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Post-harvest Science and Technology of Citrus Fruits

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INTRODUCTION

Jeju island is a famous sightseeing place in Korea, and its main agricultural product is satsuma mandarin (*Citrus unshiu* Marc.). Average 6×10^5 MT of citrus fruits are produced annually in Jeju, and near 50% of agricultural incomes are derived from citrus fruits in total. This study is mainly to develope post-harvest science and technology, especially storage technology of citrus fruits produced in Jeju, and also efficient utilization system including processing technology.

Post-harvest Science and Technology of Citrus Fruits

Grading of citrus fruits produced in Jeju are growing concern for improvement of market structure. Fruits quality are depended on many factors of agricultural environments such as varieties, climatic conditions of production year, cultivation areas, harvest times, size and individual variations, and etc. Therefore, physico-chemical properties, chemical analysis, sensory evaluation, factors affecting on the quality of citrus fruits for fresh consumption, and develope grading technology from their relationships were investigated. The studies included also chemical analysis of carotenoid, hesperidin, naringin, color value, UV spectrum, organic acid, free sugar, inorganic elements contents, pectin etc in citrus varieties.[1-21]

Soluble solids, total sugar and acid content of *Citrus unshiu* were 10.4～11.0°Brix, 8.24～8.79% and 1.04～1.20%, respectively. Vitamin C ranging from 41.19～46.55 mg/100 g was higher on medium type than on early type of *Citrus unshiu.* In case of inorganic elements in *Citrus unshiu*, potassium content was the highest, in the range of 108.66～132.65 mg/100 g, and it was higher on *C. platymamma* than on *Citrus unshiu.* However, the kinds and contents of carbohydrate in citrus juice were somewhat different among citrus varieties. Sucrose was 46.8～64.6% and others were glucose and fructose, 18.4～26.9% and 15.2～30.2%, respectively. Citric acid content was 75.7～96.2%, and others were malic acid, oxalic acid, and fumaric acid in the decreasing order.[6]

Alcohol-insoluble solid (AIS) of peel and flesh of satsuma mandarin were decreased quickly from 27.04 g/100 g to 12.30 g/100 g, and from 2.67 g/100 g to 1.91 g/100 g during ripening of fruits. During storage of fruits, AIS of peel was decreased from 14.32 g/100 g to 12.06 g/100 g. During ripening of fruits, water soluble pectin (WSP) of peel were increased from 420.82 mg/100 g to 601.62 mg/100 g as wet basis. Hexameta-phosphate soluble pectin (HMP) was also increased from 450.17 mg/100 g to 577.53 mg/100 g. Hexameta-phosphate soluble pectin (HSP) was decreased from 1938.80 mg/100 g to 695.14 mg/100 g[19] (Table 1).

Storage Technology of Citrus Fruits

Post-harvest physiology,[19,20,29,30] various pretreatment effects for storage,[26,32,36,48] optimum storage conditions of satsuma mandarin[22,24,31,46,47] and late maturing citrus fruits,[23,44,49] CA storage[66] and MA storage[43] were investigated. The studies included also interrelation between respiration rate, peel permeability and internal atmosphere for sealed and wax-coated satsuma mandarin,[29] an analysis of thermal convection and environmental

Table 1. Changes in pectin of satsuma mandarin during storage (mg/100 mg-AIS)

