THE EFFECT OF VARIETY AND LENGTH OF STORAGE ON THE CARBOHYDRATE CONTENTS AND TABLE QUALITY OF SWEETPOTATOES

M. Kasem Ali* and L. G. Jones

Louisiana State University, U.S.A.

(Received October 9, 1964)

Experiments were conducted to determine if a relationship existed between the dry matter, reducing sugar, non-reducing sugar, total sugar, maltose, dextrin or starch content of sweetpotatoes and table quality. Raw and baked roots were sampled at harvest, after curing, and after 4, 13 and 21 weeks of storage at 60°F. Table quality was determined by a taste panel, and the softness by a penetrometer.

A significant negative correlation was found between the amount of starch and the degree of softness; it was positive in case of non-reducing or total sugar. The changes in the dry matter and carbohydrate contents of raw and baked roots during storage have been shown in the Tables.

Sweetpotato (*Ipomoea batatas* Poir.) varieties are generally grouped into two classes on the basis of their culinary and table qualities. The 'yam' type is known as the moist type of sweet potato due to its property of becoming soft and syrupy when baked, while the 'Jersey' type is known as the dry type because it remains relatively dry and firm after baking. Among the varieties of 'yam' type some become softer when baked or canned immediately after harvest, while others become suitable for table use after being cured or stored for several months. The table quality of sweepotato is strongly influenced by the degree of firmness and consistency of the baked roots. This marked difference in table quality of different varieties has prompted many research workers to investigate into the material or materials responsible for the changes occurring during storage or during baking of the roots. Magoon and Culpepper[1] found a higher content of dextrin and a large amount of sugar in moist, soft varieties. In the firmer varieties no dextrin was found in roots canned immediately after harvest but a small amount was found in cured and stored roots. Culpepper and Magoon[2] postulated that the consistency of canned roots was directly related to the ratio of starch to moisture contents—the sweetness was affected by maltose; but during cooking no change in sucrose was marked.

Blackwell and Scott[3] observed a significant correlation between starch content of roots and firmness as determined organoleptically, whereas Morris and Mann[4] found very little relationship between the degree of sweetness and the actual sugar content. Woodroof et al.[5] reported that as the storage period of the raw roots increased the table quality of the canned products became more desirable. Sistrunk et al.[6] was of the opinion that the variety which converted a higher percentage of starch to reducing sugars during backing was smoother in texture; the firm textured varieties had a higher starch content. Regarding the effect of curing and storage conditions on the chemical constituents of sweetpotatoes, Morris and Mann[4] reported that from the time of harvest to the end of storage period the dry-matter percent changed very little but the total sugar content almost doubled. It was also found that during curing and storage there was a loss in starch and an increase in sucrose. The texture and table quality of baked roots were also found to be affected by the conditions under which the roots were stored.[5,8,9,10] Changes in the percentage of pectin, carotene, and ascorbic acid contents were also found to be influenced by the variety, and storage conditions.[11,15]

Materials and Methods

Four varieties of yellow-fleshed sweetpotatoes, namely, Acadian, Heartogold, Unit-1, and Earlyport, grown at Chase, Louisiana, were used as the experimental materials. Among the four varieties Acadian is known to be a variety that becomes soft and syrupy if cooked immediately after harvest, while Earlyport becomes suitable for table use after being cured and stored.

Samples of raw and baked roots were taken for analysis at harvest, after curing and during storage. Curing of the roots was done at about 85°F and at a relative humidity of 85 per cent for 2 weeks. After curing the sweetpotatoes were stored in a room at 60°F and a relative humidity of 72%.

For baking tests an oven heated by natural gas was used. The thermostat of the oven was cali-

* Present address: Agronomy Division, Jute Research Institute, Dacca.

brated from 250° to 550°F at 25° intervals. Before baking the roots, the oven was preheated for about 15 minutes at a higher temperature. The baking temperature of the oven was kept constant by regulating the thermostat. At the end of each baking period the roots were taken out of the oven and cooled at room temperature before taking any sample.

