

Analysis of the Physicochemical Properties and Antioxidative Activity of Napa Cabbage Pickle

Hae-Reon Son¹, Sun-Kyung Oh¹, Sang-Ok Bae² and Myeong-Rak Choi^{1*}

¹Department of Biomedical and Electronic Engineering, Chonnam National University, Yeosu 550-749, Korea

²Department of Culinary Art, Chodang University, Muan 534-701, Korea

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The principal objective of this fundamental research was to analyze the physicochemical properties and the antioxidative activity of Napa cabbage pickle (NCP) for development of low-salt pickles. NCP-1 was a smaller than NCP at amount soy sauce (10%). The pH of NCP and NCP-1 were 4.51 ± 0.15 , 4.85 ± 0.08 immediately after preparation. The pH of NCP and NCP-1 was reduced to 4.08 ± 0.05 and 4.31 ± 0.12 over time during 60 days of storage. The acidity of the NCP and NCP-1 immediately after preparation were 0.51% and 0.38% and increased to 0.67% and 0.56% after 60 days of storage. The salinity for the NCP ranged from 1.71-2.22% and NCP-1 ranged from 1.18 - 1.63%. The L value, which indicates the lightness, was the highest at day 0 and the lowest at 60 day. The tensile strength value of NCP was 10.9 ± 0.05 kgf/cm² and NCP-1 in 11.84 ± 0.11 kgf/cm² at day 0 and then significantly decreased with time in storage. The cutting force of NCP was 1004 ± 7.12 gf/cm² and NCP-1 in 845 ± 5.27 gf/cm² at day 0, which increased over time in storage. The overall acceptability of NCP was the highest at day 30, but the overall acceptability of NCP-1 was the highest at day 45. NCP-1 extracts at day 60 showed the highest antioxidant activity of 66.04%, whereas the NCP extract at day 0 showed the lowest antioxidant activity of 45.41%. These results showed that depending on the content of the seasoning pickle difference in the antioxidant activity. Thus, the best pickled Napa cabbage is determined by a smaller amount soy sauce in NCP-1, and the results could provide a basis for improving the availability and quality of Napa cabbage.

Key words : Antioxidative activity, *Brassica rapa*, napa cabbage, physicochemical property, pickle

Introduction

Sustained economic growth and development of medicine has increased age and human life expectancy. Since food supplies energy and nutrients, there is increasing interest in the functional foods to inhibit diseases associated with aging by prevention and recovery. In order to obtain health-promoting effects from a functional food, looking for excellent food material for developing functional food applications will continue to be made necessary [9]. Recent research on the physiological functionality of the Brassicaceae family has increased, in particular, this plant family's significant anti-cancer and antimicrobial effects have been recognized [18].

Lapa cabbage (*Brassica campestris* ssp. *pekinensis*) is a member of the Brassicaceae family. Historically, a sense-mediated adaptive mechanism to avoid consumption of poisons has selected for low-glucosinolate content in vegetables. Recent sensory trials have shown typical rocket salad flavor and pungency are perceived as positive sensory traits, while bitter notes, characterized by high glucosinolate content (sin-albin /gluconapin-herbaceous; sinigrin pungency), were much less acceptable. Glucosinolate concentrations in plants are around 1% dry weight in some Brassica vegetables, although these concentrations are highly variable. Glucosinolates are very stable water-soluble precursors of isothiocyanates and some fresh plants have been shown to contain glucosinolate almost exclusively and no isothiocyanates. Pickles that are prepared in many western countries use various vegetables depending on the season and region. Korean traditional jangachi production methods are similar, and mainly cucumbers, onions, tomatoes, green peppers, and cabbage are used [8]. Pickles are usually separated into salty pickles and sweet pickles, which use mainly vinegar and sugar, respectively. Salting during the manufacturing proc-

