VII[th] Symposium of the International Society for Tropical Root Crops,
Gosier (Guadeloupe), 1-6 July 1985, Ed. INRA, Paris, 1988.

STARCH-SUGAR TRANSFORMATION ON SWEET AND STAPLE-TYPE SWEET POTATOES

(Transformation amidon-sucre chez la Patate douce sucrée et non sucrée)

Franklin W. MARTIN

Tropical Agriculture Research Station, Southern Region
Agricultural Research Service, U.S.
Department of Agriculture
Mayaguez, Puerto-Rico

SUMMARY

Normally sweet potatoes contain reducing and non-reducing sugars. Cooking increase reducing but non-reducing sugars through activation of the beta-amylase enzyme. A new class of sweet potatoes (staple-type) has been produced by breeding that is not sweet or only slightly sweet after cooking. In these sweet potatoes reducing sugars are not increased or only slightly increased by cooking. Examination for amylase on acrylamide gel, with or without electrophoresis reveals that there is one spot active in hydrolysis of starch in normal sweet potatoes, and that this spot is weak or absent in staple-type sweet. Isolated starches from staple-type sweet potatoes were partially hydrolyzed when mixed with fresh normal sweet potato and cooked. Starches from normal sweet potatoes contained traces of enzyme that could hydrolyse them on cooking. In cooked mixtures of an enzyme-free starch from a staple-type sweet potato, the former was able to liberate reducing sugars from the latter.

RESUME

Les patates douces contiennent normalement des sucres réducteurs et non réducteurs. La cuisson augmente les sucres non réducteurs par activation de la beta-amylase. Une nouvelle classe de patates douces peu ou pas sucrées après cuisson a été obtenue par amélioration génétique. Les teneurs en sucres réducteurs de ces dernières sont peu affectées par la cuisson. L'examen de l'amylase, sur gel d'acrylamide, ou avec électrophorèse montre une seule bande, active dans l'hydrolyse de l'amidon des patates douces normales, faible ou absente chez les patates douces peu ou non sucrées. Les amidons isolés de patates type aliment de base furent partiellement hydrolysées en cuisson, mélangés avec des patates fraîches normales. Les amidons des patates douces *normales contiennent des traces d'enzyme qui les hydrolisent au moment de la cuisson. L'enzyme d'un amidon de patate douce normale est capable lorsqu'elle est ajoutée à un amidon de patate douce non sucrée dont elle est absente d'en libérer des sucres réducteurs.*

INTRODUCTION

The sweet potato, *Ipomea batatas* (L.) Poir., produces a tuberous root that contains starch as its principal constituent. During cooking the starch is converted to dextrins (short chain starch residues) and the reducing sugar maltose (HAMMETT and BARRENTINE, 1961). This conversion occurs in the presence of Beta amylase, an enzyme very active at cooking temperatures (KAINUMA and FRENCH, 1970). Beta-amylase is obtained commercially from sweet potatoes and is presumed to be active in all varieties.

Recently a sweet potato cultivar, Ninety-nine, was reported in which the starch is not converted to maltose by cooking (MARTIN and RUBERTE, 1983). The tuberous root of this cultivar is not sweet after cooking. Studies of the reducing power of the starch and its intrinsic viscosity suggested that the starch of this variety occurs as long, unbranched molecules (MARTIN and DESHPANDE, in press).

Since the initial finding of the cultivar Ninety-nine, many selections have been made of non-sweet and low-sweet potatoes are now called staple-type as a new staple, with sufficient potential attraction to the consumer as well as nutritive value, to be used as an everyday food.

The difference among sweet potato varieties that accounts for the non-sweet or low-sweet condition is attacked here by study of the starch-sugar transformation process in sweet and staple-type sweet potatoes.