Samples were taken in duplicate from both raw and baked roots for carbohydrates and dry-matter analysis. The carbohydrate determinations consisted of reducing sugar, non-reducing sugar, total sugar, dextrin, maltose, and starch. In the case of raw samples the skin of the roots were scraped off and the roots were split lengthwise into halves before sampling. One half of each of the ten roots were ground in a power-driven meat grinder equipped with a 4.5 mm. sieve; the ground pulp was thoroughly mixed by an electric Sunbeam Mixmaster. The same procedure was followed in the case of backed roots except that the skin was peeled by hand before the samples were ground.

In the dry-matter determination a 10 g. sample was weighed by a chainomatic analytical balance, graduated in 1/10,000 g., into a tin can and dried at 101°C for 12 hr. For carbohydrate analysis the weighed samples of 25 g. of tissue were covered with 80 ml of 95% ethyl alcohol which were then boiled for 10 min. to inactivate the enzymes and stored at 35°F room till the analysis of the samples could be run.

In the separation of carbohydrates the samples were washed with 80% alcohol as outlined in A.O. A.C.[16] The filtrate was used for the determination of sugars. The residue was then filtered with 10% alcohol for dextrin analysis. The alcohol-insoluble residue was dried on the filter paper and scraped off for starch analysis.

In developing the curve for dextrose an Evelyn Photocolorimeter with a 420/μ was used. The same instrument was likewise used in making the carbohydrate determinations. The reducing sugar analyses were completed according to the procedure as outlined by Forsee[17] and Morell;[18] the non-reducing sugars were estimated by the same method after hydrolysis by invertase, obtained from the Nutritional Biochemical Corporation, U.S.A.

Results

Effect on Softness.—The varieties were baked at 375°F for 75 minutes and tested for softness by the use of a Precision grease-cone penetrometer. It was observed that after baking, the Acadian variety was the softest and the Earlyport the firmest. On the average Unit-1 and Heartogold were identical in this respect. During storage the varieties responded differently. Unit-1, Heartogold and Acadian roots backed at harvest time and after curing were identical in softness. After 4 weeks of storage Acadian ranked first and Heartogold second. Upon prolonged storage Acadian continued to be the softest, while Heartogold and Unit-1 were concurrent. The softness of all varieties increased during the early part of storage period, but very little increase in softness was observed upon prolonged storage (Table 1).

TABLE 1.—EFFECT OF VARIETY AND LENGTH OF STORAGE ON THE DEGREE OF SOFTNESS* OF BAKED SWEETPOTATO ROOTS (AVERAGE OF 12 READINGS).

Samples taken after	Variety				
	Acadian	Hearto-gold	Unit-I	Early-port	Mean
Harvesting ..	17.53	17.96	17.01	14.38	16.72
Curing ..	21.40	21.73	20.31	15.71	19.79
4 weeks of storage at 60°F	24.95	22.60	20.16	15.36	20.77
13 weeks of storage at 60°F	23.43	21.68	22.03	18.70	21.46
21 weeks of storage at 60°F	22.98	20.23	19.38	18.98	20.39
Mean ..	22.06	20.84	19.78	16.63	..

* Expressed as mm penetration into the flesh of roots in 10 sec.

L.S.D. due to	(.05 level)
Variety	0.97
Storage	1.08
Variety X Storage	2.18

Effect on Table Quality.—A panel of five faculty members tasted the baked roots organoleptically. The paired comparison method of Bradley and Terry[19] was followed. In making the table quality determination of baked roots the taste panel selected Acadian in a majority of cases as being of highest quality in softness, sweetness, flavour, and texture; Earlyport was considered to have the poorest table quality. Among the other two varieties Heartogold tasted better than Unit-1 as shown in Table 2.

