Korean J. Crop Sci. 45(5): 300~304(2000)

Changes in Sugar Contents and Storability of Yacon under Different Storage Conditions

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ABSTRACT: Tuberous roots of yacon (*Polymnia sonchifolia* Poeppig & Endlicher) were stored in different temperature and relative humidity conditions after curing for 30 days. Non-decadent percentage, moisture contents, brix degree and sugars were investigated. Whether temperature and relative humidity were high or not, most of the tuberous root decayed during storage, and the decayed percentage was increased as long as the storage period. In final, only 13% of tuberous roots remain intact at 4°C, 85% relative humidity condition to be appeared best storage condition in this experiment and all of the tuberous root decayed in other storage conditions after 6 months. Moisture contents decreased a little in the high relative humidity. Even though tuberous roots decayed when stored at 10°C and 20°C, most of brix degree reached about 17.0. Fructose, glucose and sucrose contents were 1.65, 1.15 and 0.35% at early storage period, and 1.6, 1.1 and 0.5% after 6 months at 4°C, 85% relative humidity, respectively. In 3 temperature conditions, fructose and glucose increased for a month and then decreased successively afterwards, but sucrose increased gradually during 6 months. Also in 4 relative humidity conditions, fructose, glucose and sucrose contents were changed with similar to that of in temperature. Changes of fructose and glucose were the same except on 4°C, 85% relative humidity, that was lower level than moisture of tuberous root.

Keywords **:** *Polymnia sonchifolia*, yacon, storage condition, decay, moisture contents, brix degree, fructose, glucose, sucrose.

Yacon (*Polymnia sonchifolia* Poeppig & Endlicher) plant was introduced about 15 years ago from Japan. It has been used as ingredients in various foods including iced noodles, chopped noodles, fries, pancakes and dumplings. Consume of yacon is predicted to be increased gradually in the near future, so more researches are required.

Tuberous root contained as much moisture as about 86 ± 2% (Asami *et al.*, 1989a, b), so its decay occur very early. Storage conditions such as temperature and humidity are most important to affect much physiological functions of tuberous root and tuber crops. Tuberous root of yacon is not containing starch, but brix degree changes during after-ripening and storage period (Asami *et al.*, 1989a, b, 1991a; Ohyama *et al.*, 1990). Tuberous root of yaocn after ripening for a month were stored at storage rooms with different temperature and humidity. Storability, the changes of moisture contents, brix degree and sugar were investigated,

MATERIALS AND METHODS

Plant material, cultivation and curing

Crown bud of yacon (*Polymnia sonchifolia* Poeppig & Endlicher) was obtained from the National Crop Experiment Station, Rural Development Administration. Seedlings of yacon were cultivated in the field of the experimental farm, Chonbuk National University from May 10 to November 10 (about 170 days), 1998. Fertilizers application was 70-60-200 kg/ha of N-P_2O_5-K_2O and 10 tons/ha of compost. It was tilled twice by the depth about 17 cm at 30 days and 3 days before planting and ridged at every 70 cm interval. The surface of ridges was mulched by polyethylene film, which was combined with transparency on center and black on both outside. About 15 cm seedlings were planted in ridge at 50 cm distance. At 30 days after planting, the plants were earthen up above film around roots. The tuberous roots were harvested on November 10, 1998, and then placed to after-ripening treatment in green house for a month that was covered with single-polyethylene film. Tested tuberous roots were about 150 g or more, respectively.

Storage conditions and sampling

Tuberous roots were stored under storage rooms, with 85% relative humidity which were controlled at 4 ± 0.5°C,

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<Received October 7, 2000>

10 ± 0.5°C and 20 ± 0.5°C temperature, respectively. To find the optimum relative humidity, other tuberous roots were placed in cold storage rooms at 80, 85, 90 and 95% relative humidity, and maintained at 10 ± 0.5°C temperature. Tuberous roots were sampled every 30 days during 6 months.

Storability

Storability was represented for the percentage of non-decadent number to total stored number per every treatment during 6 months.

