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I am submitting herewith a thesis written by Charles Stephen Gaines entitled "Enzymatic Hydrolysis of Baked Sweet Potato Puree." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology.

J. L. Collins, Major Professor

We have read this thesis and recommend its acceptance:

Sharon L. Melton

Hugh D. Jaques

Accepted for the Council:

Hilton A. Smith
Vice Chancellor
Graduate Studies and Research

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ENZYMATIC HYDROLYSIS OF BAKED SWEET POTATO PUREE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Charles Stephen Gaines

December 1975

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The author dedicates this thesis to his mother and father.

ABSTRACT

The objective of this study was to produce fructose enzymatically from starch and starch degradative products in baked sweet potato puree. This would have the effect of sweetening the puree without having to add sugar(s). It was hypothesized that the puree would compare favorably in sweetness with puree sweetened with sucrose to the desired level.

Three enzymes (alpha-amylase, amyloglucosidase, and glucose isomerase) and the appropriate cofactors were added to the puree which was hydrolyzed at combinations of five pH levels (pH 4.0, 4.8, 5.4, 6.2, and 6.8) and four temperatures (55, 62, 69, and 76°C) for 21 hours. The hydrolysate was analyzed for fructose, glucose, sucrose, and maltose content. Hunter L, a, and b values for color were measured also. The optimum condition for fructose production within the range studied was pH 6.8 at 64°C. As temperature and pH were increased the puree became darker, less yellow, and less red. Due to considerations of color, flavor, and odor, pH 6.8 at 55°C was chosen as the most ideal condition.

A panel of 20 university staff, employees, and students scored sweet potato puree sweetened with five levels of sucrose and sweet potato puree sweetened with five levels of hydrolysate for preference of sweetness. The panel preferred puree with 14.86% added sucrose. The puree sweetened with hydrolysate was strongly disliked and a true evaluation of its sweetness could not be obtained. The poor flavor and odor of the hydrolysate masked the perception of sweetness in the samples.

The caloric value of the puree samples sweetened with the five levels of sucrose was determined. The increase in Calories due to added sucrose was statistically highly significant.

This study shows that the enzymatic production of fructose in baked sweet potato puree, under the conditions evaluated, produces an unpalatable product containing only a small percentage of the fructose needed to compare favorably in sweetness with puree sweetened to the desired level with sucrose.

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CHAPTER I

INTRODUCTION

The sweet potato root is an inexpensive source of carotene, ascorbic acid, niacin, and thiamine as well as an excellent source of calories (7). Sweet potato roots are easily produced in large areas of the eastern and southern United States (7, 32). Per capita consumption of the sweet potato root in the United States has, however, decreased considerably in the last 20 years (33) which is probably the result of the increased affluence of the American population which can afford more proteinacious food items. Also, a concern for the calorie content of food items on the part of the consumer may have influenced the decreased consumption of sweet potatoes.

In recent months sugar prices have fluctuated sharply causing increased activity in searches for alternative sweeteners. A recently perfected enzyme system for the manufacture of high-fructose corn syrup has achieved much attention and success (20, 25). It was hypothesized that this enzyme system could be applied to baked sweet potato puree and produce a sweetner in situ which is the objective of this thesis. The effort was directed at sweetening the puree by the enzymatic conversion of the naturally occurring starch and starch degradative products to fructose. Fructose is 1.8 times sweeter than sucrose which is usually added to baked sweet potato puree (11). Such a product would be sweetened without adding sucrose. Such a technique could, therefore, help the slumping sweet potato industry.

CHAPTER II

LITERATURE REVIEW

I. THE SWEET POTATO ROOT

The sweet potato (Ipomoea botatas Lam.) is produced commercially in the United States in the areas of the middle and south Atlantic coast, the gulf coast, the southern Mississippi valley, and parts of Texas, New Mexico, and California (7). The root is an excellent source of calories and an inexpensive source of carotene, ascorbic acid, niacin, and thiamine. On a dry weight basis the root is 89.5% total carbohydrate, being principally glucose, maltose, sucrose, dextrin, and starch. (7). The average composition of the root is 5.8% crude protein, 1.4% crude fat, 2.4% fiber, 3.4% ash, 0.1% calcium, and has 8,800 I.U. of Vitamin A in 100 grams (32).

