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Fruit Quality, Total Phenol Content, and Antioxidant Activity of Fruit Obtained from a Sustainably Managed vs Conventionally Managed Asian Pear (*Pyrus pyrifolia* Nakai) Orchard

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유기농과 관행재배 된 배의 과실품질과 페놀함량 및 항산화 활성 비교

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Abstract

Although fruit grown under sustainable farming conditions is believed to be healthier for humans than is fruit grown by conventional cultivation, little scientific information on the characteristics of fruit produced using these two farming systems is available in Korea. Therefore, weinvestigated fruit quality, total polyphenolic contents, and anti-oxidant activities in 'Niitaka' pears grown under sustainable and conventional farming management systems. Treatmentsincluded use of a chitin compost admixed with liquid chitin fertilizer (plot A), and use of a chitin compost admixed with liquid chitin fertilizer treated by infrared radiation (plot B). Plots C and D used conventional management systems. Fruit qualities at harvest differed between both sustainable plots A and B and the conventional plots C and D. The average values of firmness and total polyphenolic content in fruit harvested from sustainable plots were not significantly greaterthan those of fruit grownin conventional plots, after 60 days of storage. Fruit grown in all plots had low polyphenol oxidase (PPO) activity at harvest but this increased during storage. Fruit from sustainable plot B showed an increased electron donating ability compared with fruit grown using the other systems.

Key words : Organic, fruit quality, polyphenol, antioxidant activity, chintin, DPPH

Introduction

People have gradually become interested in health risks which can be caused by conventionally grown fruits with synthetic chemical fertilizers, and they are seeking to buy "environmentally friendly" organically grown fruits. Because there is a higher price for organic apples than that for conventional apples, lower yield and higher production cost in the organic farming systems can be figured out by economically more profits (1). The chitin compost and liquid fertilizer are made from crab shells mixed with by-product which is composed of rice straw, wheat straw, and barely straw. It has known that the chitin decomposing fungi had strong resistance against plant pathogenic bacteria (2,3,4). Therefore, the chitin decomposing microorganisms prevented the plant disease by dissolving the cell wall of fungi or the ovisac cell wall of nematode (4,5).

Application of chemical fertilizer or insecticide would affect the contents of phenol compounds in the plants. The organically grown fruits had greater total phenolic compounds compared to conventional fruits (6,7). Phenol compounds play a role in plant defense mechanism thorough the chemical barrier against phytopathogens, and the defense response was related to the total amount of phenol compound oxidized by

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phenolases (8,9). Also, the phenol compound can increase plant resistance against the mechanical stress or harvesting damage and biological invasion by fungi, bacteria, and virus. The phenol compound by polyphenol oxidase (PPO) converted into the polymerization, quinones, which improved a plant defense mechanism by increasing plant toxicity against phytopathogens (10,11). Yamaguchi (12) reported that polyphenol compounds with phenol hydroxyl group in plants showed marked trends toward combining with macro molecules, resulting in increasing antidisease and antioxidant activities. The phenol compounds in apples would be controlled by several internal factors and decreased by application of synthetic chemical fertilizer, insecticide, and herbicide at the conventional apple orchard. There has been studied that some natural substance in fruits and vegetables can suppress free radicals that could partly cause some disease in plants (13). The flavonoid, antocyanin, and isoflavone are parts of polyphenol compound and can maintain products synthesized biochemically in crops (6).

This study was conducted to investigate fruit qualities and antioxidant activities of fruits grown under sustainable farming systems which applied the chitin compost added with chitin liquid or added with chitin liquid treated by ultra infrared radiation as well as fruits grown under conventional farming systems with the synthetic chemical fertilizer, herbicide, and insecticide.

Materials and Methods

Site condition and fertilizer application

The study was conducted with mature 'Niitaka' pears grown under a private orchard in YoungAm, Chonnam, Korea in 2005. The experimental plot consisted of 1 ha (hectare) as a sustainably managed farming system after 1995 and of 3.3 ha as a conventionally managed system. Trees received one of three different treatments: 1) chitin compost and chitin liquid fertilizers (plot A), 2) chitin compost and chitin liquid fertilizer treated with ultra infrared radiation (plot B), and 3) conventional systems (plots C and D). Chitin compost fertilizers were applied at a rate of 4 kg (Jikimi®) per tree at the sustainable farming system during a winter, and foliar chitin applications were applied for 14 times during a growing season. The chitin compost was composed of 30% of hog manure, 30% of rice hulls, 20% of saw dust, 9% of *Bacillus Cereus*, and 1% of mineralized N-P-K. Plots C and D were conventionally managed, using chemical fertilizer, inscetcide, and herbicide.