Measurement of moisture contents

Before loading the tuberous root samples, weight of petri dishes were measured after being dried at 10 ± 51°C for 2 hours and cooled in desiccators. Petri dishes with about 2~3 g tuberous root were measured as soon as tuberous roots were sliced off from 4 to 6 pieces with 23 mm, respectively, and then it's weights were measured after being dried at 105 ± 1°C for 3 days and cooled on desiccator. Moisture contents was calculated as the following equation.

$$\text{Moisture contents (\%)} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

W_1 :Weight of petri dish
W_2 :Weight of petri dish with fresh sample
W_3 :Weight of petri dish with dried sample

Measurement of brix degree

Washed tuberous root was chipped off the skin, juiced using a juicer and then heated for 30 minutes at 60 ± 1°C. Brix degree was measured directly by digital refractometer. This method also was used expect on a kiwifruit (Dull *et al.*, 1992).

Analysis of sugars

To analyze free sugars, 200 g of tuberous roots were sliced and placed in a warring blender. The samples were covered with 100% ethanol to make the final concentration of 80% ethanol. Tuberous root and ethanol were blended at 4,000 rpm for 20 minutes. The mixture was then filtered with suction, and the residue was washed with 200 ml ethanol and filtered once more. The volume of the filtrate from the extract and the washing was reduced to less than 25 ml by a rotary vacuum evaporator. The concentrated samples were made up to 25 ml with distilled water. For elimination of colorful pigment and small particles, the concentrate was passed through the recommended Sep-Pak C_{18} plus cartridge. The 15 μl of the decolored concentrate was injected into High Performance Liquid Chromatography (HPLC) of which conditions are presented in Table 1.

Table 1. Conditions of HPLC for analysis of sugars in the tuberous root of yacon.

	Conditions
Instrument	Beckman HPLC (U.S.A.)
Column	Carbohydrate analysis column (4.6 × 250 mm)
Detector	Waters model 410 refractive index
Sensitivity	× 8
Temperature	35°C
Mobile phase	Acetonitrile/water (75/25)
Flow rate	1.5 ml/min.
Attenuation	× 4
Sample size	15 μl

RESULTS

Storability during storage

Non-decadent percentage according to different temperature and relative humidity were shown in Table 2. Whether temperature and relative humidity were high or not, most of the tuberous root decayed during storage, and the decayed percentage was increased as long as the storage period (Fig. 1). After 3 months period of storage, 90% tuberous root of yacon did not decay when it were stored at 4°C but 23% tuberous root did not decay when it were stored at 20°C. After 4 months, most of tuberous root was decayed when it were stored at 10°C, 95% and 20°C, 85% relative humidity, but 20 and 8% tuberous root did not decay when it were stored at 4°C, 85% and 10°C, 80% relative humidity, respectively, after 5 months. In final, only about 13% of tuberous roots were not decayed when it were stored at 4°C, 85%,

Table 2. Non-decadent percentage of tuberous root according to different temperature and relative humidity during storage.

Storage condition		Storage period (months)					
Temp. (°C)	RH‡ (%)	1	2	3	4	5	6
4	85	100.0	100.0	89.5	45.6	20.5	12.7
10	80	100.0	96.5	75.3	36.4	7.6	0.0
	85	100.0	94.4	74.6	37.8	0.0	-
	90	98.2	95.5	73.7	33.5	0.0	-
	95	96.8	92.3	65.5	0.0	-	-
20	85	96.5	79.2	22.8	0.0	-	-