*Corresponding author

Tel : +82-61-659-7303, Fax : +82-61-659-7309

E-mail : mrchoe@chonnam.ac.kr

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ess affects qualities such as taste, flavor, and texture. These qualities are highly dependent on the salt concentration, storage temperature, storage time, and brine used. A food is pickled after saltwater cause the dehydration of the material, and the separated plasma is made of a component of the penetrated sauce [17]. So far, research has been performed on jangachi prepared with pickled turnip, cauliflower, ginseng, bellflower, deodeok, lotus root, and mushroom [16]. Though reports have been made about pickling a variety of agricultural products, research on the pickle using napa cabbage has not been conducted. This study examines the using potential of napa cabbage as a low-salt pickle product, in hopes of contributing to the diversification of food with napa cabbage to generate pickle-oriented revenues.

Materials and Methods

Materials

Napa cabbage was produced at Yeosu-si Dolsan-eup, Korea and harvested in October 2015. Napa cabbage pickle (NCP) samples were prepared with napa cabbage (65%) (v/v), soy (15%), apple vinegar (7%), water (7%), garlic (1%) and condiment sauce (5%), and napa cabbage pickle(NCP-1) samples were prepared with napa cabbage (65%), soy sauce (10%), apple vinegar (7%), water (12%), garlic (1%) and condiment sauce(5%), and stored at 4°C during 60 days after preparation.

Preparation of NCP and NCP-1 extracts

NCP and NCP-1 were ground to a particle size of 5-10 mm using a high speed mixer (Blender, Hanil, HNF-340, Seoul, Korea). NCP and NCP-1 samples (10 g) were placed in a round flask in a Soxhlet extractor with 80%(v/v) ethanol in a round flask extracted at 60°C for 24 hr. After cooling at room temperature (RT) of 25°C, the extracts were filtered with a Whatman No. 2 filter. The filtrate was evaporated by an evaporator (EYELA, Tokyo, Japan) at 60°C, and then the extracts were transferred to a freeze-drying tube and lyophilized. The dried extracts were weighed to get ethanol extract (10.98%). After each extracts stored at 0°C prior to analysis. The absorbance of extracts (300 µl) was analyzed in a 96-well plate (SPL Lifescience Co., Pocheon, Korea) using a Microplate Reader (UVM340, Biochrom, Cambridge, UK).

pH and titratable acidity

NCP and NCP-1 were ground to a particle size of 5-10 mm using a high speed mixer, and then, they were strained through a sterile gauze. The pH of each sample was measured based on the mean value of 3measurements from 10 ml of the undiluted liquid portion of NCP and NCP-1 using a pH meter (Orion 520A, Boston, USA). Each sample was diluted 2×by mixing 10 ml of sample with 10 ml of distilled water, followed by measurement of the quantity of a 0.1 N NaOH solution used to titrate the mixture to a pH of 8.3 for measurement of titratable acidity.

Salinity

NCP and NCP-1 were ground to a particle size of 5-10 mm using a high speed mixer, and then they were strained through a sterile gauze. The salinity of each sample was measured based on the mean value of 3measurements from 35 ml of the undiluted liquid portion of NCP and NCP-1 using a salimeter (TM-30D, Tokyo, Japan).

Color measurement

Color measurement was performed using a Color Reader (JC801S, Color Techno System Co., Japan) with an 8 mm diameter measuring area. The instrument was calibrated with a standard white plate. Measured L, a, and b values were used as indicators of lightness, greenness, and yellowness, respectively.

Hardness analysis

NCP and NCP-1 samples measuring 4×1 cm were cut from the central part of the NCP and NCP-1 at each stage of storage. The hardness of the NCP and NCP-1 was measured using a rheometer (CR-500DX, Osaka, Japan). A 10.00 kg load cell was installed at the rheometer cross-head and chart speeds were 5 and 1.0 mm/s. Hardness analysis is a type of compression test that is used to determine the hardness of a sample. Moreover, compression elasticity test jig and cutting force test jig were used to determine the tensile strength and cutting force of the materials, respectively. Samples were stored at room temperature for 30 min before analysis.