During the 1930's a relatively large quantity of sweet potatoes was produced. The roots were inexpensive and the annual per capita consumption was about 12.5 kg. Since that time, however, consumption and production of sweet potato roots have decreased steadily. The primary reason is that Americans have had enough money to purchase foods rich in protein rather than foods rich in digestible carbohydrate like the sweet potato (7). In 1972 the annual per capita consumption of sweet potato roots was 2.2 kg (33).

Promptly after harvesting, sweet potato roots are cured for about five days at 29°C to 32°C and 80% to 90% relative humidity (2, 16, 23).

These conditions allow development of periderm which causes rapid and complete healing of wounds incurred during harvesting. Rapid healing provides protection against moisture loss and rot-producing micro-organisms such as Rhyzopus stolonifer which causes soft rot (7).

During the curing period starch of the root is converted to sugars faster than the sugars are depleted by respiration. This results in a net increase in the sugar content and a decrease in the starch content (26). Other carbohydrate fractions such as dextrins and amylopectin also increase in concentration. These, together with the sugars produced, are associated positively with the organoleptic quality of the sweet potato root (10).

Cured roots can be stored for several months successfully if stored within a temperature range of 12.8°C to 15.6°C and within a relative humidity range of 85% to 95% (5, 8). During storage the roots shrivel if more water is lost during transpiration than is produced by respiration. Therefore, the high relative humidity is essential to keep shriveling to a minimum (7).

During proper storage the sugar content remains at a relatively constant level. Starch is converted to sugar which serves as fuel for the respiratory process (26).

Baking the roots converts large amounts of starch to maltose and dextrins. From 9% to 15% maltose and up to 4.5% dextrins, on a dry weight basis, are produced during baking of sweet potato roots (29, 34).

During baking a maximum internal temperature of about 100°C is reached at the end of 80 to 90 minutes baking time. After the first 30

minutes of baking most of the starch hydrolysis occurs. After a 90 minute baking period the levels of sugars and dextrins reach a near maximum and the flesh becomes soft and syrupy, a quality deemed most satisfactory for human consumption (13).

II. FRUCTOSE PRODUCING ENZYME SYSTEM

Alpha-amylase (alpha-1, 4-glucan 4-glucanohydrolase, E.C. 3.2.1.1) hydrolyses the alpha 1,4-glucan linkages of polysaccharide molecules. Hydrolysis causes a rapid drop in the viscosity of starch suspensions.

The pH and temperature optima and the rate of activity vary according to the source of the enzyme (24). Commercial sources include Bacillus subtilis, Bacillus licheniformis, and Aspergillus oryzae. Alpha-amylase of fungal origin is generally less heat stable than alpha-amylase of bacterial origin.

Alpha-amylase is used widely in the food industry. Usages include the production of distilled alcoholic beverages, corn syrups, barley malt, and removal of starch from pectin. It is used as a wheat four supplement and is added to fruit cakes (24).

Amyloglucosidase (alpha-1,4-glucan glucohydrolase) hydrolyses alpha-1-4, and alpha-1,6, and alpha-1,3 glucosidic linkages of polysaccharides. Amyloglucosidase releases glucose units quantitatively from the nonreducing end of the saccharide molecule (24, 31).

Commercial sources for amyloglucosidase are Aspergillus niger, Aspergillus oryzae, and Rhizopus delemar. The optimum temperature

range of amyloglucosidase is 50°C to 60°C for up to 24 hours. The optimum pH range is pH 4 to 5 (24).

Amyloglucosidase is used extensively in the production of corn syrups and quantitative starch determinations (4, 17, 28).

Glucose isomerase (D-glucose 6-phosphate ketol isomerase, E.C. 5.3.1.9) (24) isomerizes D-glucose to D-fructose (35). This enzyme is produced commercially from Streptomyces albus which is capable of hydrolyzing xylan to xylose (17). Some other organisms which produce glucose isomerase are Lactobacillus brevis and Pseudomonas hydrophila (21, 35). A major commercial use of glucose isomerase is the production of high-fructose corn syrup (20).

III. GAS CHROMATOGRAPHY OF TRIMETHYLSILYL SUGAR DERIVATIVES

Birch (3) reported that Henglein and Scheinost were the first to report the preparation of trimethylsiyl derivatives of sugars in 1956. Birch (3) also reported that four years later Hedgely and Overend first reported gas-liquid chromatography of sugar trimethylsilyl esters. It was hoped that this procedure would shorten the time of the routine determination of carbohydrates (3). By 1963 Sweeley and others perfected the basic method used today for trimethylsilyl sugar analysis (30).

