m*l* of 30% H_2O_2) was added to 99.4 m*l* of citrate phosphate buffer (a mixture of 0.02 M citric acid and 0.04 M Na_2HPO_4), pH 7.0. The assay solution was protected against exposure to light and equilibrated at 25℃. The assay was conducted by adding and mixing rapidly 0.1 m*l* of the enzyme extract (same extract as used for LOX) to 2.9 m*l* of the assay solution in a cuvette. The linear rate of hydrogen peroxide degradation was calculated.[7)] CAT activity was expressed as the decrease in absorbancy (240 nm)/min/g dry wt.

POD activity was measured by the following assay

procedures. A stock H_2O_2 solution was prepared by adding 1 ml of 30% H_2O_2 to 99 m*l* of deionized water. A protion (1 m*l*) of the stock H_2O_2 was added to 99 m*l* of 0.04 M citrate phosphate buffer, pH 5.0 followed by 0.83 m*l* of 1% dianisidine in methanol to serve as a hydrogen donor. The substrate mixture was made fresh daily and protected against exposure to light and equilibrated to 25℃. The assay was conducted by adding 0.1 m*l* of the enzyme extract (same extract as used for LOX) to 2.9 m*l* of the substrate mixture in a cuvette followed by rapid mixing. POD activity was determined spectrophotometrically at 460 nm from the linear period and expressed as the increase in absorbancy (460 nm)/min/g dry wt.[8] All observations in this study were conducted in quintuplicate.

Results

Effect of pickle product brine

There was oxidation of linolenic acid by brine (without LOX or MHG) from some commercial pickle products, such as spears, fresh pack chips, processed sweet pickles and peppers (Table 1). These products apparently contained oxidants.

Brine without flavor or color reduced oxidation of linolenic acid by LOX or MHG. With added brine from nine commercial pickle products, there was varying levels of inhibition of LOX or MHG catalyzed oxidation of linolenic acid. Also, some brines were observed to stimulate oxidation of linolenic acid by MHG. In particular, hamburger dill slices and processed sweet pickles inhibited LOX catalyzed oxidation of linolenic acid by about 81 and 71%, respectively. Brine of relish and pepper reduced linolenic acid oxidation by MHG was inhibited about 60% with brine from both processed sweet pickles and relish. Oxidation by MHG was slightly stimulated by brine from fresh dills and spears, 4 and 9.3% respectively. Brine from fresh pack dills, spears and fresh pack chips reduced LOX catalyzed oxidation by about 10 to 12%.

The brine of hamburger dill slices manufactured by ten pickling companies tended to inhibit oxidation by LOX more than 30% (Table 2). Hamburger dill slice manufactured by Vlasic exhibited some linolenic acid oxidation by the brine itself. Especially, oxidation by LOX was reduced more than 84% by adding brine of hamburger dill slices manufactured from Paramount, Western Maid, Best Maid and Mt. Olive. Oxidation by MHG was reduced more than 32% with brine manufactured from Nally, Paramount and Sechler's, and its was stimulated by 1.6% and 6.3% with brine from Roddenbery's and Best Maid, respectively.

The oxidation of linolenic acid by brine alone from Vlasic's hamburger dill slices increased with increasing amounts of brine (Table 3). With increasing amount of brine added, oxidation by LOX was decreased (89.4% inhibition with 0.6 m*l* of brine), but oxidation by MHG was almost unaffected. After incubating brine for 2 days at 40℃, the brine lost its inhibitory influence on oxidation by LOX.

Brine of sweet pickles manufactured from ten pickling companies reduced linolenic acid oxidation by LOX and MHG more than 40% and 50% (Table 4). More than 80% of the oxidation by LOX was inhibited with brine of sweet pickles manufactured from Paramount, Oxford and Cates. The inhibition of oxidation by MHG was similar (70~80%) with brine from the other eight pickling companies.

Effect of individual ingredients

Dill oil emulsion, garlic emulsion, onion concentrate and oil cassia apparently contained fatty acid substrates

Table 1. Effect of brine from commercial pickle products on linolenic acid oxidation by lipoxygenase or methemoglobin.