Storage days	Peel				Flesh			
	WSP	HMP	HSP	TPS	WSP	HMP	HSP	TPS
0	3.79 (543.70)*	3.55 (507.82)	4.69 (672.28)	12.03 (1723.80)	2.99 (64.27)	1.19 (25.51)	4.12 (88.67)	8.30 (178.45)
15	3.69 (495.47)	2.97 (398.01)	4.46 (598.68)	11.12 (1492.16)	2.17 (47.09)	1.29 (27.91)	3.77 (81.72)	7.23 (156.72)
30	3.32 (417.64)	2.37 (298.16)	3.30 (415.43)	8.99 (1131.23)	2.19 (46.13)	0.97 (20.41)	2.76 (58.32)	5.92 (124.86)
45	3.63 (451.00)	2.36 (293.76)	3.20 (397.76)	9.19 (1142.52)	2.32 (49.34)	0.91 (19.40)	2.54 (54.19)	5.77 (122.93)
60	3.92 (481.82)	2.35 (288.74)	3.22 (396.27)	9.49 (1166.83)	2.69 (55.37)	0.88 (18.14)	2.46 (50.63)	6.03 (124.14)
75	4.03 (490.14)	2.30 (279.80)	3.02 (367.06)	9.35 (1137.00)	2.83 (51.82)	0.88 (16.09)	2.41 (44.08)	6.12 (111.99)
90	4.11 (502.59)	2.37 (289.72)	2.93 (359.21)	9.41 (1151.52)	2.74 (48.16)	0.93 (16.44)	2.48 (43.56)	6.15 (108.16)
105	4.15 (505.42)	2.32 (282.02)	2.92 (354.95)	9.39 (1142.39)	2.76 (42.29)	0.94 (14.33)	2.39 (36.52)	6.09 (93.14)
120	4.07 (483.22)	2.32 (275.69)	2.89 (343.28)	9.28 (1102.19)	3.01 (47.32)	1.06 (16.70)	2.27 (35.68)	6.34 (99.70)
135	4.21 (510.13)	2.39 (289.44)	2.98 (361.69)	9.58 (1161.26)	3.27 (49.08)	0.98 (14.74)	2.39 (35.82)	6.64 (99.64)
150	4.85 (584.31)	2.28 (275.47)	2.91 (351.36)	10.04 (1211.14)	3.36 (49.99)	0.87 (12.98)	2.33 (34.69)	6.56 (97.66)

*The values in parenthesis were calculated as mg per 100 g of citrus fruits.
WSP: water soluble pectin, HMP: hexametaphosphate soluble pectin, HSP: hydrochloric acid soluble pectin, TPS: total pectin substance.

control[27,28,35,41,42] in agricultural-products storage system, prediction of shelf-life for short-term storage,[30] oily wax-coating[29,30,33,34] and seal packaging effects[22,31,34] during storage, economic evaluation.[45] The pretreatment of natural products such as grapefruit seed extract, chitosan, peel oil, Ca-compounds[33,38,40,49] were investigated to reduce decay ratio and to prolong the storage periods. Other researches on the storage of citrus fruits were also carried out.[22-49]

Quality changes of satsuma mandarin (*Citrus unshiu* Marc. var. *miyagawa*) by storage warehouse were investigated. Citrus were treated with 2000-folds diluted iminoctadime-triacetate solution and 1.5% chitosan with 0.5% $CaCl_2$ solution, and were at 30°C for 24 hr before storage. The citrus of about 12 kg/26 L plastic container were stored at room temperature, and at 4°C with 87% relative humidity. Decay ratio of citrus with precise temperature and humidity control were lower than the others during storage. *Penicillium italicum, Monilia candida, Alternaria citri, Mucorhiemalis, Phomopsis citri, Botrytis cinerea, Phoma citricarpa, Glomererella cingulata, Penicillium digitatum* were identified as putrefactive microorganisms in citrus storage. Weight loss, moisture content of peel and flesh were decreased slowly during storage. 24% of original acid content were decreased at room temperature on 120 days' storage, compared to 15~18% loss on cold storage. Total sugar of citrus was decreased rapidly after 90 days, and vitamin C content were also decreased rapidly after 60 days during storage.[47]

Processing Technology of Citrus Fruits

Isolation, screening and identification of strains for citrus wine-making, pectinase production conditions and characteristics of its enzymes, and effects of pectinase addition for the clarification of wine, fermentation conditions, chemical analysis, aging effects, sensory evaluation for citrus wine and brandy were investigated.(50-54)

Physicochemical properties for processing of citrus fruits, development of processing technology for jam and liquid-type tea with *Citrus unshiu, Citrus natsudaidai,* Kumquat and Fig were investigated. Citrus jam and tea products were commercialized by Samda Agricultural Co. Ltd. (Jeju) through transfer of our technology in 1993 and 1994, respectively.(55-60)

Others Related to Citrus Fruits

Effect of supercritical carbon dioxide treatment on quality of citrus juice, inactivation of pectin esterase in citrus juice by supercritical carbon dioxide were investigated.(61-62) Flavonoids of citrus during maturation were also investigated.(63-65)

Hesperidin content in Halla (a kind of *C. unshiu*) harvested at early of maturation was 28.70 mg/g, and it was the highest among tested citrus fruits. Rutin content in Hungjin harvested at early of maturation was 2.66 mg/g. Naringin in all citrus species and hesperetin in Halla, Gungchun, Namgam-20 and Chungdo were just appeared in samples harvested at early of maturation, respectively. Hesperidin and rutin were detected mainly in all citrus species, and other flavonoids were in trace. Individual flavonoids content were high in peel of fruits at early of maturation, and then was decreased rapidly. These results showed that immatured citrus fruits is more proper to utilize flavonoids than matured citrus fruits(63) (Table 2).