Fruit quality

Ten trees of each treatment were randomly selected in 2005, and five fruits per tree were used for all evaluations in this experiment. Fruit analysis was conducted both at harvest and after refrigerated storage (0℃) for 60 days. The soluble solids were measured by using a refractometer (ATAGO, Japan), and titrate acidity (%) was reported by titrating a 10 ml juice aliquot with 0.1 N NaOH.

Phenol content

Total phenol compound was conducted by modifying the method of Whang et al. (14). Fresh tissue of 50 g with 250 ml of 80% ethanol was ground and centrifuged with 13,500 g for 5 min. The extractions were decompressed and filtrated through Whatman No 5. The extracted aqueous was decompressed and concentrated at 50℃, which was then diluted by 30-fold. Total phenol compound was determined with Folin-Ciocalteu' reagent, mixing phosphomolybdate and phosphotungstate, according to Ferraris et al. (15). Polyphenol oxidase (PPO) extraction for fruit samples was assayed in 50 mM phosphate buffer (pH 6.8), and the analysis was followed according to Barrett et al. (16). After the samples were filtered and centrifuged, the supernatant was considered as a coenzyme solution. Pyrogallol was used for a substrate to the enzyme reaction, and the absorbance (450 nm) was measured using a UV-visible spectrophotometer (Shimadzu UV-1601, Japan) for the PPO activity.

Antioxidant activity

The electron donating ability (%) in the fruits was measured with the reducing ability of the samples to 1,1, diphenyl-2-picryl hydrazyl (DPPH). Ethanol and water were used as solvent for the sample extractions. One ml of 1.5×10^{-4} M DPPH solution was added into 4 ml of extracted aqueous, and the mixed solutions were shaking for 30 minutes at a room temperature before the absorbance was measured at 520 nm. The electron donating ability (%) was determined followed as

100 of electron donating ability - {(absorbance with the aqueous/absorbance without the aqueous) x 100}.

Experimental design

The study was completely randomized design with 10 replications. Statistical analysis was conducted with Duncan's multiple ranged test level of 0.05 (SPSS, Version 16.0, SPSS, Chicago, IL, USA). Five fruits per tree were randomly chosen.

There were no differences between the tree age in their response variances ($P < 0.05$). Therefore, the data presented in this paper was ignored the effect of tree age on the orchard farming systems.

Results and Discussion

Fruit quality

The plot A treated by the chitin compost added with chitin liquid fertilizers had heavier fruit weights and greater fruit soluble solids but lower firmness (Table 1). The plot B applying the chitin compost and chitin liquid fertilizer treated with ultra infrared radiation showed the highest fruit firmness at harvest time. Plots A and C with greater fruit weight had a lower fruit firmness, and the larger fruits usually produces soften fruits (17). Overall, averages of the fruit weight, firmness, and soluble solids in sustainable plots (A and B) were insignificantly greater compared to the conventional plots (C and D), which was agreed with the previous report (18). Therefore, the sustainable fruits grown in the Southern Korea showed the possibility for the organic farming system because the soluble solids would satisfy consumers' tastes and delaying fruit softening maintains fruit storage life during a long time. Titrate acidity in fruits was greater at the conventional plot D (3.02%), which had the lowest fruit soluble solids (12.1%). There were no treatment effects for the hunter value L as a light index of fruit. The fruits grown under the plots A and B showed the yellowest and reddest colors, respectively (Table 1).

