CONTROLLED HEAT PROCESSING OF JEWEL SWEET POTATOES FOR PUREE PRODUCTION[1]

WILLIAM M. WALTER, JR.[2,3] and STEVEN J. SCHWARTZ[4]

[2]*United States Department of Agriculture*
Agricultural Research Service
and
[3,4]*North Carolina Agricultural Research Service*
Department of Food Science
North Carolina State University
Raleigh, NC 27695-7624

Accepted for Publication September 26, 1992

ABSTRACT

'Jewel' sweet-potato slices 0.5 cm thick were precooked at 100, 125 and 150C for varying periods of time, finish-cooked for 15 min at 150C, and pureed. Selected chemical and physical properties of the purees were compared to a puree prepared from conventionally baked sweet potatoes (1.25 h at 195C). Purees from the controlled heat process were also compared to the baked puree by a sensory panel. Of all the treatments, puree from the 100C, 6-min precook treatment was the most silimar to puree from baked sweet potatoes with respect to chemical and physical characteristics. The sensory panel found the two purees to be different, but were equally divided when asked to express a preference. Subsequent analysis showed that the starch of the baked control had been more completely hydrolyzed than the starch of the other treatments. This was reflected by higher maltose, lower starch content and by decreased starch molecular size and viscosity of the control compared with the other treatments.

INTRODUCTION

In today's market, frozen, microwaveable vegetable products are widely available. However, only a limited number of sweet-potato products are included.

[1]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or North Carolina Agricultural Research Service, nor does it imply approval to the exclusion of other products that may be suitable.
[2]Corresponding author. Telephone 919-515-2990.

Journal of Food Quality **16** (1993) 71–80.

Since baked sweet potato is the form favored by many consumers in the United States, it would seem that pureed sweet potato similar in texture and flavor to the baked potato would be commercially successful. Several such products made from the white potato are currently enjoying considerable success. One reason that a sweet-potato product is not commercially available is because the long baking time prior to pureeing dictates a batch process. Microwave-cooked sweet potatoes do not require such long cooking times, but the organoleptic quality is not as high because rapid heating characteristic of this process inactivates amylolytic enzymes before starch hydrolysis has progressed far enough to generate the preferred sweet taste and moist mouthfeel. Other workers have described processes to prepare good quality purees. Harris (1955) described a steam kettle process in which whole sweet potatoes were cooked at 75C in a steam-jacketed kettle and pureed. Smith *et al.* (1982) cooked sliced sweet potatoes at 75C in a steam-jacketed kettle, and Silva *et al.* (1989) cooked sliced sweet potatoes at 121C before pureeing. All of these processes are of the batch type and, consequently, would be difficult to adapt to large-scale industrial production.

The purpose of the research described in this report was to learn if a precook-finish-cook process using sliced sweet potatoes could be used to prepare a puree similar in quality to puree from conventional baking.

MATERIALS AND METHODS

Jewel cultivar sweet potatoes that had been cured and stored for 3 months (Wilson *et al.* 1980) were used in this study. For the precook-finish-cook process, the roots were hand-peeled, sliced into 0.5 cm thick slices perpendicular to the long axis, and each slice enclosed in aluminum foil. Foil-covered slices were precooked from 2–10 min at either 100, 125, or 150C in either an electric or gas-fired convection oven whose temperature was constantly monitored with a thermocouple sensor and maintained within 3C of the target temperature by manual adjustment of the oven controls. Slices were removed at timed intervals, immediately finish-cooked for 15 min at 150C, pureed by passage through a colander (3 mm diameter holes), and analyzed. This study was done in duplicate. In another set of experiments, foil-covered slices were cooked at temperatures of 100, 125, or 150C for 2–20 min and then analyzed. Controls were prepared by baking foil-wrapped whole sweet potatoes at 195C in a gas-fired convection oven for 1.25 h. After cooling to ambient temperature, the roots were peeled and pureed as described above. Sufficient puree was prepared for two sensory evaluations and for analyses.

Compositions Analysis

Moisture Content. Weighed 10-g samples (in duplicate) were dried at 65C for 24 h, followed by drying at 100C for 8 h and the weight loss measured.