MATERIALS AND METHODS

The experimental materials consisted of 13 cultivars of sweet potato developed at the Tropical Agriculture Research Station, Mayaguez, Puerto Rico. The reducing sugar contents of typical tuberous roots of these varieties are given in Table 1. On the basis of observed sweetness after cooking the cultivars had been classified by the investigator as staple (no sweetness perceived), sub-staple (only slight sweetness perceived), tropical (typical sweet potato of the tropics, white or yellow in color), and dessert (sweet and orange in color) (it must be remembered that sweetness depends as well on the presence of non-reducing sugars, not studied herein, and on individual differences in the threshold of perception of sweetness). Two of the cultivars were selected as typical of the extremes, Ninety-nine, the cultivar in which

TABLE 1 : The effects of cooking on the reducing sugar content of sweet and non-sweet potatoes 1/

Cultivar	Type	Reducing sugars (g/100 g dried sample)			
		before cooking	After cooking	Amount of increase	Percent increase
Francia	Substaple	7.6	12.8	5.2	68
Limonette	Substaple	3.7	3.8	0.1	3
Margarita	Staple	2.6	2.4	-0.2	-8
Mojave	Staple	3.2	5.7	2.5	78
Ninety-nine	Staple	0.8	0.8	0.0	0
Nutty	Tropical	8.5	22.1	13.6	160
Papota	Substaple	2.4	6.8	4.4	183
Sahara	Staple	3.2	3.1	-0.1	-3
Sneaky	Tropical	16.2	25.7	9.5	59
Sunny	Dessert	11.8	20.3	8.5	72
Toquecita	Tropical	4.2	21.2	17.0	405
Viola	Substaple	3.9	12.6	8.7	223
Wart	Tropical	7.6	17.6	10.0	132

1/ Data adapted from MARTIN (in press).

sugars are initially low and are not increased by cooking, and Sneaky, a variety in which sugars are moderate, and reducing sugars are greatly increased by cooking. The content of non-reducing sugars is not increased by cooking.

The effects of time on the starch-sugar transformation in the cultivars Ninety-nine and Sneaky were studied by grinding a mixture of 1 part fresh sweet potato to 10 parts water. These mixtures were cooked in a double boiler at 100°C for 0, 2.5, 5, 10, and 20 minutes. The samples were then dried. All reducing sugar measurements were made with standardized techniques of the Association of Official Analytical Chemists (HOROWITS, 1980) and all reports were standardized in terms of g/100 g dried sample.

The presence of amylase was tested on 7 per cent acrylamide gel (cyanogum 41) in buffer solution. Small portions of fresh tissue or of dried starch were ground in mortar and pestle with approximately 5 volumes of saline extraction solution. Thick rectangles of filter paper 2 x 3 x 0.5 mm were satured in the solution. These were placed in slots cut into acrylamide gel sheets of 2 mm thickness. After 15 minutes either the gels were stained (without electrophoresis), or treated by a direct current of 100 volts (about 35 miliamperes) to affect separation.

At the time of staining the filter pieces were removed and discarded. The gel was rinsed with distilled water, and the surface was flooded with a 1 per cent soluble starch solution. A container with the gels was then placed in a warm water bath (100°C) for 10 minutes. The gels were finally rinsed and stained by starch with an IKI solution. Areas that contained amylase were light in color or colorless, as compared to the pale blue of the enzyme-free areas. The strength of the amylase action was judged from 0 to 5.

Starch was obtained from each cultivar by blending 50 g fresh root with 500 ml water. This mixture was allowed to stand and then the water was decanted. The crude starch was rinsed in water and centrifuged 3 times, decanting each time, and was then dried in a forced draft oven at 50°C. The reducing sugar content of the starches was measured before and after cooking and after mixing and cooking with fresh sweet potato of the cultivar Sneaky.

The reciprocal effects of starch and fresh root of Ninety-nine and Sneaky were determined in samples of 2 g starch, 10 g sweet potato, or 1 g starch mixed with 5 g sweet potato. The samples were ground together and dried with or without cooking for 10 minutes in the water bath.

The kinetics of the reaction of fresh tuber of Sneaky with starch of Ninety-nine were studied with samples analysed after 0, 2.5, 5, 10 and 20 minutes of cooking.

RESULTS

The reducing sugar content of cooked sweet potatoes depended not only on the initial content but also on the amount of new reducing sugars produced on cooking. Of 13 cultivars tested, reducing sugars increases on cooking little or not at all in 4 (Limonette, Margarita, Ninety-nine, and Sahara). In all other cultivars reducing sugars increased on baking up to 16 g/100 g. The cultivar Ninety-nine had the lowest reducing sugar content before and after cooking. The cultivar Sneaky had the highest reducing sugar content before and after cooking yet the total increase (g/100 g) or the percentage increase was not the greatest.