Although specific methods vary slightly as to the reagents and relative quantities of reagents used, trimethylsylation of dried sugars is accomplished in the following manner. Sugars are suspended in 10

parts pyridine and reacted with 2 parts hexamethyldislazane and 1 part trimethylchlorosilane (30).

"Silylation" is the introduction of a silyl group into a molecule by substituting the silyl group for an active hydrogen. Two examples of silylation follow:

(1) $$C_2H_5OH + (CH_3)_3SiCl \rightleftharpoons C_2H_5OSi(CH_3)_3 + HCl$$

(2) $$2(C_4H_9)_2NH + (CH_3)_3SiNHSi(CH_3)_3 \rightleftharpoons 2(C_4H_9)_2NSi(CH_3)_3 + NH_3 \quad (22)$$

Replacing the active hydrogen of the molecule reduces the hydrogen bonding between molecules and lowers the boiling point such that, depending on its molecular weight, it is sufficiently volatile for gas-liquid chromatography (22).

Pyridine acts as a proton acceptor, e.g.,

$$CH_3COOH + (CH_3)_3SiCl + C_5H_5N \longrightarrow CH_3OOS(CH_3)_3 + C_5H_5NH + Cl^-,$$

and drives the silylation reaction, which is normally reversible, to the right. Pyridine also speeds the reaction by desolving the compounds being silynized (22).

When the usual mixture of hexamethyldisilazane and trimethylchlorosilane is used, ammonia from the hexamethyldisilazane—sugar reaction neutralizes the hydrogen chloride produced by the trimethylchlorosilane—sugar reaction thereby producing ammonium chloride as follows:

$$3ROH + (CH_3)_3SiNHSi(CH_3)_3 + (CH_3)_3SiCl \longrightarrow 3ROSi(CH_3)_3 + NH_4Cl.$$

Ammonium chloride does not interfere with the sylation reactions or the chromatographing of the sylated sugars (22).

The basic method of trimethylsilyl sugar analysis utilizes dried carbohydrate samples. Drying the sample removes any water molecules which might compete with hydroxyl groups of sugar molecules for the silyl reagent molecules. Water also decomposes the silyl reagents (34).

Trimethylsilylation of most carbohydrates takes place rapidly and virtually completely at room temperature (30). McDonald and Newson reported, however, that at least 8 hours are required for fructose to form completely its penta-o-trimethylsilyl derivative (19).

Gas-liquid chromatography is used as a technique for separating sugars of similar molecular weight and mixtures of saccharides of varying molecular weight both as derivatives of single or multiple isomeric forms. All reducing sugars exhibit anomerization. Alpha and beta anomers of a particular ring form of mono- or disaccharide usually can be separated. Exactly which anomer is eluted first depends on the particular sugar observed. In general, those anomers whose anomeric -OH group is equitorial have the longest retention time. The alpha-anomers of D-fructose, D-glucose and maltose are eluted first (3). Only minimal anomerization of carbohydrates occurs in pyridine at room temperature (30).

When the multiple peaks derived from various amoneric forms of a mixture of sugars interfere with each other, reduction of the aldoses

to alditols and silyation of the alditols yield singular peaks for each sugar present. However, glucose and fructose yield the same alditol which limits this method for analysis of these two sugars (22).

Both polar and nonpolar liquid phases can be used for sugar analysis. Polar phases are more useful for separation of substances with similar boiling points and molecular weights such as aldohexoses. Nonpolar phases are more useful for separation of substances of more widely varying boiling points and molecular weights such as mono-, di-, and trisaccharides (30).

When analyzing sugars by the trimethylsilyl method an internal standard is necessary because precision is a problem due to sample injection technique and silicon dioxide film buildup on the detector reducing detector response (3). The use of an internal standard can assure results of about 1% accuracy (22).

Considerable use of the trimethylsilyl derivative method for the analysis of sugars has been made. It is used for analysis of sugars in glucose syrups prepared by starch hydrolysis (14); for rapid routine quality control of soybean meal (6); and for the analysis of sugars in cocoa (18), confectionery, honey and brewery products (3). In research work trimethylsilyl derivatives are used to study the course of mutarotational reactions of sugars which occur during food preparation and processing (12). Sugars occurring in potato tubers and sweet potato roots have been analyzed by this method, also (15, 19, 27).