Sensory evaluation

For the sensory evaluation, stored NCP and NCP-1 were periodically removed from storage (0, 7, 15, 30, 45 and 60 days). The sensory evaluation was performed by 10-trained

panelists, who were graduate students at the Chonnam National University, that were familiar with NCP and NCP-1 consumption. The panelists evaluated the NCP and NCP-1 randomly. The appearance, color, flavor, texture and overall acceptability were evaluated using a 5-point scale(1= very weak, 3=moderate, 5=very strong).

DPPH radical scavenging activity

The electron donation ability of the obtained methanol extracts was measured by bleaching a purple-colored solution of DPPH radicals based on the method of Blois [14]. Briefly, NCP and NCP-1 extracts were dissolved in ethanol (1 mg/ml) and were added to a 1 ml DPPH radical solution in methanol (final concentration of DPPH 0.2 mM). The solution was incubated for 30 min in the dark at RT, and the mixture absorbance was measured at 517 nm. The control absorbance was measured 0.02% BHT (v/v). The DPPH radical scavenging activity was calculated according to the following equation:

$$\text{DPPH scavenging activity (\%)} = (1 - \text{sample absorbance} / \text{control absorbance}) \times 100$$

Statistical analysis

All tests and analyses were repeated at least three times. The results were expressed as mean ± standard deviation (SD). One way analysis of variance (ANOVA) and Duncan’s test were used for multiple comparisons with SPSS version 21.0 (SPSS Institute, Chicago, IL, USA). The values were considered as significantly different if the P value was less than 0.05.

Results and Discussion

pH and titratable acidity

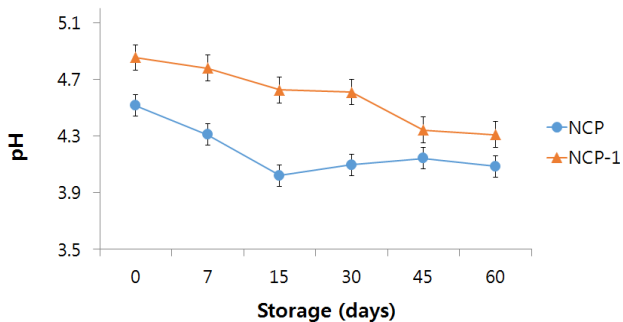


Fig. 1. Decreasing the pH at napa cabbage pickle and napa cabbage pickle-1 during storage. (●: Napa cabbage pickle, ▲: Napa cabbage pickle-1)

The pH changes in NCP and NCP-1 over time are shown in Fig. 1 The pH of NCP and NCP-1 were 4.51±0.15, 4.85±0.08 immediately after preparation (p<0.05). The pH of NCP and NCP-1 was reduced to 4.08±0.05, 4.31±0.12 over time during 60 days of storage. Oh *et al* [10] showed that the longer the storage time, the lower the pH; the pH of pickled turnips was reduced to 3.0-3.2 after day 35 days storage at 20°C. Flemig *et al* [3] showed the pH of cucumber pickles ranged from 3.1-3.2 after 30 days of storage at 25°C. These reported pH values are lower than the results of the present study, probably due to different seasoning composition and storage conditions. However, our leaf mustard pickles differed from turnip, pickles due to differences epidermal thickness and the moisture content of the main component [16]. The pH changes over time in our study were similar to the results found for turnip pickles; the acidity increased over time (Fig. 2). The acidity of the NCP and NCP-1 immediately after preparation were 0.51%, 0.38% and increased to 0.67% and 0.56% after 60 days of storage (p<0.05). Park *et al* [12] showed lotus root pickle acidity was 1.50% immediately after preparation and increased to 1.88% after 30 days of storage; these results are similar our study. Increased acidity during NCP and NCP-1, storage it is mainly due to the penetration of vinegar into the solid material, resulting in small amounts of acid produced by fermentation.

