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# Quality Characteristics during Storage of *Yackwa* added with Ethanol Extract from *Ulmus davidiana*

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# 저장기간 동안 유근피 에탄올 추출물 첨가 약과의 품질특성

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## 국문요약

최근 식품에 첨가하는 합성 항산화제가 생체효소의 활성을 억제하고, 암을 유발시키는 등의 안정성에 문제가 되는 것으로 보고되면서 천연 식물자원으로부터의 항산화 물질을 개발하고자 하는 연구가 활발하게 진행되고 있다. 느릅나무의 껍질인 유근피는 항산화 효과가 매우 우수한 것으로 보고되고 있어서, 천연 항산화제로 유근피 에탄올 추출물을 0, 0.05, 0.1, 0.2%로 약과에 첨가하여 합성 항산화제인 BHT와 천연 항산화제인 L-ascorbic acid를 0.02%로 첨가한 약과와 저장기간에 따른 품질특성과 지질산패 정도를 비교하였다. 유근피의 첨가량이 증가할수록 산패취와 경도는 감소하였고, 반면에 수분활성도, 팽화도, 관능평가 등은 증가하였다. 특히 유근피를 첨가함에 따라 약과의 명도가 감소한 것으로 나타났는데, 이는 약과의 메일라드 반응에 의한 갈색물질인 멜라노이딘류의 생성 때문으로 추정된다. 또한 약과의 저장 기간이 증가함에 따라서 경도, 색도, 산패취 등이 증가하였고, 반면에 수분활성도와 팽화도, 색, 맛, 조직감, 전반적인 기호도 등의 관능적 특성은 감소하였다. 유근피가 약과의 저장성에 미치는 영향을 살펴보기 위해서 산가와 과산화물가를 측정하여 실험한 결과, 유근피를 첨가한 약과는 첨가하지 않은 약과에 비해서 지질산화가 적게 일어나, 약과의 저장성을 증가시켜 주는 것으로 나타났다. 관능적인 특성을 비롯한 품질특성과 지질산패 정도를 평가한 결과, 유근피 추출물을 0.1% 첨가한 약과가 가장 좋을 것으로 평가되었다.

Key words: *Ulmus davidiana*, *yackwa*, quality characteristics, lipid peroxidation, storage stability

## Introduction

*Yackwa* is a Korean traditional fried cookie made from wheat flour, honey and other ingredients such as sesame oil, rice wine, and used traditionally as a holiday foods in Korea. Recently, much interest has been focused on commercialization of *yackwa* to satisfy consumer's needs for traditional foods on Korea. *Yackwa* have been manufactured in pilot plants and marketed on limited scale, but some problems still exist for mass production and commercialization of *yackwa* (Kim et al. 2004). Particularly, the oil absorbed during the frying process produces secondary products such as hydroperoxide, dimer, and polymers (Frankel EN 1984), which can cause development of undesirable flavors and tastes in *yackwa*. Lipid oxidation is a major deteriorative reaction in fried foods, and often results in significant loss of quality (Alexander JC 1978; Pearson et al. 1983; Wu & Nawar 1986). Generally, these changes reduce consumer acceptance of oxidized products.

Antioxidants are usually added to fats, oils, and foods containing fat to inhibit the development of off-flavors arising from

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the oxidation of unsaturated fatty acid. However, the commercial use of synthetic antioxidants is strictly controlled and increasing consumer awareness of food additives and safety has prompted increased interest in the use of natural antioxidants as alternatives to synthetic compounds. Accordingly, many studies on the antioxidant activity of medicinal and edible plants and their application to food preservation have been conducted (Choi et al. 1992; Gadow et al. 1997; Pietta et al. 1998; Masuda et al. 1999). Accordingly, the new application of using plant extracts as an antioxidant material is of significant interest, especially due to an annually increasing food production. Clearly, the utilization of plant extracts would contribute to maximizing available resource use, and could expand the market for food products. The extraction of phenolic antioxidants from plant extracts could also help in the production of biodegradable fertilizers, due to their antioxidant activity. Synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and propylgallate (PG) have been widely used in raw and precooked ground meat, meat products, and fried foods for storage, to retard lipid oxidation (Shahidi et al. 1987; St. Angelo AJ 1996; McCarthy et al. 2001). However, the demand for natural antioxidants has recently increased due to the toxicity and carcinogenicity of synthetic antioxidants (Branen AL 1975; Ito et al. 1983). Thus, there is increasing interest for finding medicinal and edible plants with high antioxidant activity. Several studies have documented the effectiveness of the antioxidative components in herbs and spices, such as flavonoids, phenolics and polyphenolics, and related compounds, for the prevention of lipid oxidation in meat, meat products, and fried foods (Ahn et al. 2002; Botsoglou et al. 2002; Sallam et al. 2004).

*Ulmus davidiana* is a deciduous tree widely distributed in Korea. The root and stem bark are used in traditional oriental medicine to treat edema, mastitis, gastric cancer, and inflammation. *Ulmus davidiana* water extract was developed based on the herb's known functions, as described in the literature of traditional Chinese and Korean medicine (Jun et al. 1998). Previous research has found that the *Ulmus davidiana* is high in antioxidants (Jun et al. 1998; Kim et al. 2005; Guo & Wang 2007; Jung et al. 2008). Although of *Ulmus davidiana* is used to treat chronic diseases, the mechanism by which it functions is not well understood. There are some scientific reports on the biologically active compounds in *Ulmus davidiana* as well as their biological actions. For example, catechin, catechin glycoside, and uldavioside have been isolated from *Ulmus davidiana*. Additionally, four lignan xylosides and two neolignan glycosides were isolated from the stem and root bark (Lee et al. 2001). Thus, we expect the *Ulmus davidiana* to also have high antioxidant activity, and even synergism among the antioxidants. So far, however, there have only been attempts to investigate the antioxidant properties of *Ulmus davidiana* in food products, and there is limited information available on the antioxidant content and activity of *Ulmus davidiana* extracts.

In our laboratory, we have tried to discover natural antioxidants from *Ulmus davidiana*. The *Ulmus davidiana* extract was reported to have strong antioxidant activity (Guo & Wang 2007). Therefore, we obtained extracts from *Ulmus davidiana* by using 70% ethanol. It was applied to *yackwa* dough before the frying process. From this study, we observed advantageous results with *Ulmus davidiana* treatment that has a *yackwa* base.

## Materials and Methods

### 1. Preparation of plant extracts

*Ulmus davidiana* root (Jungsun, Kangwon-do, Korea) was purchased from an oriental herb market (Kyung-Dong) in Seoul, Korea. Dried *Ulmus davidiana* root was crushed in a grinder for 2 min, but at 15 s intervals the process was stopped for 15 s to avoid heating the samples. The *Ulmus davidiana* sample (100 g) were extracted by stirring with 500 mL of 70% ethanol at 80℃ for 3 h two times, and then filtered through Whatman No. 2 filter paper. The solvent of the combined extracts was evaporated under reduced pressure using a rotary vacuum-evaporator at 50℃ and the remaining water was removed by freeze-dried.