Sugar Content. Duplicate 5-g sampels were macerated with 75 ml 95% ethanol and 12 ml water, transferred to a 100-ml volumetric flask and diluted to the mark with ethanol. After 7 days, the solution was mixed and the sugar content measured by HPLC using the system described by Walter (1992).

Alcohol Insoluble Solids (AIS). Duplicate 15-g samples of the puree were homogenized with 100 ml of 95% ethanol and filtered. The residue was homogenized with 150 ml of boiling 80% ethanol, cooled and filtered. The extraction was repeated twice and the residue dried to constant weight.

Starch Content. Duplicate 15–20 mg samples of AIS were put into 16 × 133 mm test tubes, wetted with 0.1 ml ethanol, mixed with 3.0 ml water, and put into a boiling water bath (10 min) to gelatinize the starch. The suspension was cooled, 1 ml of a solution containing 1 mg of amyloglucosidase (*Rhizopus* mold; Sigma Chemical Company; 5,000 units/g) and 0.1 mg alpha amylase (*Bacillus* sp.; Sigma; 1500 units/mg protein) in 0.01 M phosphate buffer (pH 4.5) was added, and the tubes incubated for 4 h at 37C. The tubes were then placed in boiling water for 10 min to inactivate enzymes, cooled, and diluted to 50 ml. The glucose content was measured with a glucose oxidase procedure (Procedure #510, Sigma) and the starch content calculated.

Physical Analysis

Puree Viscosity. Apparent viscosities of the purees adjusted to the same moisture content were measured at 5 frequencies with a Bohlin Rheometer model VOR equipped with a cone and plate system, CP 5/30. The frequencies selected gave a range of shear rates from 0.0245 to 25.17 s^{-1}.

High Performance Size Exclusion Chromatography (HPSEC) of Starch. AIS were extracted with 99% dimethylsulfoxide (DMSO) and the extracted material precipitated from the DMSO with acetone and centrifuged; the pellet was redissolved in 5 ml DMSO and chromatographed as described by Chang-Rupp and Schwartz (1988).

Sensory Analysis. Purees were adjusted to the same moisture content before serving to the panel. The untrained panel consisted of personnel and students from

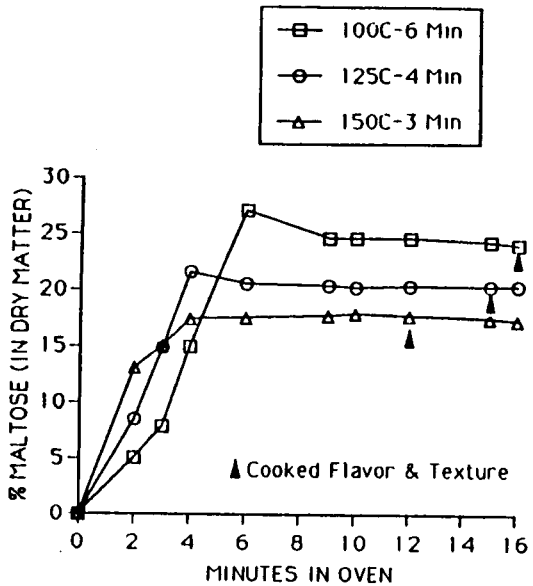

FIG. 1. FORMATION OF MALTOSE IN 'JEWEL' SWEET-POTATO SLICES AS A FUNCTION OF TIME AND OVEN TEMPERATURE

the Department of Food Science. Purees were assigned random-numbered codes and were served to the panel in booths illuminated with red light. The design was a triangle test (Larmond 1977). Each panelist was asked if there were any differences between the three coded samples. Statistically significant differences were assigned based on "Statistical Chart 1" (Larmond 1977). The panelists were also asked whether the odd sample was preferred over the two like samples. Preference data from those judges giving a correct response to the first question were compared to the data in "Statistical Chart 2" (Larmond 1977) to assign statistically significant differences in preference.