Salinity

Fig. 3 shows that salinity of the NCP ranged from 1.71-2.22% and NCP-1 ranged from 1.18-1.63%(p<0.05). Park *et al* [11] reported that salinity of pickled lotus root was not changed extract substantially during fermentation, and also showed similar results to this NCP and NCP-1 study. Han *et al* [29] found salinity greater than 3.0% after 30 days of storage of salt-pickled aralia. The average salinity of fer-

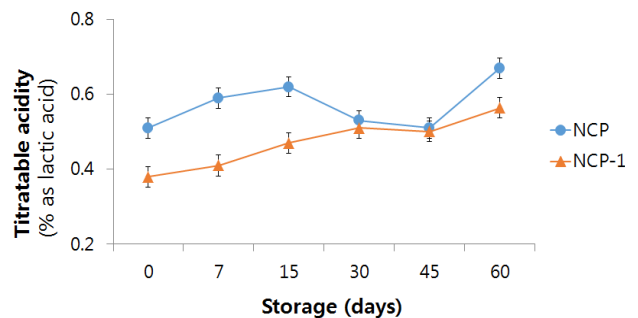


Fig. 2. Increasing titratable acidity at napa cabbage pickle and napa cabbage pickle-1 during storage. (●: Napa cabbage pickle, ▲: Napa cabbage pickle-1)

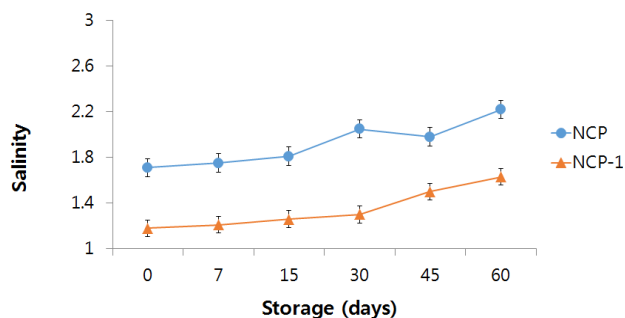


Fig. 3. Indicating the value of less than 3% in salinity changes at napa cabbage pickle and napa cabbage pickle-1 during storage. (●: Napa cabbage pickle, ▲: Napa cabbage pickle-1)

mented vegetables like the commercial pickle is 3.56-6.75%, depending on the type [6]. However, since the NCP and NCP-1 in this study contained less than 3% salinity after 60 days of storage, it should be considered a relatively low-salt pickle.

Color measurement

The results of the color change of NCP and NCP-1 during storage are shown in Table 1. The L value, which indicates the lightness, was the highest at day 0 and the lowest at 60 days ($p < 0.05$). Hence, the L value result shows that lightness significantly decreased with longer storage period. The L value of lotus root pickle also decreased overtime [8], low-salt yacon added leaf mustard pickle and a low-salt yacon with pepper pickle with yacon pickl showed decreased lightness after 50 days of storage, the results of this are similar to that reported before. The a value of our NCP was increased from -1.41 ± 0.18 to -2.29 ± 0.01 and NCP-1 was increased from -1.3 ± 0.03 to -1.84 ± 0.01 . In the result of Park *et al* [13], the inherent green color of salted cucumbers turned red and the a value increased over time in storage. This was similar to our results in that the a value was increased, but

NCP and NCP-1 stayed green, as seen by the naked eye, and did not changed red. The b the value of the NCP increased from 11.54 ± 0.32 to 13.12 ± 0.11 and the NCP increased from 9.36 ± 0.09 to 12.4 ± 0.08 . The longer storage was time increased b values in low-salt yacon pickle added leaf mustard pickle with yacon, turnip pickles [15], and lotus root pickles [8]. Therefore, browning phenomenon progresses over pickling time that can be seen by the changes in L, a and b values.