IV. SWEET TASTE

The sweet taste is one of the four basic tastes (sweet, sour, bitter, and salty). The magnitude of sweet taste is achieved by the activation of the taste receptor by a sweetener molecule of specific dimensions. The potential of a sweetener molecule to incite the sweet taste response is dependent on its anomeric form, binding constant with the taste receptor, intramolecular hydrogen bonding capacity of adjacent hydroxyl groups, rate of diffusion into taste-bud receptors, and the stereospecificity of the taste-bud receptors (11).

The sweetness value of the common sugars is usually compared to sucrose which is assigned the arbitrary value of 100. The relative sweetness value of the common sugars varies as to the physical form in which they are tasted. For example, fructose is 1.80 times as sweet as sucrose when tasted in solid form. However, when tasted in solution fructose varies from 1.15 to 1.75 times as sweet as sucrose depending on whether the solution is freshly prepared (high value) or has had time to mutarotate (low value) (11).

V. SIMILAR PRODUCTS

High-fructose corn syrup is produced by using alpha-amylase, amyloglucosidase, and glucose isomerase. The automated procedure for producing high-fructose corn syrup uses alpha-amylase to liquify a raw corn starch slurry. The purified slurry is then treated with the saccharifying enzyme, amyloglucosidase, to produce a high dextrose

equivalent corn syrup. This syrup is refined and pumped through a pressure-leaf filter on which glucose isomerase has been immobilized, thus isomerizing 45% of the D-glucose present in the syrup to D-fructose. The resulting syrup contains 42% fructose and 50% glucose (20, 25).

A syrup made from sweet potato roots was produced on a pilot scale in the 1920's. Sweet potato syrup was made by cooking the sweet potato roots until soft, crushing them into pulp, treating them with a malt enzyme for a short period, pressing out the syrup, and evaporating the syrup to the desired solids content. The syrup was then filtered through diatomacious earth to remove most of the pigments. Sweet potato syrup produced in this manner retained a slight sweet potato flavor (9).

CHAPTER III

MATERIALS AND METHODS

I. SOURCE

Roots of Jewel and Jasper varieties of sweet potatoes were produced in 1974 on the Plant Science Farm by personnel of the Department of Plant and Soil Science of the University of Tennessee.

II. PREPARATION

The roots were washed and those having 2 to 9 cm diameter were baked at 191°C until soft, which required 80 to 120 minutes. The roots were cooled, peeled and trimmed by hand, and pureed in a Hobart food chopper. The puree was placed into liter sized plastic bags and frozen in an air-blast freezer at -29°C. When all of the roots had been prepared in this manner the resultant puree was allowed to thaw and was mixed together by variety. The mixed puree was repacked into plastic bags and frozen in a manner similar to that stated previously. The material was stored at -23°C until used for study.

III. HYDROLYSIS

Seventy-five gram portions of the puree were hydrolyzed for 21 hours at each of four temperatures (55, 62, 69, and 76°C) and five pH levels (4.0, 4.7, 5.4, 6.1, and 6.8). Hydrolysis was accomplished by combining the puree and the enzyme system in a specific gravity cylinder

(14 cm × 3.5 cm). The enzyme system contained 0.33 ml alpha-amylase (Ban 120, NOVO Enzyme Corp., Mamaroneck, N.Y.), 0.33 ml amyloglucosidase (Diazyme L-190, Miles Laboratories, Inc., Elkhart, Ind.), 1.0 gram glucose isomerase (Optisweet-P, Miles Kali-Chemie Biochemische Werke G.m.b.H. and Co., Hannover Kleefeld Postfach, West Germany), 0.015 gram cobalt chloride and 0.15 gram magnesium sulfate. The pH of each sample was adjusted with 8 N sodium hydroxide and 8 N citric acid. Each cylinder containing the puree and the above mentioned enzyme system was covered with plastic wrap and partially submerged in a water bath at the proper temperature. The puree was stirred continuously during the hydrolysis period by a locally manufactured stirrer which contained 13 "teeth" per 12 cm. The stirrer was driven by an electric motor whose speed was controlled by a variable transformer which was set on 40 of its 100 point scale. Two cylinders were placed in each of four water baths at a time. All of the stirrers, electric motors, and variable transformers used were identical. Two replications of each time/temperature combination were made.