Product (Company)	Oxidation μg O_2 consumed/min*			% of Control	
	Alone	LOX	MHG	LOX	MHG
Control	ND**	12.6	7.5	100.0	100.0
Brine***	ND	10.0	6.3	83.3	84.0
Dill Pickles (Nally)	ND	11.9	5.3	94.4	84.0
Hamburger Dill Slices (Western)	ND	2.4	7.3	19.0	97.3
Relish (Cates)	ND	7.6	2.9	69.3	38.7
Processed Sweet Pickles (Cates)	0.6	3.6	3.2	28.6	42.7
Fresh Pack Dill (Paramount)	ND	11.2	7.8	88.9	104.0
Kosher Spears (B & G)	0.1	11.7	8.2	92.9	109.3
Fresh Pack Chip (Vlasic)	0.1	11.4	7.7	90.5	102.7
Peppers (Monarch)	1.7	6.2	7.6	49.2	101.3

*μg O_2 consumed/min was used to determine oxidation of linolenic acid mediated by brine alone (0.2 m*l*) and by combination of brine and lipoxygenase (LOX) extract (0.1 m*l*) or methemoglobin (MHG, 0.1 mg) in the assay solution(3.1 ml). **ND=not detected. ***Brine without flavoring or color (laboratory preparation).

Table 2. Inhibition of lipoxygenase and methemoglobin catalyzed oxidation of linolenic acid by brine from commercial hamburger dill slices.

Company	Oxidation				
	μg O_2 consumed/min*			% of Control	
	Alone	LOX	MHG	LOX	MHG
Control		12.8	6.4	100.0	100.0
Best Maid	ND**	0.8	6.8	6.3	106.3
Cates	ND	9.3	5.8	72.7	90.6
Claussen	ND	8.5	5.8	66.4	90.6
Mt. Olive	ND	1.4	5.9	10.9	92.2
Nally	ND	8.2	3.1	64.1	48.4
Paramount	ND	2.0	4.3	15.6	67.2
Roddenbery's	ND	7.7	6.5	60.2	101.6
Sechler's	ND	4.9	4.3	38.3	67.2
Valsic	0.1	7.9	5.8	61.7	90.6
Western Maid	ND	0.8	5.7	6.6	89.1

*μg O_2 consumed by 0.2 ml of brine alone or in combination with 0.1 ml of lipoxygenase (LOX) extract or 0.1 mg of methemoglobin (MHG) in the assay solution (3.1 ml). **ND=not detected.

Table 3. Inhibition of lipoxygenase and methemoglobin catalyzed oxidation of linolenic acid by brine from Vlasic's hamburger dill slices.

Brine (ml/2.8 ml)	Oxidation μg O_2 consumed/min*				
	Initial			Incubated**	
	Alone	LOX	MHG	LOX	MHG
ND***	ND	9.4	5.9	9.4	5.9
0.2	0.1	8.1	6.2	9.8	5.7
0.3	0.2	3.0	—	—	—
0.4	0.2	1.6	6.1	9.4	6.0
0.6	0.4	1.0	6.4	9.5	5.7

*μg O_2 consumed by 0.2, 0.3, 0.4, or 0.6 ml of brine alone or in combination with 0.1 ml of lipoxygenase (LOX) extract or 0.1 mg of methemoglobin (MHG) in the assay solution. **Brine was adjusted to pH 5.5 and incubated for 2 days at 40°C. ***ND=not detected.

for LOX and MHG, since oxidation was observed in the absence of linolenic acid (Table 5). When compared to the control containing linolenic acid, garlic emulsion had no effect on oxidation by LOX or MHG. However, other ingredients such as dill oil emulsion, onion concentrate, polysorbate 80, oil cassia and oleoresin of turmeric acid inhibited oxidation of linolenic acid by LOX and MHG. Dill oil emulsion reduced oxidation by LOX and MHG by 86% and 71%, respectively.

Oxidation by MHG was reduced by more than 80% by onion concentrate and oleoresin of turmeric acid. Oil cassia resulted in 44.9% and 6.5% inhibition of oxidation by LOX and MHG.

Polysorbate 80 decreased LOX or MHG catalyzed oxidation of linolenic acid with increasing concentration

Table 4. Inhibition of lipoxygenase and methemoglobin catalyzed oxidation of linolenic acid by brine from commercial sweet pickles.