Texture analysis

The hardness values of the NCP and NCP-1 are presented in Table 2. The tensile strength values of NCP was 10.9 ± 0.05 kgf/cm² at day 0 and then significantly decreased with time in storage. Also, the tensile strength values of NCP-1 was 11.84 ± 0.11 kgf/cm² at day 0 and then significantly decreased with time in storage. The lowest hardness level (9.63 ± 0.03 kgf/cm²) was recorded after 90 days of storage. Lee *at al* [2] also reported decreased onion hardness after higher blanching temperatures. Cutting force of NCP was 1004 ± 7.12 gf/cm² and NCP-1 was 845 ± 5.27 gf/cm² at day 0, which increased over time in storage. After that, cutting force increased to 1574 ± 11.95 and 1324 ± 7.93 gf/cm² ($p < 0.05$), respectively. Thus, after the blanching heat treatment process, the change in volume, density, weight, and cell structure of plant tissues are related to differences in texture [1].

Sensory evaluation

The results of NCP and NCP-1 sensory evaluation are shown in Table 3, 4. Over time, color was increasingly stronger, and texture was gradually decreased with the longer times in storage. Appearance showed similar results as a whole. The overall acceptability of NCP was the highest at day 30. But the overall acceptability of NCP-1 was the highest at day 45. At 10% salinity or greater, a fetid or soft phe-

Table 1. Changes in the color of napa cabbage pickle and napa cabbage pickle-1 during storage

sample	Color value	Storage (days)					
		0	7	15	30	45	60
NCP	L	$22.62 \pm 0.13^{Ca1)}$	22.93 ± 0.21^{Aa}	22.13 ± 0.17^{Ba}	22.01 ± 0.17^{Fa}	19.31 ± 0.15^{Ea}	18.15 ± 0.08^{Da}
	a	-1.98 ± 0.01^{Cc}	-2.15 ± 0.08^{Ac}	-2.29 ± 0.01^{Bc}	-2.08 ± 0.03^{Fc}	-1.42 ± 0.15^{Ec}	-1.41 ± 0.18^{Dc}
	b	11.54 ± 0.32^{Cb}	11.45 ± 0.32^{Ab}	12.28 ± 0.24^{Bb}	12.98 ± 0.18^{Fb}	13.12 ± 0.11^{Eb}	12.74 ± 0.06^{Db}
NCP-1	L	31.58 ± 0.05^{Ba}	29.88 ± 0.03^{Fa}	28.76 ± 0.05^{Ea}	26.34 ± 0.13^{Aa}	25.3 ± 0.03^{Da}	23.14 ± 0.05^{Ca}
	a	-1.32 ± 0.13^{Bc}	-1.45 ± 0.18^{Fc}	-1.68 ± 0.10^{Ec}	-1.84 ± 0.01^{Ac}	-1.30 ± 0.03^{Dc}	-1.35 ± 0.03^{Cc}
	b	9.36 ± 0.09^{Bb}	10.15 ± 0.10^{Fb}	11.47 ± 0.13^{Eb}	11.95 ± 0.21^{Ab}	12.05 ± 0.04^{Db}	12.40 ± 0.08^{Cb}

¹⁾All values are mean \pm SD of the triplicate determination. The mean in row (a-c) and a column (A-F) followed by different superscripts are significantly different at $p < 0.05$ by Duncan's range test.

Table 2. Changes in the tensile strength and cutting force at hardness of napa cabbage pickle and napa cabbage pickle-1 during storage

sample	H ¹⁾	Storage (days)					
		0	7	15	30	45	60
NCP	TS ³⁾	10.90±0.05 ^{Ca2)}	10.82±0.15 ^{Ea}	10.88±0.73 ^{Aa}	10.70±0.82 ^{Fa}	9.51±0.62 ^{Da}	9.16±0.13 ^{Ba}
	CF ⁴⁾	1004±7.12 ^{Cb}	1258±5.47 ^{Eb}	1441±3.16 ^{Ab}	1487±4.66 ^{Fb}	1562±5.92 ^{Db}	1574±11.95 ^{Bb}
NCP-1	TS	11.84±0.11 ^{Ab}	11.65±0.03 ^{Fb}	11.54±0.08 ^{Cb}	10.94±0.34 ^{Bb}	10.85±0.41 ^{Db}	9.72±0.31 ^{Eb}
	CF	845±5.27 ^{Aa}	914±3.48 ^{Fa}	987±1.01 ^{Ca}	1054±5.07 ^{Ba}	1235±5.34 ^{Da}	1324±7.93 ^{Ea}

¹⁾Hardness

²⁾All values are mean ± SD of the triplicate determination. The mean in row (a-b) and a column (A-F) followed by different superscripts are significantly different at *p*<0.05 by Duncan's range test.