Table 1. Characteristics of 'Niitaka' pear fruits with different cultivation methods

Treatment[1)]	Fruit weight (g)	Firmness (kg/ϕ5mm)	Soluble solids (%)	Acidity (%)	Hunter value[2)]		
					L	a	b
A	793^{a}[3)]	1.86^{b}	13.5^{a}	2.84^{ab}	63.8^{a}	8.96^{b}	42.2^{a}
B	664^{b}	2.65^{a}	12.9^{ab}	2.60^{ab}	63.9^{a}	10.38^{a}	41.1^{ab}
C	728^{a}	1.73^{b}	12.9^{ab}	2.35^{b}	64.0^{a}	9.76^{ab}	41.7^{ab}
D	570^{c}	2.30^{a}	12.1^{b}	3.02^{a}	64.5^{a}	8.79^{b}	41.0^{b}

[1)] A and B: organically managed plots, C and D; conventionally managed plots.
[2)] L = lightness (1-100); a = green (-60)~red (60); b = blue (-60)~yellow (60).
[3)] Mean separation within columns by Duncan's multiple range test at P = 0.05.

The strongest fruit firmness were observed during the 60 days storage period at the sustainable plot B, and the fruits grown under sustainable plot A had a constant firmness during the whole storage periods (Fig. 1). Conversely, the fruits grown under the conventional plot D was rapidly soften after 60 days of harvest. Conventional farming management system had greater internal ethylene concentrations for 'Gala' apples during 3 months at a refrigerated storage compared to an organic system (18). In addition to the ethylene, the conventional fruits had a greater nitrogen content compared to organic and integrated management systems, which was related to the lower fruit firmness. However, more research needed to observe if the integrity of cell wall, related to the firmness, was controlled by which factors, such as water content, calcium concentration, and carbohydrates, involved.

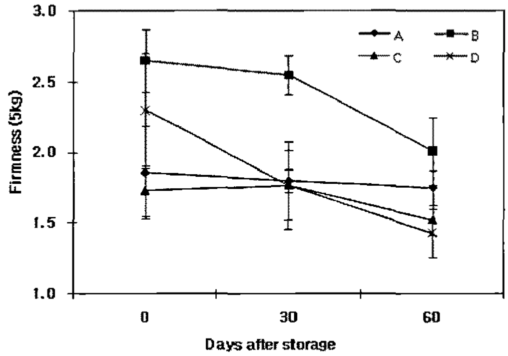

Fig. 1. Monthly firmness of 'Niitaka' pear fruits with different cultivation methods during storage.

A and B: organically managed plots, C and D; conventionally managed plots. Vertical bars indicated mean of the standard deviation.

Phenol compound and antioxidant activity

Although, organically grown fruits had greater firmness and phenolic compounds compared to the integrated production system for 'Golden Delicious' apples (6,7), the variation of phenol compound was followed by the similar graphic trends of the fruit firmness of each treatment during 60 days storage period (Fig. 2). Average of total phenol content in sustainable plots tended to have greater than the conventional plots at 60 days storage. Overall, the total phenol compounds decreased at all plots during the fruit storage.

The fruits grown under all plots did not have significantly different polyphenol oxidase activities (PPO) at harvest (Fig. 3). Average of PPO activity in conventional plots C and D had slightly greater than that of sustainable plots A and B during the 60 days storage. Fruits may encounter internal and external physiological disorders during the long storage life, but the average of phenol compounds in sustainable fruits tended to be constant during the whole period in this study. The maintenance of firmness and lower internal ethylene could have partly affected stable compartments in the fruits even though the phenol compounds were not significantly different among the treatments at the initial storage time (Fig. 2). Seo et al. (19) reported that decreased phenol compound was significantly related to the increased PPO activity to prevent some potential disease and physiological disorders in Asian pear trees.

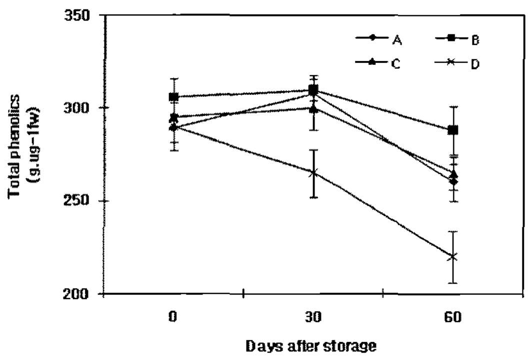

Fig. 2. Monthly total phenolic content of 'Niitaka' pear fruits with different cultivation methods during storage.

A and B: organically managed plots, C and D; conventionally managed plots. Vertical bars indicated mean of the standard deviation.