On electrophoresis 11 of the 13 cultivars showed signs of amylase activity, varying from a none to a completely decolorized spot, 5 (Table 2). The Rf of the spot was 0.21. Amylase activity could be detected without electrophoresis as a diffused, decolorized area in the gel around the slot where the treated filter paper had been placed. The cultivars with lowest increase in reducing sugars corresponded to those cultivars without or with weak amylase spots (staple-type).

Extracts from starches did not reveal amylase spots. Starch itself plated on the gel and washed away before staining did not demonstrate amylase activity.

Increase in the reducing sugar of Sneaky was found to depend on time (Fig. 1). Reducing sugar content increased rapidly on cooking and was essentially complete in 5 minutes. No further changes occured with 10 or 20 minutes of cooking. In the case of the cultivar Ninety-nine, cooking for different times did not affect the reducing sugar content (Fig. 1).

Some of the extracted starches contained low amounts of reducing sugars (Tables 3). The reducing sugars increased in starches of 11 of 13 cultivars on cooking starch in water. In general, those cultivars with the lowest increase in reducing sugars on baking (staple-types) were also those with the lowest reducing sugar content before and after cooking of starch.

When starches were mixed with fresh tuberous root of the cultivar Sneaky and then cooked, the amount of reducing sugars in the cooked mixture was greater than would have been expected if the starch and tuberous root were cooked separately. This increase tended to be greatest in staple-type cultivars.

In the case of the two contrasting cultivars, Ninety-nine and Sneaky, the tests were repeated and extended to gain a better understanding of the influence of fresh tuberous root on starch, when cooked. The results are given in Table 4.

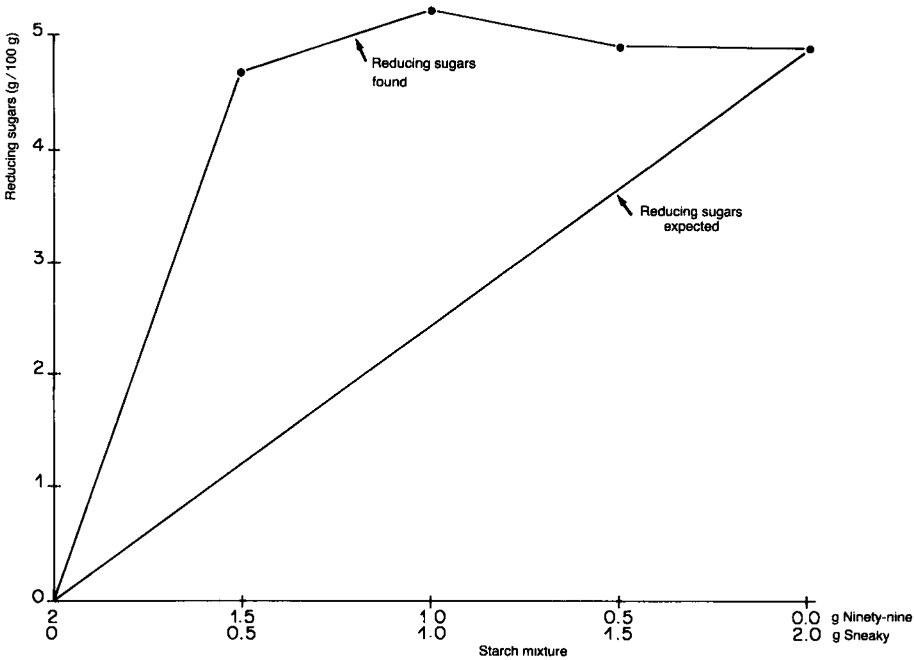

Fig. 1.- Increase in reducing sugar content in two distinctive sweet potato cultivars as influenced by time and cooking.

