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Pyruvic Acid and Sugar Contents during Storage Duration in Onion (*Allium cepa* L.)

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Abstract. This study was carried out to access the stauts of pyruvic acid and sugars in onion bulbs during storage at room temperature. Pyruvic acid content remained in a steady state until 3 months of storage. However the pyruvic acid content gradually increased as the onions started to root, and rapidly increased after sprouting. There was no difference in dry matter contents during storage.e. Sucrose content increased as storage duration extended, and then gradually decreased right after the onions started to sprout. Fructose content gradually decreased after 45 days of storage, and remained in a steady state after sprouting. Glucose content had a tendency to increase as storage duration extended. Pyruvic acid/total sugar (PA/TS) ratio decreased after 1 month of storage, and then increased after 135 days, and was 83% higher at 150 days of storage than at harvest. Sweetness gradually decreased until 1 month of storage, but thereafter remained steady. Therefore it is desirable that pyruvic acid analysis for sweet onion selection should be conducted before breaking the dormancy.

Key words : pyruvic acid, rooting, sprouting, storage, sweetness

Introduction

The secondary organosulphur compounds of onions are responsible for the pungent flavour and aroma. Thiosulphinates, the predominant flavour compounds in raw onion, are formed when the flavourless S-alk(en)yl-L-cysteine sulphoxides (ACSOs) are lysed by the alliinase upon tissue disruption. The initial products of this reaction are sulphenic acid, pyruvate and ammonia. Depending on the alk(en)yl substituent present, sulphenic acids condense in pair to form thiosulphinates or arrange to form thiopropanal sulphoxides of lachrymatory factor (Block, 1992). The alliinase is responsible for breaking down these precursors to pyruvate, ammonia, and a thiosulphinate. Total ACSOs levels were significantly correlated with pyruvate ($R^2 = 0.864$, $p < 0.0001$) and there was a significant inverse relationship between the pyruvate level of onion bulbs and their sweetness, as described by the first series of taste-panels ($R^2 = 0.4397$, $p < 0.0001$) (Crowther et al., 2005).

Plants produce a large number of secondary metabolites for bioactivities including reproduction, defense, pathogenicity, stress resistance and resource storage (Jones et al., 2004). The suggestion that 15~20% of each plant genome is devoted to secondary metabolism is another indication of their importance (Pickersky and Gang, 2000).

ACSOs stored in onion bulb during vernalization could be transported to growing leaves, scapes and umbels. The umbels might need additional reserves of nitrogen and sulphur for pollen production. As a defense against pests, mobilization of ACSOs could improve survival and fitness of onion plant. During vernalization, the bulb would be protected by the ACSOs. Organosulphur compounds would be useful in warding off animals that would attack newly emerging fleshy tissues such as leaves and scapes. High pungency in seedling sprouts and umbels containing developing seeds would improve progeny survival (Briggs and Goldman, 2002).

Onion has a biennial life cycle. Typically, onion varieties in Korea are short-day type, which are sown in Autumn and harvested in May or June. Storage onions are circulated the market until fresh bulb onions are harvested next year. Therefore, the price steadily increased and quality remarkably deteriorate because of bulb decay. Bulb dry matter content is an important quality parameter

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of onion, and several investigations have attempted to relate bulb characteristics and storage life (Rutherford and Whittle, 1984). Dry matter is most important among factors affecting on the quality of onions, and about 80% of bulb dry matter is comprised of non-structure carbohydrates like sucrose, glucose, fructose and low-molecular weight fructans (Benkeblia et al., 2002). The metabolism of sugars is closely linked to the dormancy and sprouting states (Kato, 1966), and the most important biochemical changes occurring during long-term storage of bulbs, as with other vegetables, are related to quantitative variation in the carbohydrate constituents (Benkeblia et al., 2004). Therefore the purpose of this study is to investigate the changes of sweetness, pyruvic acid and sugar levels in bulbs during storage duration.

Materials and Methods

Seed of onion cv. '*Powerball*' (a F1 hybrid cultivar for fall transplanting, Haesung, Korea) was sown in 128-cell plug tray on September 9, transplanted on November 20 and harvested on May 27. Harvested bulbs were stored at room temperature. Dry weight during storage were examined at 15-day intervals from harvest to sprouting time.