Effect on dry Matter Content.—Raw and baked roots of four varieties were sampled at harvest time, after curing and during storage. The results showed that on the average raw roots of Heartogold and Unit-1 contained an equal amount of moisture but after baking Heartogold contained the highest (71.80%) and Unit-1 the lowest (68.17%) amount of moisture. The other two

TABLE 2.—EFFECT OF VARIETY ON THE TABLE QUALITY* OF SWEETPOTATOES BAKED AFTER 4 WEEKS OF STORAGE AT 60°F.

Quality factors	Variety				Level of significance
	Acadian	Hearto-gold	Unit-1	Early-port	
Colour ..	34	32	21	21	0.00
Softness ..	36	30	24	18	0.00
Texture ..	36	30	23	19	0.00
Sweetness ..	36	30	23	19	0.00
Flavour ..	36	30	23	19	0.00
Sample preference	36	30	23	19	0.00

*The higher the number, the better the quality.

varieties, Acadian and Earlyport were identical in dry-matter content. In all cases the dry-matter percentage of roots sharply increased during baking.

Raw roots were more or less consistent in moisture content during storage but it tremendously decreased in baked roots. On the average, raw roots contained 23.30% and 23.33% of dry-matter when sampled at harvest time and after 21 weeks of storage, respectively. On the other hand, sweetpotatoes baked at harvest retained 32.40% of dry-matter and it gradually decreased to 28.93% at the end of storage (Table 3.).

Effect on Startch Content.—The starch content of all varieties decreased sharply during baking. During the baking process Earlyport retained the highest amount of starch throughout the sampling period and Unit-1 the lowest. Among the other two varieties Acadian had more starch before baking, but it was reversed after baking.

Starch content of raw roots, generally decreasing after curing, showed little change during the early part of storage and fluctuated somewhat during the later part of storage depending on the variety. Roots baked immediately after harvest contained 7.43% of starch; it reduced to 4.18% after curing and to 2.63% after 4 weeks of storage. Thereafter the changes were very negligible (Table 3).

Effect of Reducing Sugar.—Reducing sugar content of all varieties increased from 0.61% of raw roots to 7.21% in baked ones. Lowest amount of reducing sugar was found in Acadian, slightly higher amount in Earlyport, and highest amount in Heartogold.

Curing or prolonged storage did not exert any influence on the reducing sugar content of sweetpotatoes, sampled after baking; although it was slightly increased in raw roots during storage.

Effect on Non-reducing Sugar.—It was determined after deducting the amount of reducing sugar from the total sugar content of a sample. There was no difference in the non-reducing sugar content of raw and baked roots. Highest amount of sucrose was found in Acadian roots, both raw and baked; Heartogold ranked second; while Unit-1 and Earlyport were at the lowest level (Table 3).

Sucrose content was affected by curing and storage. The amount gradually increased during curing and storage.

Effect on Total Sugar.—Total sugar content was determined after converting the non-reducing sugars to reducing sugars with the enzyme invertase. Raw sweetpotatoes contained 4.34% of total sugar and the baked roots 11.03%. Heartogold and Acadian contained a slightly higher amount of sugar before baking. After baking Acadian showed highest amount of sugar and Earlyport the lowest.

At harvest, raw roots contained a very small percentage of sugar (1.82%), during curing the amount rose sharply to 4.60% and changed very little during storage. Roots baked immediately after harvest had 9.16 per cent of sugar and the amount increased to 11.04% when baked after curing. Thereafter, the total sugar content of baked roots did not change much. On the average the total sugar content of sweetpotatoes gradually increased during curing and storage.

Effect on Dextrin.—There was no measurable amount of dextrin present in the raw roots of any one of the varieties tested at harvest time. A very small amount was found in raw flesh of cured and stored sweetpotatoes. The varieties were similar in dextrin content before baking, but during baking Unit-1 converted a larger amount of starch of cured potatoes to dextrin than that of the other varieties. The dextrin content of varieties increased considerably during curing and in the early part of storage period but it decreased in the later part of storage (Table 4.).