Company	Oxidation				
	μg O_2 consumed/min*			% of Control	
	Alone	LOX	MHG	LOX	MHG
Control		10.5	5.6	100.0	100.0
Brine**		9.9	5.8	94.3	103.6
Best Maid	ND***	2.8	1.6	26.7	28.6
Cates	ND	1.6	1.3	15.2	23.2
Mt. Olive	ND	6.2	1.5	60.8	26.8
Nally	ND	4.7	1.6	44.8	28.6
Oxford	ND	1.2	2.7	11.4	48.2
Paramount	0.1	1.7	2.2	16.2	39.3
Roddenbery's	ND	5.9	1.8	56.2	32.1
Sechler's	ND	3.4	1.5	32.4	26.8
Valsic	ND	3.8	1.4	36.2	25.0
Western Maid	ND	4.4	1.1	41.9	19.6

*μg O_2 consumed by 0.2 ml of brine alone or in combination with 0.1 ml of lipoxygenase (LOX) extract or 0.1 mg of methemoglobin (MHG) in the assay solution (3.1 ml). **Brine without flavoring or color. ***ND=not detected.

Table 5. Oxidation of pickle product ingredients by cucumber lipoxygenase and methemoglobin, and the influence of ingredients on linolenic acid oxidation.

	Oxidation*			
	μg O_2 consumed/min			
	Without Linolenic Acid		With Linolenic Acid	
Components**	LOX	MHG	LOX	MHG
Control	ND***	ND	13.6	4.6
Dill Oil Emulsion	0.3	2.0	1.9	1.3
Garlic Emulsion	0.4	0.4	13.1	4.7
Oil Cassia	0.3	1.6	7.5	4.3
Oleoresin Turmeric	ND	ND	3.8	0.4
Onion Concentration	0.3	0.2	6.8	0.9
Polysorbate 80	ND	ND	6.3	3.8

*μg O_2 consumed by 0.1 ml of lipoxygenase (LOX) extract or 0.1 mg methemoglobin (MHG). **Assay contained 0 (control) or 0.45 μl of each component/ml of the assay solution. Oxidation was observed by adding 0.1 ml of lipoxygenase extract or 0.1 mg of methemoglobin to the assay solution (3.0 ml). ***ND=not detected.

(Table 6). No effect of 46 μg of polysorbate 80 per ml of the assay solution was observed. With adding 460 μg of polysorbate 80 per ml of the assay solution, 60% and 17.5% of the oxidation by LOX and MHG was inhibited, respectively. Oxidation of linolenic acid by the LOX and MHG also decreased with increasing concentration of turmeric acid. With 3.2 μg of the turmeric acid per ml of the assay solution, 49.7% and 93% of LOX and MHG catalyzed oxidation of linolenic acid was inhibited, respectively.

Table 6. Inhibition of lipoxygenase and methemoglobin catalyzed oxidation of linolenic acid by polysorbate 80 and turmeric acid.

	Oxidation*	
	μg O_2 consumed/min	
Amount (μg/ml)	LOX	MHG
Control	16.5	5.7
Polysorbate 80		
46.0	16.0	6.0
230.0	14.7	4.7
460.0	6.6	4.7
Turmeric Acid		
3.2	12.4	2.1
16.0	10.2	0.4
32.0	8.3	0.4

*μg O_2 consumed/min/0.1 ml of lipoxygenase (LOX) extractor 0.1 mg methemoglobin (MHG) in assay solution (3.0 ml).

Table 7. Lipoxygenase (LOX), peroxidase (POD) and catalase (CAT) activity in dry spices used in pickle products.

Dry Spice	Source	LOX*	POD**	CAT***
Allspice	Zesty	ND****	ND	0.6
Allspice	Delli Dill	ND	ND	ND
Black Pepper	Zesty	ND	ND	0.2
Black Pepper	Delli Dill	ND	ND	ND
Cinnamon	Delli Dill	ND	ND	ND
Clove	Delli Dill	ND	ND	ND
Fennel	Delli Dill	ND	ND	ND
Garlic	Delli Dill	ND	ND	0.3
Garlic	Zesty	6.8	ND	0.5
Ginger	Delli Dill	ND	ND	ND
Mustard Seed	Delli Dill	6.8	8.5	ND
Mustard Seed	Zesty	ND	9.1	ND
Red Pepper	Zesty	40.7	ND	0.5

*Activity is expressed as μg O_2 consumed/min/g dry wt. **Activity is expressed as absorbancy (460 nm)/min/g dry wt. ***Activity is expressed as absorbancy (240 nm)/min/g dry wt. ****ND=not detected

Oxidases in dry spices

LOX activity was present in garlic (zesty), mustard seed (deli dill) and red pepper (zesty) (Table 7). It was especially high in dry red pepper. POD activity was observed in mustard seed from both deli dill and zesty sources, but no activity was observed in the other spices. CAT activity was found to be present in garlic (both deli and zesty), black pepper (zesty), allspice (zesty) and red pepper.