Pungency was evaluated by measuring the quantity of pyruvic acid present in extracts as modified method from Yoo et al. (1995) using UV-vis spectrophotometer (UV-1201, Shimadzu, Kyoto, Japan) in 485 nm. Values are expressed as the mean of five replicates for each organ at each time point. Onion bulbs were immediately chopped into pieces 5 mm square and incubated for 5 minutes in room temperature. After that bulb tissues were blended with liquid nitrogen to inactivate the alliinase. The frozen powder were mixed with an equal volume of distilled water for 15 minutes in room temperature and then centrifuged at 15,000 rpm for 15 minutes. The supernatant could be used for samples. DNPH (2,4-dinitrophenylhydrazine, Kanto Chemical, Tokyo, Japan) was dissolved in 2 N HCl and sodium pyruvate (Junsei Chemical, Tokyo, Japan) was used as a standard preparation of pyruvate.

Sugar content was analyzed with HPLC (Waters 2695, Massachusetts, USA), Waters Sugar-Pak 1 (6.5×30 mm) column making use of sucrose, glucose and fructose as standard materials. Analysis condition was column temperature 85°C, flow rate 0.6 ml/min, injection volume 10 μl. Distilled water was used in mobile phase and RI detector (Waters 2414, Massachusetts, USA) was used for detection. Sweetness was calculated by converting analysis result of free sugar composition according to each kind of sweet level coefficient (Kim et al., 2001), PA/TS rate which calculated pyruvic acid (PA) content to total sugar (TS) content based on the Vavrina (1993) was used an indicator to measure pungent flavor of onion.

Results and Discussion

The existence of a true period of dormancy in onion bulbs is still a matter of debate (Komochi, 1990). If the containing meristematic activity of apical meristems can be ignored, onion bulbs are considered to enter a period of dormancy near harvest, when their foliage collapses (Yasin and Bufler, 2007). Metabolic activity of onions doesn't cease completely for the duration of dormancy (Lang et al., 1987) and is suddenly on the rise again after sprouting (Komochi, 1990).

Middle maturing cultivar '*Powerball*' showed symptoms of rooting after 120 days of storage and then sprouting was observed within scales. About 46% internal sprouting was observed after 135 days of storage and most of the onions (about 80%) sprouted within 150 days of storage (Table 1).

Pyruvic acid content gradually decreased until 75 days of storage, and then it increased slowly again until 135 days of storage. After 135 days, pyruvic acid content increased rapidly (Fig. 1). These results are in disagreement with the previous findings that pyruvic acid content slightly increased after 2 months in room temperature storage (Lee et al., 2007). In this experiment this may be resulted from long dormancy period of middle maturing cultivar, which is longer than early maturing cultivar.

Table 1. Seasonal changes in rooting and sprouting rate after harvest.

Days after harvest	Rooting rate (%)	Sprouting rate (%)
90	0.0	0.0
120	27.3	9.1
135	100.0	45.5
150	100.0	80.0

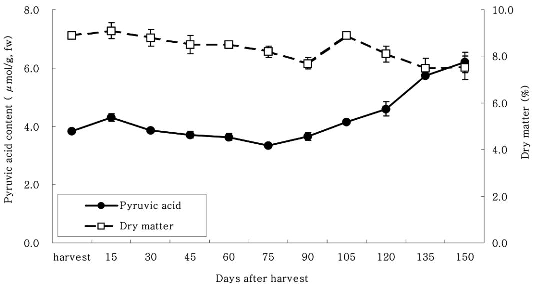

Fig. 1. Seasonal changes in pyruvic acid and dry matter content of onion bulb after harvest. Vertical bars indicate standard error (n = 5).

As the storage duration got longer, flavour and taste of onions got worse and fresh weigh of onion bulbs gradually decreased because soluble solids content was increased as water content of onion bulbs decreased (Lee et al., 2007). Storage life of onion was extended (Smittle et al., 1979), quality was remained (Foskett and Peterson, 1949) and resistance of rot disease was increased (Owen et al., 1950) as dry matter increased. In this experiment, it was shown that the dry matter content of onion bulbs was 8.3% at harvesting time and then decreased slowly as storage duration extended. Finally it decreased up to 7.5% after 150 days of storage (Fig. 1). This result is agreement with the previous result that the dry matter content of the inner scale decreased continuously more or less during storage (Yasin and Bufler, 2007) and it had no difference during storage (Bacon et al., 1999).