### 2. Preparation of *yackwa*

For preparation of model *yackwa*, wheat flour (120 g), sesame oil (15 g), honey (54 g), rice wine (5 g), water (5 g) and salt (2 g) were mixed together and kneaded. *Ulmus davidiana* extracts, BHT, and L-ascorbic acid were added during mixing and kneading process at level of 0.05%, 0.1%, 0.2% and 0.02% (w/w) of total ingredients for dough preparation, respectively. The levels of *Ulmus davidiana* extracts, BHT, L-ascorbic acid were determined by preliminary study. The control *yackwa* sample was prepared with 120 g of wheat flour, 15 g of sesame seed oil, 54 g of honey, 5 g of rice wine, 5 g of water and 2 g of salt. The resulting dough was kneaded and divided into small pieces, which weighed about 14 g. Each piece was shaped using a *yackwa* mould (0.7 cm thick, 3.5 cm in diameter) and fried in

soybean oil (C.J.Co., Seoul, Korea). Prepared dough was molded and fried in soy bean oil at 120 ± 5℃ for 15 min. Fried *yackwa* base was placed in bamboo basket for 30 min to remove the excessively absorbed surplus oil and then stored without packing in an incubator at 60℃ for 5 days.

At intervals of 1 day, the *yackwa* was removed from the incubator to extract. A *yackwa* (5 g) was ground into a cream state in a mortar, suspended in ethanol (10 mL, 99.5%), and incubating shacking incubator at 2,500 rpm for 20 min, and then filtered through Whatman No. 2 filter paper. The *yackwa* extracts were obtained from supernatant, and diluted two concentrations (0.05 or 0.5 kg/L) with 75% ethanol to analyze the profile of their antioxidant properties.

### 3. Water activity of *yackwa*

Water activity instrument (ART, Rotronic, Zurich, Switzerland) was turned on 10 min prior to use. When the LCD display read '0.000', two salt solutions of known water activity were inserted and used to calibrate the instrument. Once calibrated, prepared samples were placed in the instrument and the water activity was determined.

### 4. Expansion ratio of *yackwa*

Expansion of the dough and the *yackwa* was characterized as width, length, and height. The width, length, and height of the *yackwa* were then measured prior to and after frying and the difference was then expressed as a ratio.

### 5. Color measurement of *yackwa*

The color values of lightness (L), redness (a) and yellowness (b) of the external color were measured using a Colorimeter (CR-300, Minolta Co., Ltd, Osaka, Japan). The colorimeter was standardized using a white tile (L* = 97.26, a* = −0.07 and b* = 1.86).

### 6. Texture analysis of *yackwa*

Texture analysis of *yackwa* was conducted using a Texture Analyzer (TA-XT express, Stable Micro System, Haslemere, U.K.) equipped with a 2.0-mm-dia probe (Woo et al. 2005). The pretest speed was 5.0 mm/sec, the test speed was 5.0 mm/sec, the posttest speed was 10.0 mm/sec and the load cell was 5 kg. The samples were compressed to 50% of the strain of the original vertical height. The texture of *yackwa* was analyzed 5 times per replication.

### 7. Sensory evaluation of *yackwa*

Trained panelists comprised of graduate students who were familiar with *yackwa* evaluated each of the stored samples daily for 5 days. Prior to the experiment, they were instructed in the purpose of the test, as well as on how to evaluate the sample. The judgments were quantified using a 9-point rating scale, with very poor (weak) corresponding to 1-point, and very good (powerful) corresponding to 9-points. In addition, when rancidity was considered, 1-point indicated extremely light yellow color and fresh flavor, while 9-points indicated a heavy yellow and extremely distasteful flavor. All samples were coded and presented in a randomized arrangement.

### 8. Measurement of acid value (AV)

Acid value (AV) was determined using the AOCS method (1996). Briefly, 5.0 g aliquots of the samples were weighed into 200 mL glass stoppered Erlenmeyer flasks. Next, 100 mL of ether-ethanol solution (2:1, v/v) were added and the sample was then thoroughly agitated for 1 min to dissolve the fat. Next, 2~3 drops of 1% phenolphthalein indicator were added to the solution with moderate agitation. The sample was then transferred into the burette of an automatic titrator (VITLAB Gmbh, VITLAB, Seeheim-Jugenreim, Germany) equipped with stirrer and the titration was then allowed to run against KOH ethanolic solution (0.1 N). Titrant from the burette was added to the solution until a permanent (at least 30 s) faint pink color was observed. The amount of KOH required to neutralize the free fatty acids in 1 g of fat was then used to determine the AV, which was calculated using the following equation.

$$AV = \frac{\text{Titrant volume (mL)} \times (0.1\text{N KOH solution factor}) \times 5.611}{\text{Weight sample (g)}}$$

### 9. Measurement of peroxide value (POV)

Peroxide value (POV) of *yackwa* was measured using the method described by Kirk & Sawyer (1991) and expressed as milliequivalents (mequiv) of active oxygen per kilogram of oil. Briefly 1.0 g aliquots of the samples were added to 250 mL stopper conical flasks that contained 10 mL of chloroform, 15 mL of glacial acetic acid and 1 mL of fresh saturated aqueous potassium iodide solution. The flask was then stoppered and shaken vigorously for 1 min, after which it was kept in the dark for an additional 5 min. Next, distilled water (30 mL) was mixed thoroughly with the solution, which was then titrated against a 0.01 N sodium thiosulphate solution using soluble starch solution

(1%) as an indicator. One blank reagent (without any sample) was prepared. The POV was then determined using the following equation:

$$\mathrm{POV(meq/kg)} = \frac{(V_1 - V_0) \times F \times 10}{W}$$

Where $V_1$ is the titre value (mL) of sodium thiosulphate solution for the sample, $V_0$ is the titre value (mL) of sodium thiosulphate solution for the blank, F is the normality of the sodium thiosulphate solution and W is the weight of the sample.

### 10. Statistical analysis

The results of the treatments are expressed as the mean ± standard deviation (SD). The data were analyzed by two-way analyses of variance (ANOVA) using SPSS (Statistical Analysis Program, version 12.0) to determine the effects of the *Ulmus davidiana yackwa*. Significant differences between treatment means were determined by Duncan's multiple range tests ($p$<0.05).

## Results and Discussion

### 1. Water activity of *yackwa*

*Yackwa* were found to have textures typical of products that are stored while maintaining constant moisture content during storage. Therefore, changes in moisture content during storage are very important for maintaining the quality of these products. The water activities of the *yackwa* are shown in Table 1. The initial water activities of the *yackwa* were in the range of 0.34~0.57, which is within the ideal range of 0.58~0.68 for maintaining stability during the storage of foods that are subject to lipid oxidation (Kang HY 2005). The water activity of the control on the day it was manufactured was reportedly 0.44, however, this value was increased with the addition of *Ulmus davidiana* extract and then decreased throughout the storage period. Furthermore, it is known that when the moisture content was approximately 10%, the water activity value was approximately 0.6, which is similar to the results of the current study.