Discussion

In considering the performance of four varieties of sweetpotatoes it was found both by the taste panel and the penetrometer test that after baking Acadian roots were the softest and Earlyport the hardest. The other two varities remained equally soft when baked at harvest, but after storage

TABLE 3.—THE EFFECT OF VARIETY AND LENGTH OF STORAGE ON THE DRY MATTER, TOTAL SUGAR, NON-REDUCING SUGAR AND STARCH CONTENT OF RAW AND BAKED SWEETPOTATOES.

Samples taken after	Varieties									
	Acadian		Heartogold		Unit-I		Earlyport		Mean	
	Raw	Baked	Raw	Baked	Raw	Baked	Raw	Baked	Raw	Baked
PERCENT DRY MATTER										
Harvesting	24.43	33.43	22.41	30.34	22.46	33.33	23.90	32.57	23.30	32.40
Curing	24.57	31.81	22.86	28.90	24.61	35.96	25.37	31.77	24.35	32.11
4 wks. of storage	25.02	31.26	24.59	29.51	22.80	30.95	25.61	29.41	24.50	30.28
13 wks. of storage	24.34	28.28	23.01	26.98	22.55	30.04	25.10	30.56	23.75	28.97
21 wks. of storage	23.21	28.38	23.17	25.25	23.64	28.86	23.32	29.23	23.33	27.93
Mean	24.31	30.61	23.21	28.20	23.21	31.83	24.66	30.71	23.84	30.34
PERCENT TOTAL SUGAR										
Harvesting	2.21	9.75	1.93	9.16	1.93	8.79	1.31	8.93	1.82	9.16
Curing	4.98	11.58	5.11	10.70	4.15	11.30	4.15	10.61	4.60	11.04
4 wks. of storage	5.28	12.70	4.90	12.03	4.15	10.76	4.06	11.09	4.60	11.64
13 wks. of storage	5.35	12.46	5.91	11.68	4.68	11.15	4.84	11.78	5.19	11.77
21 wks. of storage	5.77	11.94	6.01	12.28	4.90	11.54	5.32	10.46	5.50	11.56
Mean	4.70	11.68	4.77	11.17	3.96	10.71	3.93	10.57	4.34	11.03
PERCENT NON-REDUCING SUGAR										
Harvesting	1.76	2.17	1.25	1.99	1.54	1.83	1.02	1.52	1.39	1.88
Curing	4.73	4.74	3.82	3.20	3.77	3.63	3.49	4.10	3.95	3.92
4 wks. of storage	4.99	5.37	3.74	4.38	3.49	3.85	3.38	3.42	3.90	4.25
13 wks. of storage	4.95	5.61	4.34	4.25	3.57	3.70	3.89	4.20	4.19	4.45
21 wks. of storage	5.40	5.64	4.66	4.95	3.86	3.77	4.31	3.95	4.56	4.57
Mean	4.36	4.71	3.56	3.75	3.24	3.35	3.21	3.43	3.60	3.81
PERCENT STARCH										
Harvesting	15.30	7.13	12.60	7.05	12.15	6.85	14.40	8.70	13.61	7.43
Curing	11.70	3.80	10.35	3.90	12.15	2.44	13.50	6.57	11.92	4.18
4 wks. of storage	12.45	1.97	11.70	3.17	10.50	1.30	13.65	4.10	12.07	2.63
13 wks. of storage	12.15	1.35	10.40	2.09	10.57	1.34	14.01	3.78	11.78	2.14
21 wk.s of storage	10.23	2.18	10.73	3.26	11.47	2.09	11.47	3.28	10.97	2.70
Mean	12.36	3.28	11.15	3.89	11.36	2.80	13.40	5.28	12.07	3.81

TABLE 4.—THE EFFECT OF VARIETY AND LENGTH OF STORAGE ON THE DEXTRIN CONTENT OF RAW AND BAKED SWEETPOTATOES.
(PERCENT OF RAW WEIGHT AT SAMPLING TIME).