Changes of flavonoids contents of late maturing citrus varieties during maturation were also investigated. Naringin and neohesperidin content in the peel of Jawdung harvested at the early stage of maturation were 34.02 mg/g and 13.68 mg/g, respectively, and it was highest among the tested citrus fruits. Hesperidin content in the

Table 2. Change of flavonoids in satsuma mandarin (mg/g)

	Date	RT	NGI	HD	NHD	DN	QT	NGE	HT	KL	NT	FL	TT
Illnam-1	8/27	1.68	0.24	25.87	N	N	0.13	N	0.21	N	0.11	0.06	0.02
	9/27	1.01	N	13.12	N	N	0.08	N	N	N	0.06	0.03	0.01
	10/29	0.89	N	11.39	N	N	0.07	N	N	N	0.05	0.02	N
Halla	8/27	2.01	0.12	28.70	N	N	0.18	N	0.10	N	0.10	0.01	0.02
	9/27	0.68	N	9.33	N	N	0.05	N	N	N	0.04	0.01	N
	10/29	0.58	N	8.63	N	N	0.05	N	N	N	0.02	N	N
Gungchun	8/27	1.97	0.12	23.46	N	N	0.14	N	0.16	N	0.10	0.07	0.03
	9/27	0.86	0.03	9.78	N	N	0.06	N	0.05	N	0.07	0.08	0.01
	10/29	0.88	N	9.06	N	N	0.07	N	N	N	N	0.01	N
Hungjin	8/27	2.66	0.23	24.57	N	N	0.18	N	0.21	N	0.13	0.08	0.02
	9/27	1.00	N	10.50	N	N	0.08	N	0.02	N	0.06	0.04	0.01
	10/29	0.89	N	10.25	N	N	0.07	N	0.02	N	0.05	0.03	0.01
	12/9	0.87	N	10.19	N	N	0.08	N	0.03	N	0.07	0.03	0.02
Namgam -20	8/27	1.25	0.26	16.40	N	N	0.10	N	0.20	N	0.11	0.06	0.04
	9/27	1.09	0.02	15.11	N	N	0.06	N	0.05	N	0.07	0.05	0.02
	10/29	0.94	N	13.83	N	N	0.05	N	N	N	0.06	0.04	0.01
	12/9	0.57	N	12.53	N	N	0.05	N	N	N	0.08	0.03	0.03
Chungdo	8/27	1.58	0.09	17.85	N	N	0.11	N	0.09	0.02	0.06	0.06	0.02
	9/27	1.37	0.01	16.21	N	N	0.07	N	0.02	N	0.06	0.05	0.02
	10/29	1.17	N	14.56	N	N	0.07	N	N	N	0.08	0.04	0.02
	12/9	0.92	N	11.34	N	N	0.07	N	N	N	0.05	0.03	0.01

N: Not detected, Unit: mg/g.

RT: rutin, NGI: naringin, HD: hesperidin, NHD: neohesperidin, DN: diosmin, QT: quercetin, NGE: naringenin, HT: hesperetin, KL: kaemferol, NT: nobiletin, FL: 3,5,6,7,8,3'4'-methoxylated flavone, TT: tangeretin.

peel of Mucott harvested at the early stage of maturation was 12.48 mg/g. Rutin content of Sambogam harvested at the early stage of maturation was 5.13 mg/g. Quercetin, naringein, kaempferol, nobiletin, 3,5,6,7,8,3',4'-methoxylated flavone flavonoids were in trace. Flavonoid contents of Singamha, Sambogam and Jawdung were high in the peel of fruits at the early stage of maturation, after which time they decreased rapidly.[65]

Almost all of these results were summarized on the book of *'Citrus Industry, Post-harvest Science and Technology'*[67] published in 2000.

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