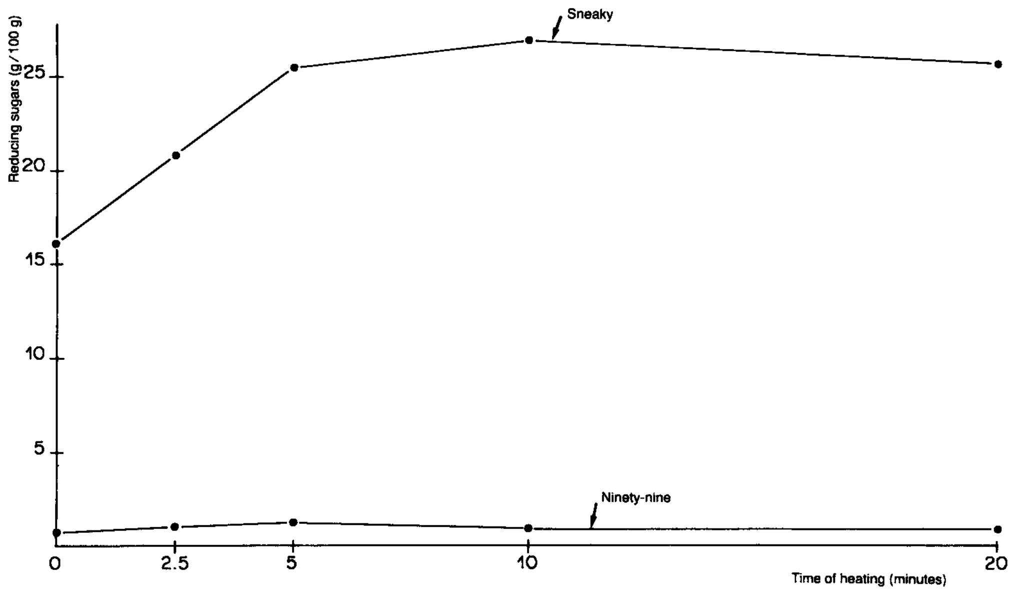

Fig. 2.- Amounts of reducing sugars found in a cooked mixture starches from the cultivars Sneaky and Ninety-nine as influenced by the proportions of each in the mixture.

TABLE 2 : Strength of principal amylase spots

	Fresh tuberous root extract		Starch	
	Spot treatment	After electrophoresis	Starch extract spot treatment	itself removed before staining
Francia	1[1/]	1	0	0
Limonette	2	1	0	0
Margarita	0	0	0	0
Mojave	5	5	0	0
Ninety-nine	1	1	0	0
Nutty	4	4	0	0
Papota	1	2	0	0
Sahara	2	2	0	0
Sneaky	3	5	0	0
Sunny	4	4	0	0
Toquecita	4	4	0	0
Viola	4	4	0	0
Wart	5	4	0	0

1/ Rated as 0 (no activity) to 5 (highest activity).

TABLE 3 : Reducing sugars in uncooked and cooked starches, and in a cooked mixture of starch with fresh sweet potato

Cultivar	Reducing sugars in (g/100 g) Uncooked starch	Cooked starch	Cooked starch sweet potato mixture	Calculated amount expected[1/]	Excess or shortage
Francia	1.1	30.7	33.1	28.2	4.9
Limonette	0.3	6.4	20.9	16.0	14.9
Margarita	0.0	0.0	31.7	12.8	18.9
Mojave	0.4	12.2	36.6	19.0	17.6
Ninety-nine	0.0	0.0	31.8	12.8	19.0
Nutty	2.5	33.2	35.9	29.4	6.5
Papota	1.3	15.6	35.9	20.6	15.3
Sahara	0.2	6.6	27.3	8.2	19.1
Sneaky	0.8	31.2	33.7	28.4	5.3
Sunny	0.0	9.9	33.5	17.7	15.8
Toquecita	2.8	33.2	30.8	29.4	1.4
Viola	0.7	20.5	31.5	23.1	8.4
Wart	1.2	20.9	32.3	23.3	9.0

1/ Five g of the fresh sweet potato Sneaky contributed 12.85 g/100 g reducing sugar. One go of the starch in question contributed the remainder.