Varieties	Raw or baked	Samples taken after					Mean
		Harvesting	Curing	4 wks of storage	13 wks of storage	21 wks of storage	
Acadian	Raw	0.00	0.26	0.30	0.23	0.23	0.20
	Baked	1.15	2.48	2.79	2.29	2.10	2.16
Heartogold	Raw	0.00	0.16	0.23	0.23	0.23	0.17
	Baked	0.78	1.19	1.60	1.47	0.89	1.18
Unit-I	Raw	0.00	0.23	0.23	0.23	0.23	0.18
	Baked	1.11	3.42	2.32	2.36	1.94	2.23
Earlyport	Raw	0.00	0.30	0.30	0.26	0.23	0.22
	Baked	1.02	1.27	2.09	2.01	1.67	1.61
Mean	Raw	0.00	0.24	0.26	0.24	0.23	0.19
	Baked	1.01	2.09	2.20	2.03	1.65	1.79

Heartogold showed a tendency to become softer than Unit-1. All the varieties increased markedly in softness after having been stored for 4 weeks. Further storage resulted into very little change in softeness of baked roots.

Increase in dry-matter content during baking was due to evaporation of water from the roots. During baking, although the roots became moist and syrupy, the water content was however lower than that of the raw roots. There was no consistent relationship between the moisture content of varieties and softness of baked roots. The decrease in dry-matter content during storage may be due to the loss of dry matter through respiration as pointed out by Shiever.[20]

The varieties behaved differently during baking as to conversion of starch to sugars. Unit-1 and Acadian were the most effective varieties in the conversion of starch to sugars while Earlyport was the least active. Increase in reducing sugar and total sugar contents of all varieties during baking agrees with the results of Magoon and Culpepper,[1] Gore[21] and Jenkin and Geiger.[22] The Acadian variety showed the lowest amount of reducing sugar and the highest amount of non-reducing sugar in both raw and baked roots. The reducing sugar content was affected very little by the length of storage but the non-reducing and total sugar contents increased gradually as the sampling time was extended from harvest time to 21 weeks of storage. Similar results were reported by other workers.[2,21] The importance of maltose and dextrin has been stressed [1,2,22] as the cause of increased softness of sweetpotatoes during curing and baking processes. In this investigation there seemed to be very little difference between the maltose content of soft and hard varieties. The softest variety Acadian as measured by 'penetrometer and taste panel did not contain any more dextrin and maltose than those in the other firm varieites. Maltose and dextrin did not increase appreciably during storage.

The starch content of all varieties decreased sharply during baking. This loss in starch content corresponds with the increase in sugar and dextrin contents.

The inconsistency in the relationship between the reducing sugar, maltose or dextrin and the degree of softness of baked roots is in contradiction to the statements made by previous workers.[1,23] A

TABLE 5.—RELATIONSHIP BETWEEN THE CARBOHYDRATE CONTENT AND THE DEGREE OF SOFTNESS OF BAKED SWEETPOTATO VARIETIES.

Varieities	r value					
	Reducing sugar	Non-reducing sugar	Total sugar	Maltose	Dextrin	Starch
Unit-1 ..	+ 0.395	+ 0.581	+ 0.779	+ 0.488	.. 0.686	— 0.886*
Earlyport ..	— 0.267	+ 0.702	— 0.597	+ 0.084	.. 0.522	— 0.796
Heartogold ..	+ 0.971**	+ 0.630	+ 0.715	+ 0.539	.. 0.899	— 0.839
Acadian ..	— 0.435	+ 0.934*	— 0.988**	+ 0.329	.. 0.900*	— 0.955*

* Significant at 0.05 level ** Significant at 0.01 level

positive correlation which occurred with non-reducing sugar or total sugar and softness meant that the higher the sugar content the softer the variety. On the contrary, a negative correlation between starch content and softness confirmed that the softest variety contained the lowest amount of starch (Table 5). These observations agree with those of Magoon and Culpepper,[1] Blackwell and Scott,[3] and Sistrunk et, al.[6]

Conclusion

Among the four varieties, Acadian was the best in table quality, Unit 1 and Heartogold were intermediate and Earlyport was definitely inferior regardless of sampling date. The softness of baked roots increased with the length of storage period.