³⁾Tensile strength (kgf/cm²) in hardness.

⁴⁾Cutting force (gf/cm²) in hardness.

Table 3. Changes in the sensory evaluation of napa cabbage pickle during storage

Sensory characteristics	Storage (days)					
	0	7	15	30	45	60
Appearance	3.51±0.12 ^{Bb1)}	3.70±0.04 ^{Cb}	3.65±0.07 ^{Ab}	3.70±0.02 ^{Fb}	3.50±0.05 ^{Eb}	3.43±0.04 ^{Db}
Color	2.70±0.05 ^{Bd}	3.25±0.08 ^{Cd}	3.45±0.01 ^{Ad}	3.35±0.05 ^{Fd}	4.05±1.02 ^{Ed}	4.10±0.07 ^{Dd}
Flavor	3.10±0.04 ^{Ba}	3.55±0.01 ^{Ca}	3.60±0.04 ^{Aa}	3.15±0.05 ^{Fa}	3.03±0.03 ^{Ea}	3.12±0.09 ^{Da}
Texture	3.80±0.04 ^{Be}	3.65±0.14 ^{Ce}	3.62±0.05 ^{Ae}	3.55±0.03 ^{Fe}	3.30±1.01 ^{Ee}	3.13±0.02 ^{De}
Overall acceptability	3.70±0.13 ^{Bc}	3.80±0.04 ^{Cc}	4.02±0.02 ^{Ac}	4.11±0.41 ^{Fc}	3.15±0.17 ^{Ec}	2.97±0.01 ^{Dc}

¹⁾All values are mean ± SD of the triplicate determination. The mean in row (a-e) and a column (A-F) followed by different superscripts are significantly different at *p*<0.05 by Duncan's range test.

Table 4. Changes in the sensory evaluation of napa cabbage pickle-1 during storage

Sensory characteristics	Storage (days)					
	0	7	15	30	45	60
Appearance	3.58±0.5 ^{Ba1)}	3.65±0.01 ^{Fa}	3.74±0.05 ^{Aa}	4.04±0.03 ^{Ca}	3.85±0.08 ^{Ea}	3.55±0.04 ^{Da}
Color	3.17±0.05 ^{Bb}	3.40±0.05 ^{Fb}	3.75±0.01 ^{Ab}	3.35±0.05 ^{Cb}	4.12±0.02 ^{Fb}	3.80±0.05 ^{Db}
Flavor	3.14±0.06 ^{Bd}	3.48±0.04 ^{Fd}	3.65±0.05 ^{Ad}	3.31±0.04 ^{Cd}	3.37±0.02 ^{Ed}	3.42±1.01 ^{Dd}
Texture	3.80±0.04 ^{Be}	3.65±0.05 ^{Fe}	3.62±0.02 ^{Aa}	3.55±0.03 ^{Ca}	3.30±1.01 ^{Ea}	3.13±0.02 ^{Ds}
Overall acceptability	3.65±0.11 ^{Bc}	4.01±0.03 ^{Fc}	4.07±0.14 ^{Ac}	4.14±0.04 ^{Cc}	4.25±0.10 ^{Ec}	3.81±0.21 ^{Dc}

¹⁾All values are mean ± SD of the triplicate determination. The mean in row (a-e) and a column (A-F) followed by different superscripts are significantly different at *p*<0.05 by Duncan's range test.

nomenon is seen in pickles due to bacteria, fungi or yeasts [7]. However, since the salinity of our NCP and NCP-1 were less than 3%, they did not appear soft and fetid during storage. Therefore, we consider the low-salt napa cabbage pickling method to be a good method.