IV. GAS CHROMATOGRAPHIC ANALYSIS

A 0.5 gram portion of hydrolysate from each sample was mixed by stirring one hour with 50 ml deionized water. The extract was allowed to settle for 10 minutes after which approximately 20 ml of supernatent were decanted and centrifuged for 5 minutes at 48,200 × G. One ml of the supernatant was placed in a small vial (Silli-vials, Applied Science Laboratories, Inc., State College, Pa.) to which approximately 0.8 mg of

stearic acid was added. The contents of the vials was dried in a vacuum oven for 24 hours at 35°C and 58 torr and stored in a desiccator.

Sylation was accomplished by adding 1.0 ml of premixed sylation reagent (9 parts pyridine, 3 parts hexamethyldisilazane, 1 part trimethylchlorosilane, Applied Science Laboratories, Inc., State College, Pa.) to the dried samples in the vials. The vials were shaken on a mechanical shaker for 30 minutes and allowed to set overnight before the contents were chromatographed.

Samples were chromatographed using a Model 810, F & M Research Gas Chromatograph equipped with a flame ionization detector. A 1.83 m × 0.32 cm I.D. stainless steel column was packed with 3% OV-17 on 80/100 Supelcoport (Supelco Inc., Bellefonte, Pa.). Gas flow rates were as follows: nitrogen, 30 ml/minute; hydrogen, 40 ml/minute; and air, 400 ml/minute. The heating schedule was programmed at 15°C/minute starting at 135°C with a 2 minute post injection interval to 255°C with a 3 minute upper limit interval. The injection port temperature was 325°C and the detection port temperature was 375°C. Attenuations varied from 8 to 32 and the range used was 10^2. Sample injection size was 8 microliters.

Samples were analyzed for the amount of fructose, glucose, sucrose, and maltose present by preparing 2 replications. The internal standard used was 0.8 mg/ml of specially pure stearic acid (Gallard-Schlesinger Chemical Mfg. Corp., Carle Place, N.Y.). The detector response (K) values were determined by the slopes of the linear calibration curves obtained for each sugar by chromatographing varying amounts of sugar with constant amounts of internal standard and plotting the ratio of the

total area of the sugar to that of the standard against the ratio of the weight of the sugar to that of the standard.

$$K = \frac{\text{Total peak area for sugar/Peak area of internal standard}}{\text{Weight of sugar/Weight of internal standard}} \quad (1)$$

K values determined for the different sugars were: fructose, 1.7975; glucose, 2.0180; sucrose, 1.4328; and maltose, 1.2340. The weight of each sugar was calculated by the following formula:

$$\text{Weight of sugar} = \frac{\text{Weight of internal standard} \times \text{Peak area of sugar}}{\text{Peak area of internal standard} \times \text{Appropriate K value}} \quad (1)$$

Quantitative determination capability of the sugars was determined by performing 3%-recovery trials using added levels of 36.0, 57.6, and 79.2 mg of each sugar per gram of baked sweet potato puree.

The optimum amount of fructose produced was determined statistically by a 5 × 4 factorial design completely randomized relative to temperature and pH. The varietal component was a split-plot design. Analysis of variance was performed and differences among means were partitioned into specific orthogonal polynomials. Two observations were made per cell. The results were presented as three dimensional response surface diagrams for each sugar.

V. COLOR ANALYSIS

Hunter L, a, and b values were determined (relative to an orange tile, L = 58.5, a = +29.4, and b = +33.1) by the Hunter Color/Difference meter for each hydrolysate temperature/pH combination. Hunter L, a, or b values were layed out in a 5 × 4 factorial design randomized relative to temperature and pH. The varietal component was a split-plot design. Two replications were performed and one observation per cell was made. Analysis of variance was performed and differences among means were partitioned into specific orthogonal polynomials. The results were presented as three dimensional response surface diagrams for each Hunter value.

VI. TASTE PANEL

A panel of 20 members was chosen from among professors, graduate students, and undergraduate students who indicated that they liked sweet potatoes. The panel was asked to indicate preference for sweetness of baked sweet potato puree samples. Puree from two varieties (Jewel and Jasper) of baked sweet potatoes was sweetened with five levels (5, 10, 15, 20, and 25%) of sucrose and with five levels (10, 30, 50, 70, and 90%) of baked sweet potato puree hydrolysate.