Sucrose content increased as storage duration extended, and then gradually decreased after the onions started to sprout. Fructose content gradually decreased after 45 days of storage, and remained in a steady state after sprouting (Fig. 2). These results are in agreement with the previous result of Yasin and Bufler (2007). Glucose content had a tendency to increase as storage duration extended. Byproducts of sucrose degradation are an important factor presenting the breakdown of dormancy. Internal sprouting could be initiated by the accumulated disacchredes (Benkeblia and Selselet-Attou, 1999) and sucrose content could be decreased gradually as the onion started to sprout because sprouting induces to catabolize the glucose and sucrose when the dormancy was broken and the growth was restarted (Benkeblia et al., 2004). On the one hand, sucrose content of onion slightly increased as storage duration extended. On the other hand glucose content increased slightly during the first 5 weeks, and thereafter gradually decreased. The fructose content of onion also increased until 20 weeks, and then decreased (Salama et al., 1990). However, in the experiment of Benkeblia et al. (2004) there was no significant differences in total saccharides (glucose, fructose and sucrose) of onion bulbs stored for 6 months, because the content of free sugars depended on the cultivars (Randle, 1992). Surprisingly, however, the status of saccharides in stored onion bulbs is not clearly determined despite the metabolic importance of sucrose, which is an intermediate compound between fructans and trisacchrides, and glucose and fructose play a central role in growth and development in plants (Benkeblia and Selselet-Attou, 1999).

PA/TS rate decreased after 1 month of storage compared to harvest time, and then it increased after 135 days that started to sprout markedly. At 150 days of storage it increased up to 83% compared to harvesting time. Sweetness during storage duration decreased gradually until 1

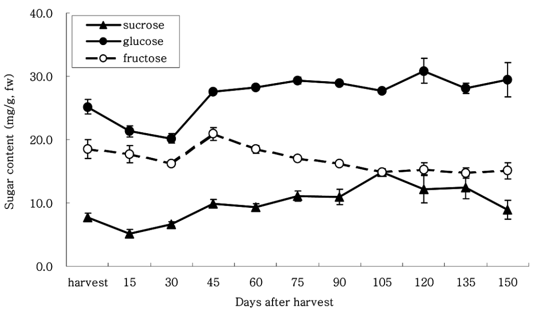

Fig. 2. Seasonal changes in individual sugar content of onion bulb after harvest. Vertical bars indicate standard error (n = 5).

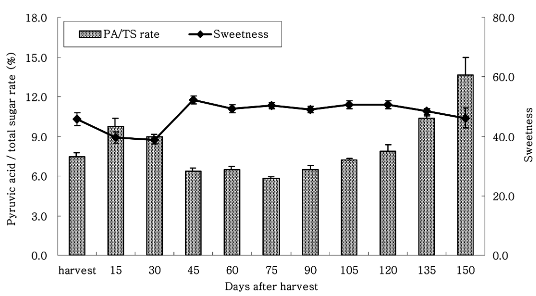

Fig. 3. Seasonal changes in PA/TS rate and sweetness in onion bulbs after harvest. Vertical bars indicate standard error (n = 5).

month of storage and increased slightly again later on. However there was no significant difference in sweetness during storage duration (Fig. 3). Therefore it is desirable that pyruvic acid analysis for sweet onion selection should be conducted before breaking the dormancy.

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Pyruvic Acid and Sugar Contents during Storage Duration in Onion (*Allium cepa* L.)

양파 저장 중의 Pyruvic Acid와 당 함량의 변화

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적 요. 본 연구는 저장 기간 중 양파 구의 pyruvic acid와 당 함량의 변화를 분석하고자 한다. 저장 중의 pyruvic acid 함량은 저장 3개월까지는 큰 변화가 없었으나 저장 120일경부터 발근이 시작되면서 서서히 증가하기 시작하여 맹아기 이후 급격히 증가하였다. 그와 대조적으로 건물함량은 저장 기간 동안 큰 변화가 없었다. Sucrose 함량은 저장기간이 경과할수록 증가하다가 맹아가 진행됨에 따라 감소하였다. Fructose 함량은 저장 45일째 이후로 서서히 감소하여 맹아기 이후에는 큰 변화가 없었다. Glucose 함량은 저장기간이 경과할수록 증가하는 경향이었다. 저장기간 중 총당(TS) 함량에 대한 pyruvic acid(PA) 함량 비율(PA/TS ratio)은 수확시에 비해 저장 한 달 이후부터 감소하였으며, 이 후 내부맹아가 관찰되는 135일째부터 급격하게 증가하여 저장 150일에는 수확시에 비해 83% 정도 증가하였다. 저장기간 중 감미도는 저장 한 달 까지는 서서히 감소하였으나 그 이후 증가하였고, 저장기간 중 큰 변화가 없었다. 따라서 단 양파 선발은 휴면이 타파되기 전에 실시하는 것이 바람직할 것으로 생각된다.

주제어 : 감미도, 맹아, 발근, 저장, pyruvic acid