TABLE 4 : Reciprocal effects of fresh sweet potato and and extracted starches with respect to release of reducing sugars, with and without cooking

Sample	Amount (g)	Cooking treatment	Reducing sugar (g/100 g)	Amount expected	Extra produced
Fresh Sneaky (S)	10	Uncooked	16.2	--	--
Fresh Ninety-nine (NN)	10	Uncooked	1.8	--	--
Starch S	2	Uncooked	0.6	--	--
Starch NN	2	Uncooked	0.0	--	--
Fresh S	10	Cooked	25.7	--	--
Fresh NN	10	Cooked	2.0	--	--
Starch S	2	Cooked	9.9	0.3	9.6
Starch NN	2	Cooked	0.0	0.0	0.0
Fresh S + Starch S	5 + 1	Cooked	26.7	17.7	9.0
Fresh NN + Starch NN	5 + 1	Cooked	1.0	1.0	0.0
Fresh S + Starch NN	5 + 1	CookeD	33.1	12.8	20.3
Fresh NN + Starch S	5 + 1	Cooked	4.9	5.8	- 0.9

Uncooked root as well as starch of Sneaky contained reducing sugars which were increased by cooking. Uncooked root of Ninety-nine, as well as its starch contained little or no reducing sugars, and these were not increased by cooking.

When the root of Sneaky was combined with its own starch and cooked, the increase in reducing sugars was greater than occurred when the two were cooked separately (Table 4). When the root of Sneaky was combined with the starch of Ninety-nine there was also an unexpected increase in production of reducing sugar. However, the root of Ninety-nine had no effect on the starches of either Sneaky or Ninety-nine.

When the starch of Sneaky and the starch of Ninety-nine was mixed and cooked, the resulting mixture contained more reducing sugars than what would have been expected if the starches were cooked separately. The effects of relative amount of the starches are presented in Fig. 2. Even the addition of a small amount of starch of Sneaky to the starch of Ninety-nine resulted in liberation of reducinh sugars. Thus, in all mixtures more reducing sugar was produced than would have been when the starches are cooked separately.

DISCUSSION AND SUMMARY

From the data that have been presented, a much clearer understanding of the nature of staple-type sweet potatoes has been obtained. It is only meaningful to speak of sweetness after cooking, for sweet potatoes are not eaten raw. Sweetness depends on the concentration of non-reducing and reducing sugars. The concentration of non-reducing sugars such as sucrose is not affected by cooking. However, in normal sweet potatoes, the concentration of reducing sugars is increased, often dramatically, by cooking.

New sweet potatoes have been produced that are not sweet or are only slightly sweet after cooking. As shown here these sweet potatoes lacked amylase, or sufficient of it. The fleshy root of the normal sweet potato that contains amylase could convert part of the starch from the staple-type sweet potatoes to reducing sugars.

On isolating starches of normal sweet potatoes, a small amount of amylase was often included in the starch preparation. This may be insoluble in water. This amount of enzyme in isolated starch was sufficient to convert some starch to reducing sugar on cooking. However, a greater conversion was achieved when the starch was mixed with tuberous root containing amylase and was then cooked. Even the residual amylase in starch from a cultivar that contained amylase was sufficient to convert some of the starch from a staple-type cultivar to reducing sugars. It is concluded that newly developed staple-type sweet potato cultivars are not sweet because they contain little or none of the amylase which characterizes normal sweet potatoes.

REFERENCES

HAMMETT H.L. and BARRENTINE B.F., 1961.- Some effects of variety, curing, and baking upon the carbohydrate content of sweet potatoes. Proc. Amer. Soc. Hort. Sci. 78 : 421 - 426.

HOROWITZ W., 1980.- Official Methods of Analysis. Associated of Official Analytical Chemists. 13th Edition. Washington, D.C. 1018 pp.

KAINUMA K. and FRENCH D., 1970.- Action of pancreatic alpha-amylase and sweet potato beta-amylase and 6^2 and 6^3 glucosylmalto-oligosaccarides. FEBS Leters 6 : 182.

MARTIN F.W.- Sugars in staple-type sweet potatoes as affected by cooking and storage. Jour. Agric. Univ. P.R. (In press).

MARTIN F.W. and DESHPANDE S.N.- Sugars and starches in a non-sweet potato, compared to conventional varieties. J. Agric. Univ. P.R. (In press).

MARTIN F.W. and RUBERTE R.M., 1983.- Sugars in staple-type sweet potatoes as influenced by cooking technique, pp. 136-138. In : MARTIN F.W. (Editor). Proc. Amer. Soc. Hort. Sci., Trop Reg. 27 (B).