Fennema OR (1996) stated the existence of strong correlationship between water activity and Maillard reaction by demonstrating the increasing tendency of water activity by the increase of Maillard reaction. Therefore, the cause of low water activity in L-ascorbic acid added *yackwa* than controls could be used as the data to prove the less progression of brown color development by Maillard reaction in *yackwa*. But in case of *Ulmus davidiana* added *yackwa*, water activity was increased by increasing the amount of addition. This indicates that the water activity was increased by the formation of browning substances due to the Maillard reaction. The cause of increased oxidation stability in heat treated foods attributable to the formation of the substances having antioxidant effects by non-enzymatic browning reaction. Among the browning reaction products, the final products of melanoidins have been reported to have various antioxidative effects through lipid peroxidation inhibition, electron donating ability, synergistic effect, and recent report demonstrated that the intermediates of the reaction had stronger antioxidative effects than the melanoidins, and there are reports on the variation of antioxidative activity of reaction products based on the amino acids and sugar types related to the Maillard reaction. In addition, the water activity levels of the tested *yackwas* were significantly different between groups ($p$<0.001); however, it is likely that the effect of water activity on lipid oxidation was

**Table 1. Change in water activity of *yackwa* with different concentrations of *Ulmus davidiana* extract during storage**

| Treatments | Storage at 60℃ (days) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| Control | 0.44 ± 0.00$^{bF}$ | 0.42 ± 0.01$^{bE}$ | 0.40 ± 0.01$^{bD}$ | 0.39 ± 0.01$^{bC}$ | 0.36 ± 0.00$^{bB}$ | 0.35 ± 0.00$^{bA}$ |
| 0.05% extract | 0.48 ± 0.00$^{cF}$ | 0.47 ± 0.01$^{cE}$ | 0.47 ± 0.01$^{cD}$ | 0.42 ± 0.01$^{cC}$ | 0.44 ± 0.02$^{cB}$ | 0.36 ± 0.00$^{cA}$ |
| 0.1% extract | 0.57 ± 0.00$^{dF}$ | 0.54 ± 0.01$^{dE}$ | 0.53 ± 0.01$^{dD}$ | 0.52 ± 0.01$^{dC}$ | 0.48 ± 0.01$^{dB}$ | 0.42 ± 0.01$^{dA}$ |
| 0.2% extract | 0.57 ± 0.01$^{eF}$ | 0.57 ± 0.00$^{eE}$ | 0.57 ± 0.00$^{eD}$ | 0.53 ± 0.01$^{eC}$ | 0.51 ± 0.01$^{eB}$ | 0.50 ± 0.01$^{eA}$ |
| L-ascorbic acid | 0.42 ± 0.00$^{aF}$ | 0.41 ± 0.00$^{aE}$ | 0.40 ± 0.01$^{aD}$ | 0.36 ± 0.01$^{aC}$ | 0.35 ± 0.01$^{aB}$ | 0.34 ± 0.00$^{aA}$ |
| BHT | 0.49 ± 0.01$^{bF}$ | 0.47 ± 0.01$^{bE}$ | 0.45 ± 0.00$^{bD}$ | 0.44 ± 0.00$^{bC}$ | 0.42 ± 0.00$^{bB}$ | 0.40 ± 0.00$^{bA}$ |

$^{a-e}$ Values with different letters within a column differ significantly ($p$<0.001).

$^{A-F}$ Values with different letters within a row differ significantly ($p$<0.001).

Each value represents mean ± S.D. (n=3).

correlated with the effect of food added natural plant extracts.

In a study conducted by Kang HY (2005), the addition of natural plant extracts and rice wine cakes to *yackwa* resulted in a low water activity value; however, this value also decreased as the storage period increased. In addition, the results of a study conducted by Kim et al. (2005) revealed that the addition of *dansam* and *ulgum* to *yackwas* resulted in lower moisture content, and that an increased storage period also lowered the moisture content.

### 2. Expansion ratio of *yackwa*

The expansion ratio of *yackwa* based on the amount of *Ulmus davidiana* extract it contained and its storage period are summarized in Table 2. When the expansion ratio of the control was set as 0, the lowest expansion ratio of *yackwa* was 1.31, whereas the group that contained 0.2% *Ulmus davidiana* had the highest value, which was 1.56. However, there was no difference in the expansion ratio of *yackwa* in response to the storage period. Therefore, the results of this study demonstrate that the addition of *Ulmus davidiana* to *yackwa* results in an increased expansion ratio.

In addition, the expansion ratio of *yackwa* depends on the lipid content. With the increase of fat content in dough, the fat content stacked in between moisture and gluten or between glutens is increased, which consequently increases the shortening power. In a study conducted by Yun & Kim (2005), it was reported that the addition of green tea to *yackwa* increased the expansion ratio, and a study by Hyun & Kim (2005) revealed that the addition of red ginseng to *yackwas* led to an increase in the expansion ratio. Furthermore, the results of a study conducted by Kang HY (2005) revealed that the addition of rice wine cake to *yackwas* resulted in an increased expansion ratio. During the course of frying *yackwa*, the exchange reaction of moisture and oil is increased as the *yackwa* is perforated, which results in the expansion ratio of *yackwa* being increased. Therefore, these results indicate that the addition of *Ulmus davidiana* extract contributed to the increased perforation of *yackwa*, thereby increasing the expansion ratio.

### 3. Color measurement of *yackwa*

The color change of the *yackwa* base during storage at 60℃ is shown in Table 3. There were significant differences ($p<0.001$) in the L, a, and b values of the external color of *yackwa*. *Yackwa* that contained *Ulmus davidiana* had slightly lower L values than the controls, and the L value of the *yackwa* that contained 0.2% *Ulmus davidiana* was significantly lower than that of the other treatments, indicating that it had the darkest color. In addition, *yackwa* that contained *Ulmus davidiana* had higher a and b values, with *yackwa* that was amended with 0.2% *Ulmus davidiana* having the highest a and b values, indicating the it had the most reddish and yellow color, respectively. Taken together, these results indicate that a decrease in L values and an increase in a and b values occurred in response to the addition of *Ulmus davidiana*. It has been reported that the oil temperature and sample thickness of products produced by deep fat frying are the most significant factors that affect the color parameters during frying (Krokida et al. 2001). The intra-variances in the surface color of *yackwa* may have occurred due to deviations in frying temperatures due to the mass production of *yackwa*. Therefore, manufacturing high quality *yackwa* products may require the development of highly controlled automatic equipment to enable its mass production. The results of this study also demonstrated that the L value decreased, but the a and b value increased slightly as the storage time increased. In general, the minor change observed

**Table 2. Change in expansion ratio of *yackwa* with different concentrations of *Ulmus davidiana* extract during storage**

| Treatments | Storage at 60℃ (days) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| Control | 1.31 ± 0.13$^{a}$ | 1.51 ± 0.11$^{a}$ | 1.52 ± 0.17$^{a}$ | 1.32 ± 0.07$^{a}$ | 1.42 ± 0.10$^{a}$ | 1.40 ± 0.21$^{a}$ |
| 0.05% extract | 1.38 ± 0.17$^{a}$ | 1.23 ± 0.08$^{a}$ | 1.57 ± 0.10$^{a}$ | 1.40 ± 0.11$^{a}$ | 1.56 ± 0.11$^{a}$ | 1.40 ± 0.20$^{a}$ |
| 0.1% extract | 1.50 ± 0.03$^{b}$ | 1.57 ± 0.18$^{b}$ | 1.52 ± 0.12$^{b}$ | 1.66 ± 0.32$^{b}$ | 1.37 ± 0.06$^{b}$ | 1.61 ± 0.20$^{b}$ |
| 0.2% extract | 1.56 ± 0.14$^{c}$ | 1.59 ± 0.23$^{c}$ | 1.52 ± 0.10$^{c}$ | 1.60 ± 0.12$^{c}$ | 1.51 ± 0.05$^{c}$ | 1.61 ± 0.22$^{c}$ |
| L-ascorbic acid | 1.38 ± 0.07$^{ab}$ | 1.48 ± 0.10$^{ab}$ | 1.45 ± 0.20$^{ab}$ | 1.50 ± 0.18$^{ab}$ | 1.55 ± 0.07$^{ab}$ | 1.44 ± 0.08$^{ab}$ |
| BHT | 1.44 ± 0.13$^{a}$ | 1.35 ± 0.15$^{a}$ | 1.36 ± 0.17$^{a}$ | 1.45 ± 0.11$^{a}$ | 1.52 ± 0.07$^{a}$ | 1.44 ± 0.13$^{a}$ |

$^{a-c}$ Values with different letters within a column differ significantly ($p<0.001$).
Each value represents mean ± S.D. (n=3).