RESULTS AND DISCUSSION

When a sweet potato is baked in a conventional oven at 150–200C, heat penetration rate is rapid enough to cook the potato within 1–2 h, but slow enough that the endogenous amylolytic enzymes are not inactivated before they hydrolyze the gelatinized starch into maltose and dextrins. The extent of hydrolysis controls the mouthfeel (due to starch breakdown) and some of the sweetness (due to maltose production). When we cooked sweet-potato slices in an oven at several

temperatures for 16 min, measured maltose formation as an indicator of starch hydrolysis, and taste-evaluated the slices at 4-min intervals we found that maltose production was greatest in the 100C slices, but the familiar cooked flavor and texture did not develop until 16 min. Both of the other oven temperatures (125 and 150C) developed the cooked characteristics earelier (Fig. 1). These data indicated that a precook step, followed by a finish-cooking step at a higher temperature would be necessary to obtain a puree with both adequate starch hydrolysis and cooked texture characteristics.

TABLE 1.

TRIANGLE TASTE PANEL RESULTS. COMPARISON OF HEAT TREATMENTS WITH BAKED SWEET POTATO

Treatment[a]	Number of Judgments	Number Correct	Preference[b]	
			Treatment	Baked Control
100 C for 6 min (Treatment 1)	36	36	17^{NS}	19^{NS}
125 C for 4 min (Treatment 2)	36	35	10*	25*
150 C for 3 min (Treatment 3)	40	40	10**	30**

[a]After heat treatments, all samples were finish-cooked for 15 min at 150 C.

[b]* = P <0.05; *** = P <0.001; NS = not statistically significant.

We then repeated the previous experiment, except that for each oven temperature (100, 125, and 150C) and cooking time (2–20 min) we finish-cooked the slices at 150C for 15 min. When we compared the compositional data for this series of protocols with compositional data from conventionally baked sweet potatoes, the following treatments were selected as most similar to puree from baked sweet potatoes: treatment 1, precook at 100C for 6 min; treatment 2, precook for 3 min at 125C; treatment 3, precook at 150C for 3 min. All precook treatments

TABLE 2.

APPARENT VISCOSITY[a] OF SWEET POTATO PUREES AT 4 SHEAR RATES

	Shear Rate (Sec^{-1})			
Treatment	0.245	1.232	6.266	25.17
Control	1130.0	267.0	58.4	17.3
100 C for 6 min (Treatment 1)	1230.0	292.0	64.6	19.0
125 C for 4 min (Treatment 2)	1340.0	359.0	83.1	25.3
150 C for 3 min (Treatment 3)	1140.0	328.0	89.8	29.1
Frequency	0.2	1.0	5.0	20.0

[a]Viscosity in Paschal Seconds (Pa.S).

[b]After heat treatments, all samples were finish-cooked for 15 min at 150 C.

were immediately finish-cooked at 150C for 15 min, pureed and enough water added to bring the moisture content to 77%, the moisture content of the control samples. Sufficient puree from each treatment was prepared for sensory evaluation.

The sensory panel detected differences between all of the treatments and the baked control (Table 1). However, when asked for a preference, the panelists were equally divided between the 100C-6 min precook, 150C finish-cook (treatment 1) and the baked control. Panelists preferred the baked control to the other two treatments. Several comments on ballots indicated that the texture of the baked control set it apart from the other treatments. Consequently, we measured the apparent viscosity of the control and the three treatments. The data showed that the viscosity of the purees increased in the order control, treatment 1, treatment 2 and treatment 3 (Table 2). There was a high degree of correlation (R = 0.983) between the viscosity of the purees and the starch content (Fig. 2). In fact, the R^2 value was 0.974, indicating that the linear model explained 97% of the variability. This indicated that the starch content played a major role in the mouthfeel of the purees and that puree viscosity was inversely related to puree preference.