Antioxidant activity

The DPPH radical scavenging activity was measured to determine antioxidant activity of NCP and NCP-1 extracts (Table 5), which ranged 87.72±2.03 of control 0.02% BHT (v/v) (data not shown). The antioxidant activities was grad-

ually decreased with the longer times in storage. The antioxidant activities from previous studies measured 43.28% in fresh cabbage, respectively [5]. When compared to this result, the antioxidant activity in NCP and NCP-1 in the present study was higher than was previously found in fresh cabbage, but lower than that observed control. NCP-1 extracts at day 60 showed the highest antioxidant activity of 66.04%, whereas the NCP extract at day 0 showed the lowest antioxidant activity of 45.41%. These results showed that antioxidant activity differ depending on the content of the seasoning pickle. So the best pickled napa cabbage is de-

Table 5. DPPH radical antioxidant activities of of napa cabbage pickle and napa cabbage pickle-1 during storage

sample	Storage (days)					
	0	7	15	30	45	60
NCP	45.41±0.68 ^{Ca1)}	46.38±0.22 ^{Ba}	45.84±0.38 ^{Ea}	47.19±0.17 ^{Fa}	46.85±0.55 ^{Aa}	48.41±0.15 ^{Da}
NCP-1	52.18±0.01 ^{Cb}	54.31±1.32 ^{Bb}	58.72±1.24 ^{Eb}	61.41±1.70 ^{Fb}	65.17±0.87 ^{Ab}	66.04±0.38 ^{Db}

¹⁾All values are mean ± SD of the triplicate determination. The mean in row (a-b) and a column (A-F) followed by different superscripts are significantly different at $p < 0.05$ by Duncan's range test.

terminated that a smaller amount soy sauce in NCP-1 and the results could provide a basis for improving the availability and quality of napa cabbage.

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초록 : 저장기간 동안 배추 피클의 이화학적 특성 및 항산화 활성 분석

손혜련¹ · 오선경¹ · 배상옥² · 최명락^{1*}

(¹전남대학교 바이오 전자 메디컬 공학 협동과정, ²초당대학교 조리과학과)

본 연구에서는 배추를 이용하여 저염 피클을 개발하기 위한 기초적인 연구로 저장기간 중 배추 피클의 이화학적 특성 및 항산화 활성에 대해 분석하였다. 조미액 함량을 달리한 각각의 배추 피클(NCP, NCP-1)을 -4℃에서 60일 동안 저장하였다. NCP 및 NCP-1의 pH는 저장 0일째 각각 4.51±0.15, 4.85±0.08로 나타났으며 이후 감소하였다. 산도는 NCP 및 NCP-1에서 저장 0일째 각각 0.51%, 0.38%로 나타났으며 이후 각각 0.67%, 0.56%로 증가하였다. 염도는 1.77~2.22% 범위를 유지하였다. 색도의 L값은 NCP 및 NCP-1 모두 0일째에서 최대값을 나타냈으며 이후 감소하였다. 또한, 색도의 a값은 증가하였고, b값은 감소하여 갈변 현상이 진행된 것을 알 수 있었다. 물성의 인장강도는 저장 0일째 NCP에서 10.90±0.05 kgf/cm², NCP-1에서는 11.84±0.05 kgf/cm²로 최소값이 나타났으며 절단력은 저장 0일째 NCP에서 1004±7.12 gf/cm², NCP-1에서는 845±5.27 gf/cm²로 최대값이 나타났다. 전체적인 기호도는 NCP-1에서 저장 45일째 4.25±0.10로 최대값이 나타났으며 항산화 활성은 저장 60일째 66.04%로 최대값이 나타났다. 60일간 저장기간 동안에도 연부현상이 발생하지 않았다. 그래서 최적의 배추 피클은 조미액 중 간장 함량을 줄인 NCP-1이 적합하다고 판단된다. 본 연구 결과는 배추가 저염 피클제품으로서 이용 가능성이 있음을 제시하고, 수입 위주의 피클을 대체함과 동시에 배추를 이용한 식품의 다양화에 기여 할 수 있을 것이라 생각된다.