**Table 3. Change in L, a and b values of *yackwa* with different concentrations of *Ulmus davidiana* extract during storage**

| Color difference | Treatments | Storage at 60℃ (days) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 |
| L value | Control | 33.19 ± 0.63$^{abB}$ | 32.57 ± 0.45$^{abAB}$ | 32.27 ± 0.73$^{abA}$ | 32.16 ± .0.28$^{abA}$ | 32.12 ± 0.24$^{abA}$ | 32.04 ± 0.21$^{abA}$ |
| | 0.05% extract | 32.62 ± 0.66$^{bB}$ | 32.53 ± 0.21$^{bAB}$ | 32.48 ± 0.21$^{bA}$ | 32.41 ± 0.71$^{bA}$ | 32.43 ± 0.74$^{bA}$ | 32.39 ± 0.85$^{bA}$ |
| | 0.1% extract | 32.41 ± 0.56$^{abB}$ | 32.41 ± 1.10$^{abAB}$ | 32.31 ± 0.30$^{abA}$ | 32.27 ± 0.30$^{abA}$ | 32.21 ± 0.27$^{abA}$ | 32.03 ± 0.45$^{abA}$ |
| | 0.2% extract | 32.33 ± 0.33$^{abB}$ | 32.24 ± 0.67$^{abAB}$ | 32.18 ± 0.41$^{abA}$ | 32.13 ± 0.28$^{abA}$ | 32.10 ± 0.42$^{abA}$ | 31.93 ± 0.49$^{abA}$ |
| | L-ascorbic acid | 34.49 ± 0.52$^{cB}$ | 34.49 ± 1.09$^{cAB}$ | 34.29 ± 1.02$^{cA}$ | 34.25 ± 1.14$^{cA}$ | 34.03 ± 1.20$^{cA}$ | 33.85 ± 1.43$^{cA}$ |
| | BHT | 32.81 ± 0.27$^{aB}$ | 32.14 ± 0.38$^{aAB}$ | 31.87 ± 0.37$^{aA}$ | 31.69 ± 0.34$^{aA}$ | 31.44 ± 0.48$^{aA}$ | 32.36 ± 0.36$^{aA}$ |
| a value | Control | 2.08 ± 0.25$^{cA}$ | 2.47 ± 0.25$^{cB}$ | 2.59 ± 0.15$^{cB}$ | 2.58 ± 0.28$^{cB}$ | 2.64 ± 0.21$^{cB}$ | 2.74 ± 0.28$^{cB}$ |
| | 0.05% extract | 2.16 ± 0.24$^{cA}$ | 2.65 ± 0.26$^{cB}$ | 2.65 ± 0.22$^{cB}$ | 2.66 ± 0.20$^{cB}$ | 2.64 ± 0.18$^{cB}$ | 2.65 ± 0.16$^{cB}$ |
| | 0.1% extract | 2.62 ± 0.31$^{dA}$ | 2.73 ± 0.42$^{dB}$ | 2.74 ± 0.46$^{dB}$ | 2.92 ± 0.29$^{dB}$ | 3.03 ± 0.49$^{dB}$ | 3.04 ± 0.24$^{dB}$ |
| | 0.2% extract | 2.81 ± 0.24$^{dA}$ | 2.82 ± 0.20$^{dB}$ | 2.84 ± 0.22$^{dB}$ | 2.87 ± 0.19$^{dB}$ | 2.88 ± 0.25$^{dB}$ | 2.91 ± 0.23$^{dB}$ |
| | L-ascorbic acid | 2.55 ± 0.32$^{bA}$ | 2.34 ± 0.19$^{bB}$ | 2.26 ± 0.08$^{bB}$ | 2.27 ± 0.14$^{bB}$ | 2.26 ± 0.04$^{bB}$ | 2.23 ± 0.49$^{bB}$ |
| | BHT | 1.04 ± 0.13$^{aA}$ | 1.93 ± 0.12$^{aB}$ | 1.94 ± 0.07$^{aB}$ | 1.95 ± 0.13$^{aB}$ | 1.99 ± 0.18$^{aB}$ | 2.04 ± 0.10$^{aB}$ |
| b value | Control | 4.45 ± 0.27$^{bA}$ | 5.48 ± 2.60$^{bB}$ | 6.57 ± 1.42$^{bBC}$ | 6.62 ± 1.18$^{bC}$ | 6.79 ± 1.51$^{bC}$ | 6.95 ± 0.84$^{bC}$ |
| | 0.05% extract | 4.55 ± 0.48$^{bA}$ | 6.53 ± 0.35$^{bB}$ | 6.64 ± 0.61$^{bBC}$ | 6.79 ± 0.55$^{bC}$ | 6.91 ± 0.43$^{bC}$ | 6.91 ± 0.56$^{bC}$ |
| | 0.1% extract | 5.07 ± 0.43$^{bA}$ | 6.68 ± 0.37$^{bB}$ | 6.78 ± 0.94$^{bBC}$ | 6.98 ± 1.13$^{bC}$ | 7.05 ± 0.95$^{bC}$ | 7.14 ± 0.86$^{bC}$ |
| | 0.2% extract | 6.91 ± 0.80$^{cA}$ | 7.07 ± 1.17$^{cB}$ | 7.11 ± 0.76$^{cBC}$ | 7.22 ± 1.27$^{cC}$ | 7.35 ± 1.06$^{cC}$ | 7.26 ± 0.74$^{cC}$ |
| | L-ascorbic acid | 4.63 ± 0.93$^{cA}$ | 6.93 ± 0.82$^{cB}$ | 7.79 ± 0.88$^{cBC}$ | 7.96 ± 0.95$^{cC}$ | 8.03 ± 0.87$^{cC}$ | 7.96 ± 0.72$^{cC}$ |
| | BHT | 3.74 ± 0.43$^{aA}$ | 5.59 ± 0.53$^{aB}$ | 5.60 ± 0.53$^{aBC}$ | 5.82 ± 0.49$^{aC}$ | 5.73 ± 0.56$^{aC}$ | 5.83 ± 0.48$^{aC}$ |

$^{a-d}$ Values with different letters within a column differ significantly ($p$<0.001).

$^{A-C}$ Values with different letters within a row differ significantly ($p$<0.001).

Each value represents mean ± S.D. (n=3).

in the L, a, and b values indicates that storage time did not have a significant impact on the color of the *yackwa* base.