Discussion

Brine from processed pickle products tended to contain more potent inhibitors of oxidation than was observed in the brine of fresh pack products. This may be partially accounted for by the different flavor ingredients used in the products. However, it is suspected that the major difference is caused by the presence of aluminum in the processed pickle products which was shown in previously[1] to be a potent inhibitor of LOX mediated oxidation. Alum is commonly used in the manufacture of processed pickles products but it is not used for fresh pack products. Obviously, the degree of inhibition was different among the various commercial pickle products and from the different sources which reflects variation in formulations and process methods.

Processed products require fermentation of cucumbers followed by storage in salt brines (brine curing) and then processing into finished products. The processed pickle products may or may not be pasteurized at 65 to 75℃ while fresh pack products are all pasteurized. The fresh pack pickles were prepared directly from fresh cucumbers that are pasteurized. Each processor used a different formulation of ingredients for their products. Pederson *et al.*, reported that linoleic and linolenic acid increased during the fermentation of dill pickles.[9] Also linoleic and linolenic acid levels in fresh pack pickles increased during 4 to 8 months storage. This may have been due to deterioration occurring in the spice oils that were used as the ingredients.[10] According to these reports, even more unsaturated fatty acid substrates were available for potential oxidation by LOX or other oxidants during the fermentation or storage of fresh pack pickles. The fact these components increase suggest that oxidants are limited or antioxidant are present. From this experimental observations, it was evident that some of these were more effective against oxidation by LOX while others were more effective against oxidation by MHG.

Since LOX is unstable at 55℃ or higher temperature,[1] then pasteurization would destroy LOX activity. Furthermore, LOX is unstable in brine solution and it has been found to be rapidly inactivated during fermentation.[11] Based on the instability of LOX, it is unlikely that it would participate in oxidation reactions after bring or processing.

Since screening ingredients present in commercial pickle products indicated antioxidation responses, further studies on pickle products ingredients were conducted. There were strong inhibitions of linolenic acid oxidation by LOX or MHG from the specific pickle product ingredients with the exception of garlic emulsion which had no effect. With 460 μg of polysorbate 80 per ml (0.046%) of the assay solution, LOX and MHG mediated oxidation was reduced. This concentration is similar to concentration of polysorbate 80 used in commercial pickle products (about 0.05%). Accordingly, polysorbate 80 as used in commercial pickle products should affect LOX or

MHG catalyzed oxidation of polyunsaturated fatty acids. Since dill oil emulsion and turmeric acid containing 2.5% NaCl at pH 3.5 without flavoring or color ingredients only slightly affected oxidation, it can be concluded that the degree of the inhibition of the oxidation by LOX or MHG was dependent on the amounts and types of ingredients present.

Some spices used for deli dill and zesty products had oxidase enzyme activities. Large amounts of LOX were present in red peppers used in pasteurized pickles, but not in red pepper used in pasteurized pickles, and refrigerated nonpasteurized products.

Apparent by the ethylene oxide treatment used on red pepper for the refrigerated (delli) product effectively inactivated LOX. A similar difference was observed in the activity of LOX in garlic between the two sources. It has been reported that red pepper seed contained LOX,[5] however this experimental observations were on the dried pulp from red bell peppers. Presently it is unknown if the presence of oxidase enzymes in the spices contributes to oxidation reactions in the products.

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상업적인 pickle product와 ingredient의 oxidant와 antioxidant로서의 역할

장미진[2], 조일영[3], 주현규[1*] ([1*]건국대학교 농과대학 농화학과, [2]퍼킨엘머 코리아, [3]케이제이 엔지니어링)

초록 : Pickle성분이 linolenic acid의 산화효소인 lipoxygenase와 methemoglobin (nonenzymatic oxidant)에 미치는 효과를 조사하였다. 그외, 피클 성분중 건조 양념내늬 lipoxygenase, peroxidase와 catalase 활성도 조사하였다. 시중에 판매중인 일부 pickle brine은 lipoxygenase와 methemoglobin에 의한 linolenic acid의 산화를 억제하였다. Dill oil emulsion, 양파 농축액 (onion concentrate), oil cassia, polysorbate 80, turmeric acid와 같은 피클 성분들은 lipoxygenase와 methemoglobin에 의한 산화를 감소시켰다. Lipoxygenase의 활성은 garlic, mustard seed, red pepper에서 발견되었다. Peroxidase의 활성은 mustard seed에서만 존재하였으며, garlic, black pepper, allspice와 red pepper에서는 catalase의 활성이 있었다.

*연락저자