‡realtive humidity

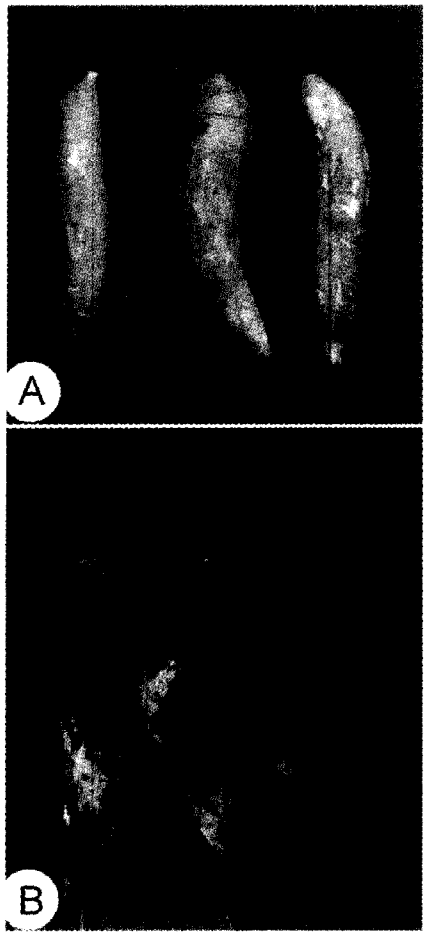

Fig. 1. (A) Non-decadent tuberous roots after 2 months and (B) decadent tuberous roots after 4 months at 10°C, 85% relative humidity.

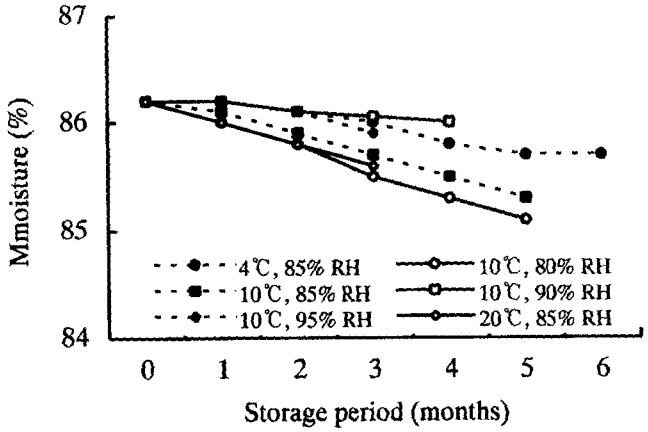

Fig. 2. Changes of moisture contents in tuberous root of yacon by the various storage conditions.

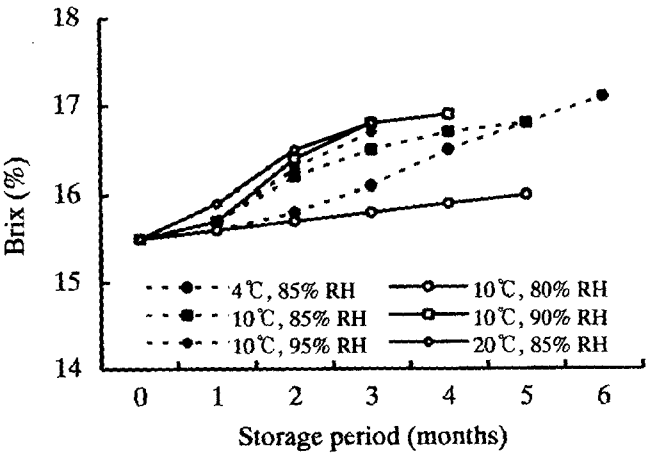

Fig. 3. Changes of brix degree in tuberous root of yacon by the various storage conditions.

and all of the tuberous root did decay after 6 months in other storage conditions. Considering only the storability, storage room should be controled to be about 4°C temperature and 85% relative humidity. However those were not suitable to store for a long time more than 3 months.

Change of moisture contents

The moisture contents of tuberous root was 86.2% when it were after-ripening for 30 days after harvesting. In 6 months storage, moisture contents were ranged from 85.1 to 86.1%, which was little decrease than those of after ripening. Moisture contents was decreased about 1% at 10°C, 80% relative humidity storage room. It was decreased a little about 0.1 and 0.2% at 10°C, 95 and 90% relative humidity, respectively (Fig. 2). This result shows that loss of moisture was related with relative humidity condition. Asami *et al.* (1989b) suggested that relative humidity is higher for store the yacon than the tuber crop such as potato.