The current study analyzed the color change during the storage of *yackwa* and came to the conclusion that the *Ulmus davidiana* added *yackwa* can have browning reaction not only by the compounds present within *yackwa* itself, but also by the storage time. Although Lim et al. (1993) reported that the L, a, and b values of soybean oil decreased according to frying time, the color changes observed in our study did not impact the shelf-life of *yackwa* base. In addition, a study conducted by Hyun & Kim (2005) revealed that the L and b value decreased as red ginseng was added to *yackwas*, but that the a value did not show any change. These results are believed to have been impacted by the addition of wheat flour and the color compositions of phenolic chemicals. In addition, the results of a study conducted by Kang HY (2005) revealed that the L and b values decreased in response to the addition of rice wine cake and increased storage time, but that the a value was increased by these factors. Therefore the frying temperature and time are generally regarded to have the most important effects on the color of *yackwa*; however, it is also believed that added substances have an effect on its color.

### 4. Texture analysis of *yackwa*

The results of the instrumental textural evaluation are shown in Table 4. Addition of *Ulmus davidiana* significantly reduced the hardness of *yackwa* ($p$<0.001), with *yackwa* containing 0.2% *Ulmus davidiana* having the lowest hardness. In addition, the change in hardness was considerably different within a fixed period of storage ($p$<0.001). Furthermore, the initial hardness of *yackwa* was lowered by the addition of *Ulmus davidiana* prior to storage. These results indicate that the shelf-life of the *yackwa* base depended on quality degradation as a result of chemical variations. The hardness of the *yackwa* increased significantly as the storage time increased, with the value of the control being 3,871.80 after 5 days and that of the 0.2% added group being only 1,610.46. In a study conducted by Woo et al. (2005), the addition of ɣ-oryzanol decreased the hardness of the product it was added to, whereas the hardness increased as the storage time

**Table 4. Change in hardness of *yackwa* with different concentrations of *Ulmus davidiana* extract during storage**

| Treatments | Storage at 60℃ (days) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| Control | 1,468.04 ± 125.89$^{cA}$ | 1,677.50 ± 126.26$^{cAB}$ | 2,060.52 ± 163.58$^{cB}$ | 2,221.10 ± 589.76$^{cC}$ | 2,847.16 ± 312.21$^{cD}$ | 3,871.80 ± 522.07$^{cE}$ |
| 0.05% extract | 1,189.72 ± 81.33$^{aA}$ | 1,237.06 ± 94.43$^{aAB}$ | 1,268.10 ± 80.11$^{aB}$ | 1,469.16 ± 117.60$^{aC}$ | 1,575.60 ± 309.80$^{aD}$ | 1,736.92 ± 144.54$^{aE}$ |
| 0.1% extract | 922.30 ± 74.03$^{aA}$ | 1,031.24 ± 62.33$^{aAB}$ | 1,186.08 ± 138.19$^{aB}$ | 1,409.26 ± 235.47$^{aC}$ | 1,488.48 ± 188.00$^{aD}$ | 1,449.88 ± 285.71$^{aE}$ |
| 0.2% extract | 869.60 ± 79.24$^{aA}$ | 972.44 ± 148.46$^{aAB}$ | 1,092.40 ± 256.23$^{aB}$ | 1,355.92 ± 223.43$^{aC}$ | 1,571.22 ± 239.23$^{aD}$ | 1,610.46 ± 254.90$^{aE}$ |
| L-ascorbic acid | 1,299.16 ± 291.94$^{bA}$ | 1,335.48 ± 464.61$^{bAB}$ | 1,581.96 ± 282.90$^{bB}$ | 1,705.50 ± 401.93$^{bC}$ | 2,053.62 ± 278.15$^{bD}$ | 2,895.16 ± 817.75$^{bE}$ |
| BHT | 1,280.02 ± 275.36$^{bA}$ | 1,417.60 ± 239.80$^{bAB}$ | 1,503.84 ± 96.36$^{bB}$ | 1,894.62 ± 314.63$^{bC}$ | 1,987.58 ± 305.12$^{bD}$ | 2,271.96 ± 385.25$^{bE}$ |

$^{a-c}$ Values with different letters within a column differ significantly ($p$<0.001).
$^{A-E}$ Values with different letters within a row differ significantly ($p$<0.001).
Each value represents mean ± S.D. (n=3).

increased. However, a study conducted by Yun & Kim (2005) reported that the addition of green tea and storage time both increased the hardness of the products they were added to. Such differences in results may be a result of differences in the production process of *yackwa*.

The physical texture of *yackwa* is also related to its moisture content and the functional properties of the uncooked product. The results of this study indicate that *Ulmus davidiana* may be useful for improving the texture of bakery goods as well as for increasing their moisture retention. In addition, the results of this study also indicate that *Ulmus davidiana* may have induced a structural change in the major components of the wheat flour system during the bread making steps as a result of its interactions with starch or gluten, and by modifying the gelatinization of starch. Also, as the storage time of *yackwa* is increased, the root extracts of *Ulmus davidiana* extract elevate the moisture holding capacity and reduces the lowering of hardness.

### 5. Sensory evaluation of *yackwa*

As shown in Table 5, there were significant differences in the color, off flavor, taste, texture and overall quality of different *yackwa* samples ($p$<0.001). The *yackwa* that contained 0.1% *Ulmus davidiana* received the highest scores for most of the items evaluated. Conversely, the control and the *yackwa* that contained 0.2% *Ulmus davidiana* received lower scores than *yackwa* that contained 0.05, 0.1, BHT and L-ascorbic acid.

The color of *yackwa* is very important in terms of product quality. Therefore, the color score of *yackwa* from each treatment group was evaluated by a trained panelist and found to be 5.00 (control), 5.57 (0.05% *Ulmus davidiana*), 6.57 (0.1% *Ulmus davidiana*), 6.14 (0.2% *Ulmus davidiana*), 6.57 (L-ascorbic acid), and 6.00 (BHT) on day 5 ($p$<0.001). Additionally, off flavor, which was defined as an objectionable flavor resulting from the accumulation of oxidative decomposition products (Park & Kim 2002), steadily increased as the storage time increased. On day 5 the off flavor score of *yackwa* that contained 0.2% *Ulmus davidiana* was lower than that of the other treatments. Sensory evaluation was employed to assess the effects of an antioxidant on the off flavor and color of stored *yackwa* base. The taste and texture scores of *yackwa* that contained *Ulmus davidiana* were significantly higher than those of the control ($p$<0.001). Finally, when overall quality was considered *yackwa* that contained *Ulmus davidiana* treatments was tougher than the controls ($p$<0.001). But, the addition of Ulmus dvidiana in *yackwa* lowers the overall quality than the L-ascorbic acid added *yackwa*. This result is considered to be attributable to catechin which is the major antioxidant and representative flavonoid compound of *Ulmus davidiana*. Catechin is the substance that highly presents in green tea. Due to its bitterness, the addition of *Ulmus davidiana* in *yackwa* lowers the overall quality than the L-ascorbic acid added *yackwa*. So, the bitterness could be reduced in some level by adjusting the basic recipe during the *yackwa* manufacturing process. Namely, the reduction of bitterness in *Ulmus davidiana* added *yackwa* could be achieved by adding more honey than basic recipe to inhibit bitter taste by sweet taste during the *yackwa* manufacturing process.

It is known that the addition of *Ulmus davidiana* to *yackwa* changes the color, off flavor, taste, and texture, thereby exerting a large influence on the overall quality. *Ulmus davidiana* extract plays an important role in shelf-life enhancement and quality, not only by reducing lipid peroxidation, but also by raising taste components that are easily perceived. Taken together, these findings indicate that treatment of *yackwa* with 0.1% *Ulmus davidiana* resulted in prolonged shelf-life and better quality.