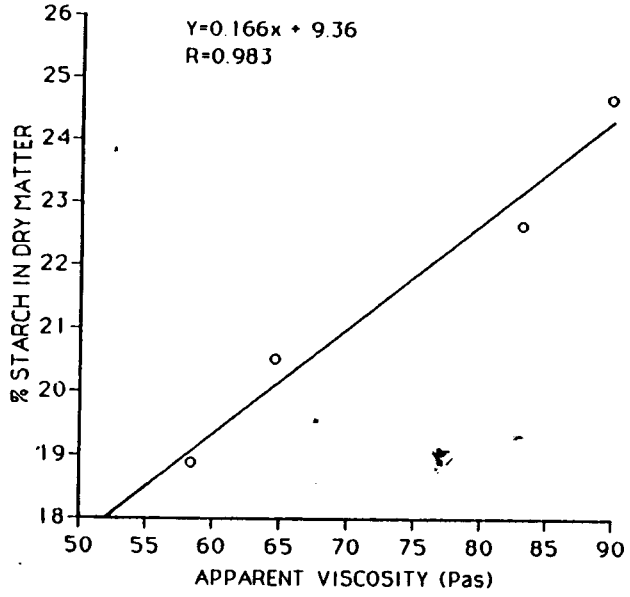

FIG. 2. RELATIONSHIP BETWEEN PUREE VISCOSITY (MEASURED AT A SHEAR RATE OF 6.27 S^{-1}) AND STARCH CONTENT (DRY WEIGHT BASIS) OF THE PUREES
All purees at a dry matter content of 23%.

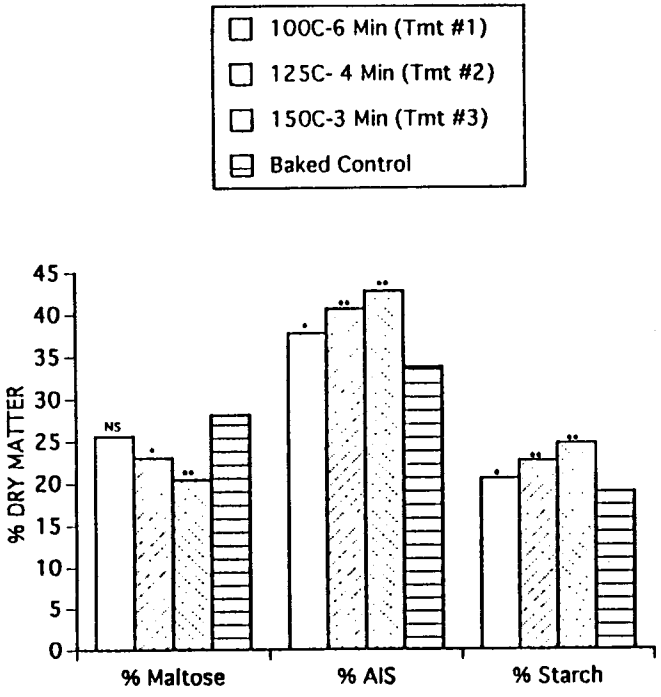

FIG. 3. AIS, STARCH, AND MALTOSE CONTENT OF PUREES FROM BAKED SWEET POTATOES AND 3 CONTROLLED-COOK TREATMENTS
NS = Not significantly different; * = $P < 0.05$; ** = $P < 0.01$.

Comparison of the AIS, starch and maltose content for the three treatments with that of the baked control indicated that the control had lower AIS and starch content than the other treatments (Fig. 3). Maltose levels were higher in the control and Treatment 1 than in the other two treatments. The other sugars present were sucrose (ca. 17–18% of dry matter), glucose (ca. 5–6% of dry matter), and fructose (ca. 6–7% of the dry matter). The amounts of these sugars were similar in all of the purees. For AIS and starch content, Treatment 1 was closest to baked control. None of our treatments resulted in as much starch hydrolysis as the control. As the precook temperature increased, the amount of starch hydrolysis decreased, presumably because of earlier inactivation of the amylolytic enzymes.

It is also possible that the decreased viscosity observed for the control sample (Table 2) could partially be due to the presence of a greater proportion of lower molecular weight starch polymers. To examine this possibility we extracted the starch from the AIS and chromatographed it on a high performance size exclusion column. The largest part of starch from all of the treatments (ca. 53–63%