During baking all varieties increased in dry-matter, reducing sugar, total sugar and dextrin but decreased in starch content. Non-reducing sugar did not change much. During storage all varieties gained in reducing sugar, total sugar, non-reducing sugar and dextrin contents but reduced in dry-matter.

A positive correlation existed between the amount of non-reducing sugar and the degree of softness of the baked roots. A negative correlation was noted between starch content and softness. Other carbohydrates were not consistently related to the softness of sweetpotatoes.

Acknowledgement.—The authors wish to thank Dr. J. C. Miller, Head of the Department of Horticulture, Louisiana State University, U.S.A., for his helpful suggestions in various phases of the work, and Dr. M. T. Henderson, Professor of Agronomy, L. S. U., for helping in statistical matters. The senior author (M.K.A.) expresses his gratitude and indebtedness to Mr. G. Merajuddin of Dacca for his guidance during the academic career.

References

1. C. A. Magoon and C. W. Culpepper, U.S. Dep. Agr. Bul., **1041**, a (1922).
2. C. W. Culperpper and C. A. Magoon, J. Agr. Res., **33**, 627 (1926).
3. C. Blackwell and L. E. Scott, Proc. Assoc. Southern Agr. Workers, U.S.A. **51**, 134 (1954)
4. L. L. Morris and L. K. Mann, Hilgardia, **24**, 143 (1955).
5. J. G. Woodroof, W. E. Dupree and S. R. Cecil, Ga. Agri. Expt. Ss. Bue., **12**, 1 (1955).
6. W. A. Sistrunk, J. C. Miller and L. G. Jones, Food Technol., **8**, 223 (1954).
7. W. F. Jenkins and W. S. Anderson, Proc. Am. Soc. Hort. Sci., **68**, 406 (1956).
8. J. S. Cooley, L. J. Kushman and H. E. Smart, Econ. Botany, **8**, 21 (1954).
9. M. T. Deonier, C. E. Steinbauer, W.D. Kimbrough and R. E. Wright, U.S. Dep. Agr., Circ., **841**, 1 (1950).
10. J. M. Lutz, U.S. Dep. Agr. Circ., **699**, 1 (1944)
11. E. M. Ahmed and L. E. Scott, Proc. Am. Soc. Hort. Sci., **71**, 376 (1958).
12. W. S. Anderson, Mississippi Farm Res., **19**, 1 (1956).
13. B. D. Ezell and M. S. Wilcox, Food Res., **13**, 203 (1948).
14. M. E. Hollinger, Food Res., **9**, 76 (1944).
15. C. L. Newton and G. C. Lowry, J. Home Econ., **29**, 114 (1937).
16. A. O. A. C. *Officeal and Tentatite Methods of Analysis* (Washington, D. C., U.S.A., 1940), 5th edition.
17. W. T. Forsee Jr., Ind. Eng. Chem. Anal. Edition, **10**, 411 (1938).
18. S. A. Morell, Ind. Eng. Chem. Anal. Edition, 13, 249 (1941).
19. R. A. Bradley and M. E. Terry, Biometrika, **29**, 324 (1952).
20. F. S. Shiver, S. C. Agr. Expt. St. Bul., **63**, 1 (1901).
21. H. C. Gore, Ind. Eng. Chem., **15**, 938 (1923).
22. W. F. Jenkins and M. Geiger, Proc. Am. Soc. Hort. Sci., **70**, 419 (1957).
23. C. A. Magoon and C. W. Culpepper, U.S. Dep. Agr. Bul., **1265**, 28 (1924).