**Table 5. Change in sensory characteristics of *yackwa* with different concentrations of *Ulmus davidiana* extract during storage**

| Sensory characteristics | Treatments | Storage at 60℃ (days) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 |
| Color | Control | 7.00 ± 1.31$^{aC}$ | 6.83 ± 0.98$^{aC}$ | 6.33 ± 0.82$^{aBC}$ | 5.63 ± 1.20$^{aBC}$ | 5.25 ± 1.04$^{aAB}$ | 5.00 ± 1.41$^{aA}$ |
| | 0.05% extract | 8.38 ± 0.52$^{cC}$ | 7.17 ± 1.33$^{cC}$ | 7.75 ± 0.89$^{cBC}$ | 7.38 ± 1.06$^{cBC}$ | 6.63 ± 1.69$^{cAB}$ | 5.57 ± 1.90$^{cA}$ |
| | 0.1% extract | 7.50 ± 0.93$^{cC}$ | 7.83 ± 0.41$^{cC}$ | 7.75 ± 2.22$^{cBC}$ | 7.75 ± 0.46$^{cBC}$ | 7.25 ± 1.58$^{cAB}$ | 6.57 ± 1.40$^{cA}$ |
| | 0.2% extract | 7.13 ± 1.55$^{cC}$ | 8.33 ± 0.82$^{cC}$ | 7.50 ± 0.55$^{cBC}$ | 7.38 ± 0.74$^{cBC}$ | 6.75 ± 1.28$^{cAB}$ | 6.14 ± 1.68$^{cA}$ |
| | L-ascorbic acid | 6.50 ± 1.60$^{bcC}$ | 6.83 ± 1.17$^{bcC}$ | 7.17 ± 1.33$^{bcBC}$ | 6.88 ± 1.64$^{bcBC}$ | 7.13 ± 1.64$^{bcAB}$ | 6.57 ± 1.72$^{bcA}$ |
| | BHT | 7.25 ± 0.89$^{abC}$ | 7.00 ± 1.79$^{abC}$ | 6.67 ± 2.16$^{abBC}$ | 6.00 ± 1.85$^{abBC}$ | 5.88 ± 1.81$^{abAB}$ | 6.00 ± 1.29$^{abA}$ |
| Off flavor | Control | 1.75 ± 0.89$^{cA}$ | 2.67 ± 0.52$^{c}$ | 4.50 ± 1.38$^{cB}$ | 4.75 ± 1.75$^{cB}$ | 5.00 ± 2.07$^{cB}$ | 5.86 ± 1.68$^{cC}$ |
| | 0.05% extract | 1.63 ± 0.74$^{bA}$ | 2.50 ± 0.84$^{b}$ | 2.75 ± 0.71$^{bB}$ | 2.75 ± 0.89$^{bB}$ | 3.25 ± 1.17$^{bB}$ | 4.43 ± 1.81$^{bC}$ |
| | 0.1% extract | 1.50 ± 0.76$^{abA}$ | 2.00 ± 0.63$^{ab}$ | 2.50 ± 0.58$^{abB}$ | 2.38 ± 0.74$^{abB}$ | 3.00 ± 0.93$^{abB}$ | 3.86 ± 1.35$^{abC}$ |
| | 0.2% extract | 2.13 ± 2.41$^{aA}$ | 2.00 ± 0.89$^{aA}$ | 2.00 ± 0.00$^{aB}$ | 2.25 ± 0.71$^{aB}$ | 2.38 ± 0.92$^{aB}$ | 2.71 ± 0.76$^{aC}$ |
| | L-ascorbic acid | 2.00 ± 2.07$^{abA}$ | 2.00 ± 0.89$^{abA}$ | 2.83 ± 0.98$^{abB}$ | 2.38 ± 0.52$^{abB}$ | 2.63 ± 0.92$^{abB}$ | 3.00 ± 0.58$^{abC}$ |
| | BHT | 1.38 ± 0.52$^{abA}$ | 1.83 ± 0.75$^{abA}$ | 2.17 ± 0.75$^{abB}$ | 2.50 ± 0.76$^{abB}$ | 2.75 ± 1.49$^{abB}$ | 3.71 ± 1.98$^{abC}$ |
| Taste | Control | 7.25 ± 1.28$^{aB}$ | 5.33 ± 1.63$^{aB}$ | 5.67 ± 1.75$^{aB}$ | 6.00 ± 1.93$^{aB}$ | 5.00 ± 1.51$^{aAB}$ | 4.00 ± 1.53$^{aA}$ |
| | 0.05% extract | 6.75 ± 1.67$^{bB}$ | 6.67 ± 1.51$^{bB}$ | 7.38 ± 0.74$^{bB}$ | 7.38 ± 1.06$^{bB}$ | 6.25 ± 1.49$^{bAB}$ | 5.86 ± 1.77$^{bA}$ |
| | 0.1% extract | 6.38 ± 1.19$^{bB}$ | 7.50 ± 0.55$^{bB}$ | 6.50 ± 1.73$^{bB}$ | 6.75 ± 0.89$^{bB}$ | 6.50 ± 1.20$^{bAB}$ | 5.29 ± 1.60$^{bA}$ |
| | 0.2% extract | 5.13 ± 1.45$^{aB}$ | 5.17 ± 2.14$^{aB}$ | 6.00 ± 0.63$^{aB}$ | 5.00 ± 1.41$^{aB}$ | 5.13 ± 0.83$^{aAB}$ | 5.43 ± 1.51$^{aA}$ |
| | L-ascorbic acid | 6.75 ± 1.17$^{bB}$ | 6.83 ± 1.94$^{bB}$ | 6.83 ± 1.60$^{bB}$ | 6.63 ± 2.26$^{bB}$ | 6.88 ± 1.55$^{bAB}$ | 5.86 ± 2.11$^{bA}$ |
| | BHT | 7.25 ± 1.17$^{bB}$ | 6.17 ± 1.72$^{bB}$ | 7.00 ± 1.27$^{bB}$ | 5.75 ± 1.58$^{bB}$ | 6.25 ± 2.12$^{bAB}$ | 5.86 ± 1.77$^{bA}$ |
| Texture | Control | 6.25 ± 1.39$^{aC}$ | 4.67 ± 2.07$^{aBC}$ | 5.50 ± 1.52$^{aC}$ | 5.38 ± 1.41$^{aBC}$ | 4.25 ± 1.83$^{aAB}$ | 3.86 ± 1.07$^{aA}$ |
| | 0.05% extract | 7.75 ± 0.71$^{cC}$ | 6.67 ± 1.21$^{cBC}$ | 7.63 ± 0.74$^{cC}$ | 7.25 ± 1.04$^{cBC}$ | 6.75 ± 1.17$^{cAB}$ | 5.86 ± 0.69$^{cA}$ |
| | 0.1% extract | 7.50 ± 1.20$^{cC}$ | 7.50 ± 0.84$^{cBC}$ | 7.75 ± 0.96$^{cC}$ | 7.63 ± 0.92$^{cBC}$ | 6.63 ± 1.06$^{cAB}$ | 6.57 ± 1.27$^{cA}$ |
| | 0.2% extract | 7.00 ± 2.20$^{cC}$ | 7.50 ± 0.84$^{cBC}$ | 7.83 ± 0.41$^{cC}$ | 7.00 ± 0.76$^{cBC}$ | 7.13 ± 1.13$^{cAB}$ | 7.29 ± 0.49$^{cA}$ |
| | L-ascorbic acid | 6.63 ± 1.41$^{bC}$ | 6.67 ± 1.63$^{bBC}$ | 6.17 ± 2.32$^{bC}$ | 6.63 ± 1.92$^{bBC}$ | 6.00 ± 1.31$^{bAB}$ | 5.43 ± 1.90$^{bA}$ |
| | BHT | 6.63 ± 1.51$^{bC}$ | 6.00 ± 2.28$^{bBC}$ | 6.67 ± 1.86$^{bC}$ | 6.00 ± 1.51$^{bBC}$ | 5.88 ± 1.89$^{bAB}$ | 5.43 ± 1.90$^{bA}$ |
| Overall quality | Control | 6.25 ± 1.17$^{aB}$ | 5.17 ± 1.47$^{aB}$ | 5.17 ± 1.17$^{aB}$ | 5.25 ± 1.58$^{aB}$ | 4.75 ± 1.28$^{aB}$ | 4.29 ± 1.38$^{aA}$ |
| | 0.05% extract | 6.75 ± 1.49$^{cB}$ | 6.67 ± 1.51$^{cB}$ | 6.88 ± 1.13$^{cB}$ | 7.38 ± 1.19$^{cB}$ | 6.63 ± 1.19$^{cB}$ | 5.43 ± 1.99$^{cA}$ |
| | 0.1% extract | 6.88 ± 0.84$^{cB}$ | 7.33 ± 0.82$^{cB}$ | 7.00 ± 0.82$^{cB}$ | 7.50 ± 0.53$^{cB}$ | 6.63 ± 0.92$^{cB}$ | 5.71 ± 1.60$^{cA}$ |
| | 0.2% extract | 6.38 ± 0.92$^{bB}$ | 5.50 ± 1.76$^{bB}$ | 6.00 ± 0.63$^{bB}$ | 6.25 ± 1.17$^{bB}$ | 5.75 ± 0.71$^{bB}$ | 5.71 ± 1.11$^{bA}$ |
| | L-ascorbic acid | 6.63 ± 1.69$^{cB}$ | 6.67 ± 1.87$^{cB}$ | 6.50 ± 1.98$^{cB}$ | 7.00 ± 2.00$^{cB}$ | 6.75 ± 1.91$^{cB}$ | 6.00 ± 2.08$^{cA}$ |
| | BHT | 7.13 ± 1.13$^{bcB}$ | 6.83 ± 0.98$^{bcB}$ | 6.83 ± 1.47$^{bcB}$ | 6.38 ± 1.19$^{bcB}$ | 6.00 ± 1.93$^{bcB}$ | 5.71 ± 1.38$^{bcA}$ |