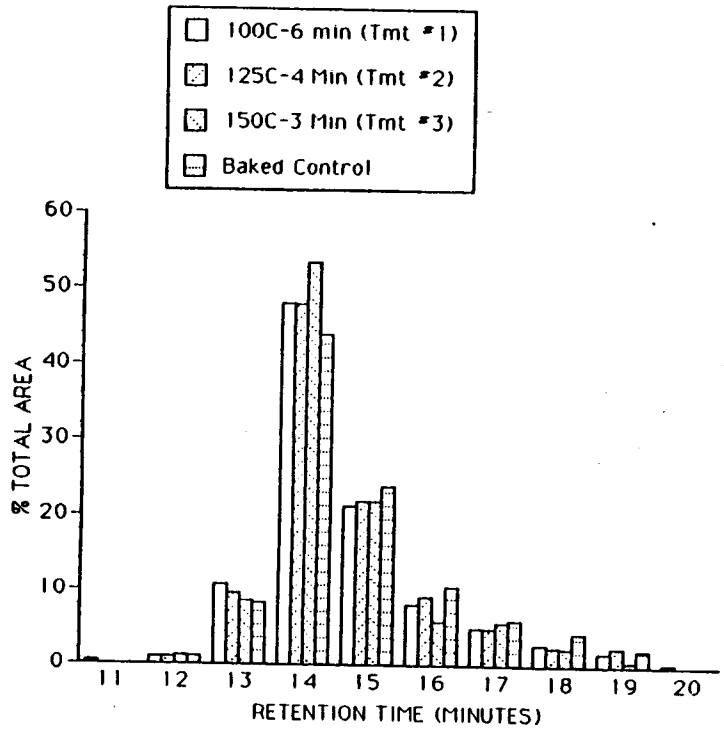

FIG. 4. ELUTION PROFILE COMPILED FROM HPSEC CHROMATOGRAMS OF STARCH FROM BAKED SWEET POTATOES AND 3 CONTROLLED-COOK TREATMENTS

of the total) had highest molecular size and eluted by 14 min (Fig. 4). Declining amounts of lower molecular size starch fractions eluted between 15 and 20 min. For the control sample a lower percentage of the total (ca. 53.5%) eluted in the highest molecular size range. However, after that time, the portion of lower molecular size molecules of the control (47.3%) was larger than that of the other treatments (ca. 37–41%). These data indicated that the average molecular size of starch from the control was lower than the average molecular size of starch from other treatments. These results also correlated well with viscosity, AIS, and starch content (data not shown). The lower molecular size starch fragments present in the control would be expected to exhibit the lowest viscosity, AIS, and total starch content of all of the treatments.

In conclusion, this study has shown that using a procedure like the one described herein, a puree can be prepared that is acceptable to a consumer panel and yet avoids the time-consuming baking process. This procedure could readily be con-

verted to a continuous process by utilization of a heating tunnel. The data suggest that the main factor responsible for observed differences between purees from any of our treatments and puree from a baked sweet potato is the inability of any of the treatments to hydrolyze the starch to the same extent as occurs in the conventional baking process. This is probably true because none of the heating protocols were able to gelatinize starch and avoid inactivation of the amylolytic enzyme systems before adequate starch hydrolysis had occurred.

ACKNOWLEDGMENTS

The authors thank Dr. D.D. Hamann and Mr. Randy Koch for their assistance with the Bohlin Rheometer.

REFERENCES

CHANG-RUPP, P.L. and SCHWARTZ, S.J. 1988. Comparison of oligo- and polysaccharides formed from starch during processing of sweet-potato puree by endogenous and exogenous enzyme treatments. J. Food Sci. *53*, 1144–1149.

HARRIS, H. 1955. New process for making frozen sweetpotato products. Proc. ASAW 52nd Annual Meeting, p. 133.

LARMOND, E. 1977. Laboratory Methods and Sensory Evaluation of Food, Publ. 1637, pp. 20–23, 63–64. Agriculture Canada, Ottawa, Canada K1A0C7.

SILVA, J.L., YAZID, M.D., ALI, M.D. and AMMERMAN, G.R. 1989. Effect of processing method on products made from sweet-potato mash. J. Food Qual. *11*, 325–396.

SMITH, D.H., MCCASKEY, T.A., HARRIS, H. and RYMAL, K.S. 1982. Improved aseptically filled sweet-potato purees. J. Food Sci. *47*, 1130–1132, 1142.

WALTER, W.M., JR. 1992. Use of refractive index to monitor changes in sugar content of stored sweet potatoes. HortScience *27* (In Press).

WILSON, L.G. *et al.* 1980. Growing and Marketing Quality Sweet Potatoes. North Carolina Agr. Ext. Serv. Publ. AGV-09.