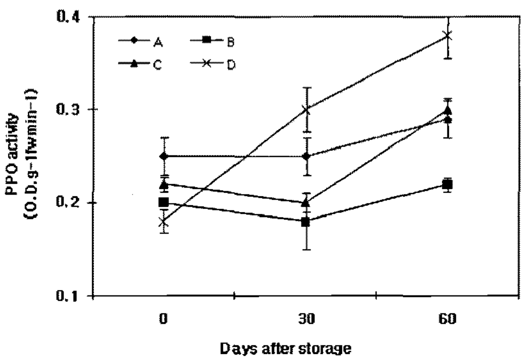

Fig. 3. Monthly polyphenol oxidase (PPO) activity of 'Niitaka' pear fruits with different cultivation methods during storage.

A and B: organically managed plots, C and D; conventionally managed plots. Vertical bars indicated mean of the standard deviation.

The electron donating conductivity in a plant can easily estimate antioxidant activity through the free radical 1,1, diphenyl-2-picryl hydrazyl (DPPH). The fruits of sustainable plot B had greater electron donating abilities which were extracted by ethanol and water, but the fruits in conventional plot D showed the decreased abilities (Fig. 4). Electron donating ability had a similar trend of the total phenolic compounds at the end of the storage (Fig. 2), and the phenol compounds would have considerably acted as an antioxidant in the fruits at a longer storage period. However, other enzyme activities also might have induced PPO activity.

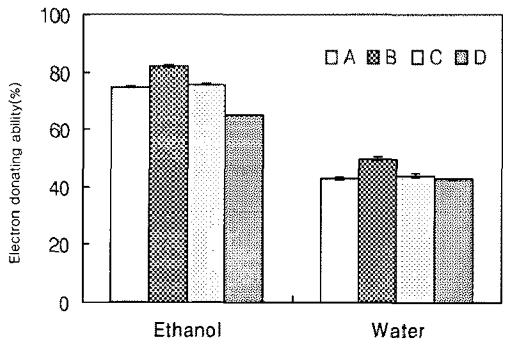

Fig. 4. Electron donating ability 'Niitaka' pear fruits with different cultivation methods.

A and B: organically managed plots, C and D; conventionally managed plots. Vertical bars indicated mean of the standard deviation.

Conclusions

Overall, the sustainably managed trees had similar internal fruit qualities at harvest compared to the conventional fruits although this experiment was one year study with the mature pear trees in private farms. Averages of firmness, phenolic compounds, and antioxidant levels in fruits harvested in sustainable plots were insignificantly greater than the conventional fruits, and farmers then could even sell the fruits with a higher price plus a higher premium at marketplace. However, the variances were existing among the sites of this experiment, and the presented results should reconfirm year fluctuations at all the treatments. Therefore, the long term research is required to investigate fruit nutrition and healthy compounds in the future in order to observe certain information of the organic pear farming system.

요 약

유기농과 관행재배 된 배 과실품질과 페놀함량 및 항산화 활성 비교

최근에 유기 재배된 과실이 관행재배와 비교해서 건강관련 물질과 관련된 화합물이 다량 분포된다는 연구와 주장이 제기되어 왔지만, 국내에서는 두 가지 재배방법에 따른 과실품질을 분석한 연구는 미비한 실정이다. 본 연구는 유기농과 관행으로 재배 된 배 '신고'의 과실품질과 폴리페놀 및 항산화 활성을 조사하였다. 처리는 키틴 복합퇴비+키틴 액비(구역 A), 키틴 복합퇴비+적외선으로 처리 된 키틴 액비(구역 B), 그리고 관행재배 시스템(구역 C와 D)으로 나누었다. 처리구간에 따른 수확기 과실 품질은 일정한 효과를 나타내지 않았다. 과실 저장 60일 후 유기농 구역 A와 B에

서 재배된 과실의 경도와 페놀함량의 평균은 관행 재배구보다 약간 더 높은 경향을 보였다. 모든 구역에서 수확 시기에는 낮은 함량의 폴리페놀 산화효소 활성을 나타냈으나, 저장 기간 동안 증가하는 경향을 나타냈다. 유기 재배구인 구역 B는 다른 재배구들에 비교해서 과실 내 높은 전자 공여도를 나타내었다.

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