$^{a-c}$ Values with different letters within a column differ significantly ($p$<0.001).

$^{A-C}$ Values with different letters within a row differ significantly ($p$<0.001).

Each value represents mean ± S.D. (n=3).

### 6. Measurement of acid value (AV)

When food is fried in heated oil, the moisture forms steam, which evaporates with a bubbling action that gradually subsides as the foods are fried. Water, steam, and oxygen initiate chemical reactions in the frying oil and food. Water, a weak nucleophile, attacks the ester linkage of triacylglycerols and produces di- and monoacylglycerols, glycerol, and free fatty acids. The free fatty acids content of frying oil increases as the usage of the oil increases (Choe & Min 2007); therefore, the free fatty acid value is used to monitor the quality of frying oil. Thermal hydrolysis primarily occurs within the oil phase rather than at the water–oil interface (Lascaray L 1949; Choe & Min 2007).

Hydrolysis is more preferable in oil with short and unsaturated fatty acids than in oil with long and saturated fatty acids because short and unsaturated fatty acids are more soluble in water than long and saturated fatty acids. Water from foods is easily accessible to short-chain fats and oils for hydrolysis (Nawar WW 1969; Choe & Min 2007). In addition, a high amount of contact between the oil and the aqueous phase of food increases the hydrolysis of oil. Furthermore, di- and monoacylglycerols, glycerol and free fatty acids accelerate the hydrolysis reaction of oil (Choe & Min 2007).

The acid values of the extracted oil in this study showed a tendency similar to that of the peroxide values (Fig. 1). The acid values of the control, BHT, L-ascorbic acid and *Ulmus davidiana* 0.05%, 0.1% and 0.2% treatments were 0.43, 0.38, 0.37, 0.39, 0.37, and 0.37 mg/g on day 0, respectively. However, the acid value of each treatment after 5 days was significantly different ($p$<0.001). Furthermore, on day 5, the acid values of the control treatment (3.11 mg/g) and the 0.05% *Ulmus davidiana* treatment (1.95 mg/g) were 3-fold and 2-fold greater than those of the BHT, 0.2% *Ulmus davidiana*, and L-ascorbic acid treated samples (1.01, 0.98, and 0.90 mg/g), respectively. Taken together, these results indicate that the 0.2% *Ulmus davidiana* treatment had a strong antioxidant property. In a study that evaluated *yackwa* that was amended with *dansam* extract, the acid value of the treated *yackwa* ranged from 0.22~0.29 during the early stage of storage at 60℃, which was similar to that of the control; however, after 5 days of storage, the acid value of the control was 2.19, which was significantly higher than the acid value of 0.78~1.68 that was observed in the *yackwa* that contained the *dansam* extract (Kim et al. 2003). Furthermore, the acid value of *yackwa* that was treated with rice wine cakes and then stored at 30℃ was found to be 0.38~0.65 during the early stages of storage, which was similar to that of the control. However, after 3 weeks of storage, the acid value was significantly increased to 0.91~1.62 after 3 weeks of storage, and these values continued to increase as the storage time was extended (Kang HY 2005). The specified acid value of fried *hangwa* is less than 2.0 (Korea Food & Drug Administration 2000). In a study that evaluated the addition of 0.05%, 0.1%, and 0.2% *Ulmus davidiana* extracts to *yackwa*, the acid values were found to range from 0.98~1.95 mg/g, which indicates that the food was safe; however, the results of the sensory tests indicated that the quality was decreased 4 days after it was manufactured.

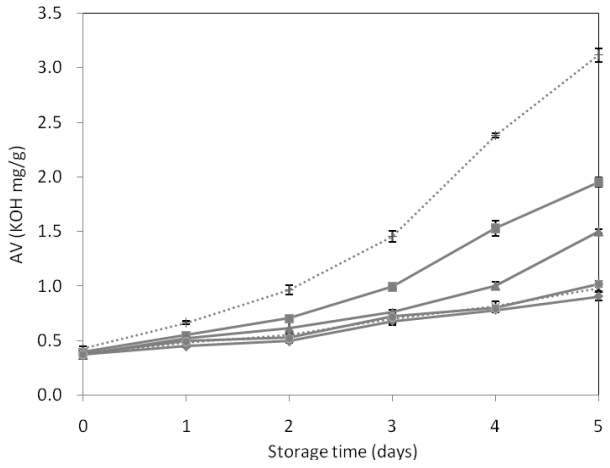


**Fig. 1. Change in acid value (AV) of *yackwa* with different concentrations of *Ulmus davidiana* extract during storage.** +: control; ■: 0.05% extract; ▲: 0.1% extract; ×: 0.2% extract; ◆: L-ascorbic acid; ●: BHT. Each value represents mean ± S.D. (n=3)