Change of brix degree

Brix degree of tuberous root was increased from 15.5 after ripening to 17.1 after 6 months stored at 4°C, 85% relative humidity, and it is increased minimal from 15.5. to 16.0 after 5 months stored at 10°C, 80% relative humidity. Though tuberous roots decayed even if it were stored at 10°C and 20, most of brix degree reaches about 17.0 except on 10°C, 80% relative humidity (Fig. 3). Brix degree was higher when tuberous root was sotred in high temperature and relative humidity of storage room. Relative humidity should be effective on brix degree because it was lower at 80% than those of 85% relative humidity or more. Brix degree in relation to contents of disaccharides such as sucrose would be important to sweetness of tuberous root.

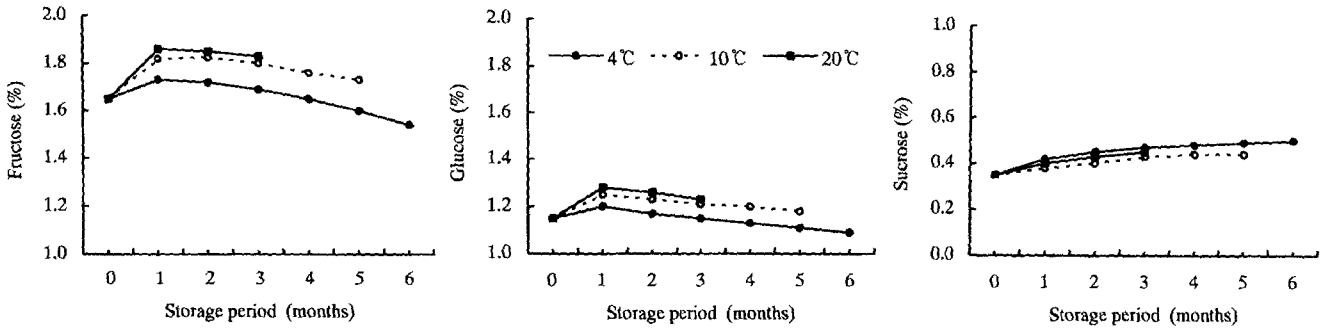

Fig. 4. Changes of sugar contents by different temperature on storage room in yacon.

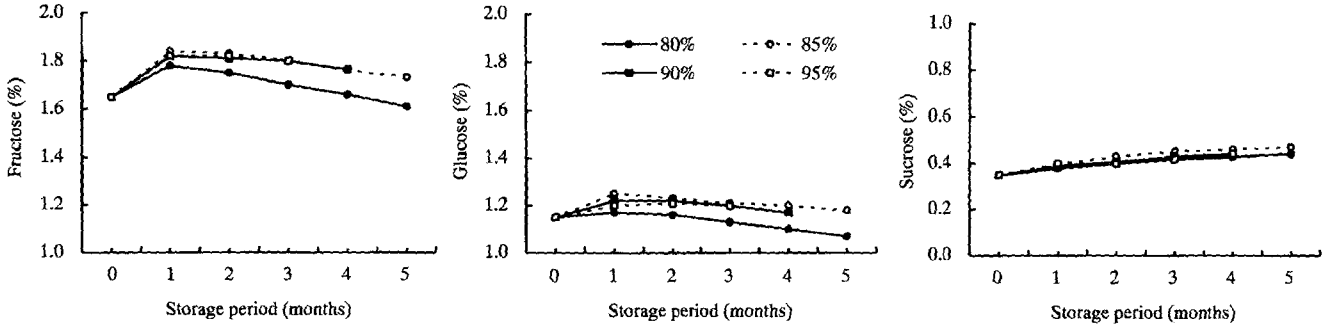

Fig. 5. Changes of sugar contents by different relative humidity during storage in yacon.