### 7. Measurement of peroxide value (POV)

The peroxide value is useful for evaluating the early stages of fat oxidation, and a product is considered rancid when a peroxide value of 20~40 meq/kg is reached (Economou et al. 1991). The antioxidant effects of *Ulmus davidiana* extract in *yackwa* during storage were directly investigated by measuring the primary and secondary lipid peroxidation products of *yackwa* during autoxidation. The initial lipid hydroperoxides values were significantly different ($p$<0.001) among groups of *yackwa* following frying in soybean oil for 15 min at 120℃. In addition, the lipid hydroperoxide formation values of *yackwa* that contained *Ulmus davidiana* extract tended to be significantly lower ($p$<0.001) than those of *yackwa* that did not, as indicated by the lipid hydroperoxide of *yackwa* that did not contain *Ulmus davidiana* increasing significantly ($p$<0.001) after 2 days and then increasing rapidly to 20.23 meq/kg *yackwa* after 3-days of storage (Fig. 2). Formation of lipid hydroperoxides in *yackwa* that did not contain *Ulmus davidiana* extract occurred very rapidly with no apparent induction period. Conversely, the peroxidation of lipids may also be facilitated by oxygen during storage. Nevertheless, all treated samples had significantly ($p$<0.001) lower peroxide values when compared to the control. The addition of BHT, L-ascorbic acid and *Ulmus davidiana* extract to *yackwa* markedly inhibited lipid peroxidation as measured by the decreasing peroxide value, most likely because their polyphenolic constituents function as antioxidants by terminating free radical chain-type reactions (Juntachote

et al. 2006). At the end of the storage period (5 days), the stability of the *yackwa* that were treated with various antioxidants decreased in the following order: L-ascorbic acid > 0.2% *Ulmus davidiana* extract > BHT > 0.1% *Ulmus davidiana* extract > 0.05% *Ulmus davidiana* extract > control. The addition of *Ulmus davidiana* extract to *yackwa* retarded the formation of lipid hydroperoxide at all levels of addition. Furthermore, the addition of *Ulmus davidiana* extract to *yackwa* had a significant effect on the lipid hydroperoxide formation after 3 days of storage. Therefore, the induction period of lipid peroxidation in *yackwa* was extended by approximately 3 days in response to the addition of *Ulmus davidiana*. During autoxidation, polyphenol compounds are gradually consumed during the incubation period, which in turn enables the absorbable oil in fried dough to be more rapidly to oxidized; therefore, the end of the induction period can be determined by a dramatic increase in lipid hydroperoxide. The polyphenol compounds degradation, oxygen absorption and lipid hydroperoxide formation in *yackwa* that contained 0.05, 0.1 and 0.2% *Ulmus davidiana* extracts were probably responsible for the antioxidant effect of *Ulmus davidiana* extract on *yackwa* during storage. Several studies (Wanasundara et al. 1995; Chen et al. 1998) have reported that natural polyphenol antioxidants provide better protection than synthetic antioxidants. However, the tests conducted in those studies were based on the action of a single synthetic antioxidant (either BHT or BHA), whereas the present study evaluated the effects of a combination of antioxidants. The use of 400~2,400 mg/kg of clove extract as a natural antioxidant has been shown to be more effective than BHT (Farag et al. 1989). However, the use of clove and rosemary extracts is limited due to their strong aroma. In previous study (Kim et al. 2003), the *dansam* extract added *yackwa* showed the similar peroxide value compared to the control at the early stage of storage when it was stored at 60℃. But acute increase was observed 1 day after the storage and the control increased to 21.4 at 3 days of the storage, and *dansam* extract added *yackwa* showed the value of 5.80~11.58 that was higher peroxide value. The peroxide value of *yackwa* added with red ginseng that were stored at 30℃ showed the acid value of 6.73~8.97 meg/kg at the early stage of storage by showing the rapidly increased all of the group, the value was significantly increased at the 6 weeks of storage to the range of 17.78~14.35 meg/kg, and the 8% red ginseng added *yackwa* was rapidly decreased 8 weeks after the storage by showing 13.92 meg/kg which was significantly lower than another *yackwa* (Hyun & Kim 2005).

In the food specification of fried *hangwa*, the peroxide value is specified as less than 40.0 (Korea Food & Drug Administration 2000). So, the 0.05%, 0.1%, and 0.2% addition of *Ulmus davidiana* extracts ranged the peroxide value of 13.81~30.91 meq/kg by showing the safe range in food safety, but the sensory test indicated that the quality was decreased 4 days after the manufacture.

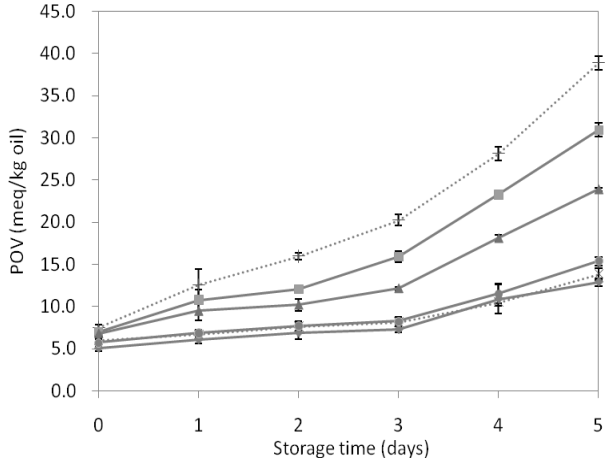


**Fig. 2. Change in peroxide value (POV) of *yackwa* with different concentrations of *Ulmus davidiana* extract during storage.** +: control; ■: 0.05% extract; ▲: 0.1% extract; ×: 0.2% extract; ◆: L-ascorbic acid; ●: BHT. Each value represents mean ± S.D. (n=3)

## Conclusions

In conclusion, as the concentration of *Ulmus davidiana* in *yackwa* increased, decreases in L value, hardness, and off flavor, as well as an increase in water activity, expansion ratio, a value, b value and sensory characteristics were observed. Treatment with *Ulmus davidiana* caused *yackwa* to be darker, most likely because of the Maillard reaction. Furthermore, treatment with *Ulmus davidiana* caused the normal dehydration that occurs during frying to decrease and the consistency of the dough to increase; therefore, it could effectively reduce oil uptake in *yackwa*. In addition, the color, off flavor, and hardness of *yackwa* increased, while the water activity, expansion ratio, and sensory characteristics, decreased with storage time. The antioxidant activity of *yackwa* base that contained *Ulmus davidiana* extract was investigated using several assay methods. The results indicated that *Ulmus davidiana* could be a good antioxidant source. Generally, treatment with L-ascorbic acid, 0.2% *Ulmus davidiana*

extract and BHT were highly effective at increasing the anti-oxidant properties assayed in this study. Although the antioxidant activity of *yackwa* that contained *Ulmus davidiana* extract was less than that of L-ascorbic acid and BHT, these compounds may be useful for retarding lipid oxidation under certain conditions. Therefore, *Ulmus davidiana* can be used to enhance the oxidative stability of oil-containing food. Furthermore, treatment with *Ulmus davidiana* did not affect the taste acceptability, and the sensory evaluations revealed that *Ulmus davidiana* could be used to substitute up to 0.1% of the wheat flour used to produce *yackwa* without decreasing acceptability. However, further studies to determine the mechanism and interaction between food and *Ulmus davidiana*, as well as studies to evaluate the biological activities of *Ulmus davidiana* should be conducted to certify that the extracts are safe.

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