Change of sugar contents

Sugars in the tuberous root of yacon were detected in high performance liquid chromatography (HPLC), which were fructose, glucose and sucrose; its type is similar to Doo (2000)'s report. The changes of sugar contents by different storage temperature during the 6 months were shown in Fig. 4. Contents of fructose, glucose and sucrose at early storage were 1.65, 1.15, 0.35%, respectively, and 1.6, 1.1, 0.5% after 6 months storage at 4°C. It showed the different trends by temperature and periods of storage; fructose and glucose were increased for a month and then decreased successively the after, but sucrose was increased gradually for 6 months. Storage at 4°C caused the low fructose, 10°C expressed middle tendency and 20°C caused the high fructose, glucose was similar tendency. Sucrose, however, was opposite trend to fructose and glucose.

The changes of sugar contents by the relative humidity of every month during the 6 months storage were shown in Fig. 5. Fructose and glucose were changed similar to that of temperature; it were increased for a month and then decreased successively the after, but sucrose was increased successively for 6 months. Fructose and glucose contents were same except on 80% relative humidity, that was lower level than moisture of tuberous root.

DISCUSSION

When moisture contents of tuberous root in yacon was decreased gradually during 6 months storage period, the brix degree was increased. Fructan in tuberous root of yacon is hydrolyzed to become fructose, glucose and sucrose during the growth and storage (Asami *et al.*, 1991a). Tuberous root of yacon, however, has not starch (Asami *et al.*, 1989b). Therefore it is question what materials to become sugars. Ohyama *et al.* (1990) suggested that tuberous root contain the fructo-oligossachride of inulin type that composed to polymer (β-2, 1-polymerization) and to low degree of polymerization (DP) oligosaccharides (DP 3 to 10 fructans).

In Jerusalem artichoke (*Helianthus tuberosus* L.) tuber, it is important to obtain fructo-oligossachride. Contents of glucose and fructose to total sugars were about 1 and 3%, respectively, and sucrose was about 3%, and GF_2~GF_7 were about 3.5~6.0%, respectively, and inulin was 66.4~71.4% (Kang *et al.*, 1993). Edelman & Jefford (1968) proposed the first model of fructan synthesis based on their work in Jerusalem artichoke. They suggested that fructan synthesis was catalyzed by the concerted action of two fructosyl transferases, SST and FFT. The composition changes originated from SST (Sucrose-Sucrose Fructosyl Transferase, EC 2.4.1.99), FFT (Fructan Fructosyl Transferase, EC 2.4.1.100), FEH (Fructan Exohydrolase, EC 3.2.126), that are enzymes on vacuole,

and from SS (Sucrose Synthase, EC 2.4.1.13), that is on cytosol, these enzymes possess at different time (Darwen & John, 1989; Frehner *et al.*, 1984). The activity was specific for fructosyl transfer from β(2 → 1)-linked 1-ketose or fructan to sucrose and β(2 → 1) fructosyl transfer to other fructans (1-FFT) (Jeong & Housley, 1992).

Plant used the cellulose to form tissue and organ, or to storage starch in fruit. When storage starch was hydrolyzed to sugar (especially sucrose, fructose and glucose) by enzyme after harvesting, water used (Cho & Bae, 1995). FFT and FEH are active maximal on 25~40°C (Jeong & Housley, 1992).

Considering the above reports and our results, sugars contents of tuberous root in yacon changed by the storage periods and conditions such as temperature and relative humidity, and source of sugars would be originate from fructo-oligossacharide. At this period, temperature accelerates the hydrolysis. However, tuberous root need to maintain nearly the same relative humidity as its moisture contents if it low in the loss of weight, otherwise if temperature will be high, large quantity of tuberous root will be decay. To obtain the fructo-oligosscharides, therefore, tuberous root should be stored for a long time possibly for the purpose of the manufacture or the fresh eat. So the disinfections of tuberous root need to be pre-treated for a while such fumigant, irradiation, little drying under the sunshine, or precooling etc.

ACKNOWLEDGMENTS

This work was supported by postdoctoral fellowships program from Korea Science & Engineering Foundation (KOSEF) in 1998.

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