The panel scored samples of puree sweetened by the five levels of sucrose and samples of puree in which five levels of hydrolysate had been added. The serving size was approximately five grams which was served in 21.3 gram paper serving cups. The samples were randomly

arranged on each tray and coded by a three place random digit code. Judging was conducted under red lights. The panelists scored the samples twice a day for two consecutive days meeting between 10:00 and 11:00 a.m. and 3:00 and 4:00 p.m. A separate replication was tested on each day. The Jewel variety was judged in the morning and the Jasper variety was judged in the afternoon. The score sheet contained a six point hedonic scale (1 = dislike very much, 2 = dislike moderately, 3 = dislike slightly, 4 = like slightly, 5 = like moderately, 6 = like very much).

The panel format was designed as a 5 × 2 factorial layed out in randomized complete blocks with two replications. Analysis of variance was performed and differences among the means were partitioned into specific orthogonal polynomials. The results were presented in graphic form.

VII. CALORIC DETERMINATION

The caloric value of baked sweet potato puree sweetened with the five levels of sucrose and of an unsweetened sample was determined using an oxygen bomb calorimeter (Parr Instrument Co., Moline, Ill.). The puree was dried in a vacuum oven at 50°C and 58 torr for four days and stored in a desiccator until use. Approximately 0.4 grams of dried puree was analyzed per observation. For calculation purposes the true dry weights of the samples were subsequently determined by drying in a vacuum oven for three days at 70°C and 58 torr. The moisture content of the starting puree was also determined by drying approximately five grams in a vacuum oven at 70°C at 125 torr for three days.

The caloric value determination was statistically designed as a 6 × 2 factorial layed out in randomized complete blocks with two replications. Analysis of variance was performed and the data was presented in tabular form.

CHAPTER IV

RESULTS AND DISCUSSION

I. HYDROLYSIS

Table I presents the results of the three sugar recovery trials. One may conclude that at the range of quantities studied, sucrose and maltose cannot be reliably analyzed quantitatively.

The analysis of variance for the effect of variables on the amount of glucose in the hydrolysate is presented in Table II. Temperature, pH, and their interaction had a significant effect. Temperature was the main factor affecting the glucose content within each variety. The varietal factor and the temperature × variety interaction had a significant effect. This indicates the greater relative importance of temperature on the presence of glucose in the hydrolysate.

Since glucose was produced and isomerized by the glucose isomerase enzyme as well as being a natural constituent of sweet potatoes, speculation regarding the complex systematic explanations for the presence of glucose in the hydrolysate should be regarded as uncertain. The response surface diagrams for glucose found in the hydrolysate are presented in Figure 1 (Jewel variety) and Figure 2 (Jasper variety). The Appendix includes the regression equations used to produce these diagrams. The glucose content was reduced dramatically at the highest pH and temperature levels. This reduction may be due to heat denaturation of amyloglucosidase. In general, a greater amount of glucose was

TABLE I

PERCENTAGE OF SUGAR RECOVERED WHEN ADDED TO BAKED SWEET POTATO PUREE

Sugar	Added Sugar (mg/g Puree)		
	36.0	57.6	79.2
	Recovered Sugar (%)		
Fructose	97.59 ± 5.78	98.59 ± 5.34	98.75 ± 4.84
Glucose	100.93 ± 5.94	98.71 ± 5.60	97.26 ± 5.25
Sucrose	124.78 ± 7.39	106.02 ± 5.33	103.82 ± 3.87
Maltose	134.62 ± 12.92	103.03 ± 7.82	91.69 ± 8.45

[a]Means of three replications (each containing two observations) ± one standard deviation.

TABLE II

ANALYSIS OF VARIANCE FOR THE ENZYMATIC PRODUCTION OF GLUCOSE IN BAKED SWEET POTATO PUREE

	Source	D.F.	S.S.	M.S.	F-ratio	Probability
A.	Total	79	70.19	0.89		
B.	pH	4	20.59	5.15	40.04	**
C.	Temperature	3	22.85	7.62	59.25	**
D.	pH × Temperature	12	11.31	0.94	7.33	**
E.	Replications within pH and Temperature[a]	20	2.57	0.13		
F.	Variety	1	8.61	8.61	140.82	**
G.	pH × Variety	4	0.65	0.16	2.66	N.S.
H.	Temperature × Variety	3	1.08	0.36	5.87	**
I.	pH × Temperature × Variety	12	1.31	0.11	1.78	N.S.
J.	Residual error[b]	20	1.23	0.06		

N.S. Not statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

[a]Item E is the error term for testing items B, C, and D.

[b]Item J is the error term for testing items F, G, H, and I.

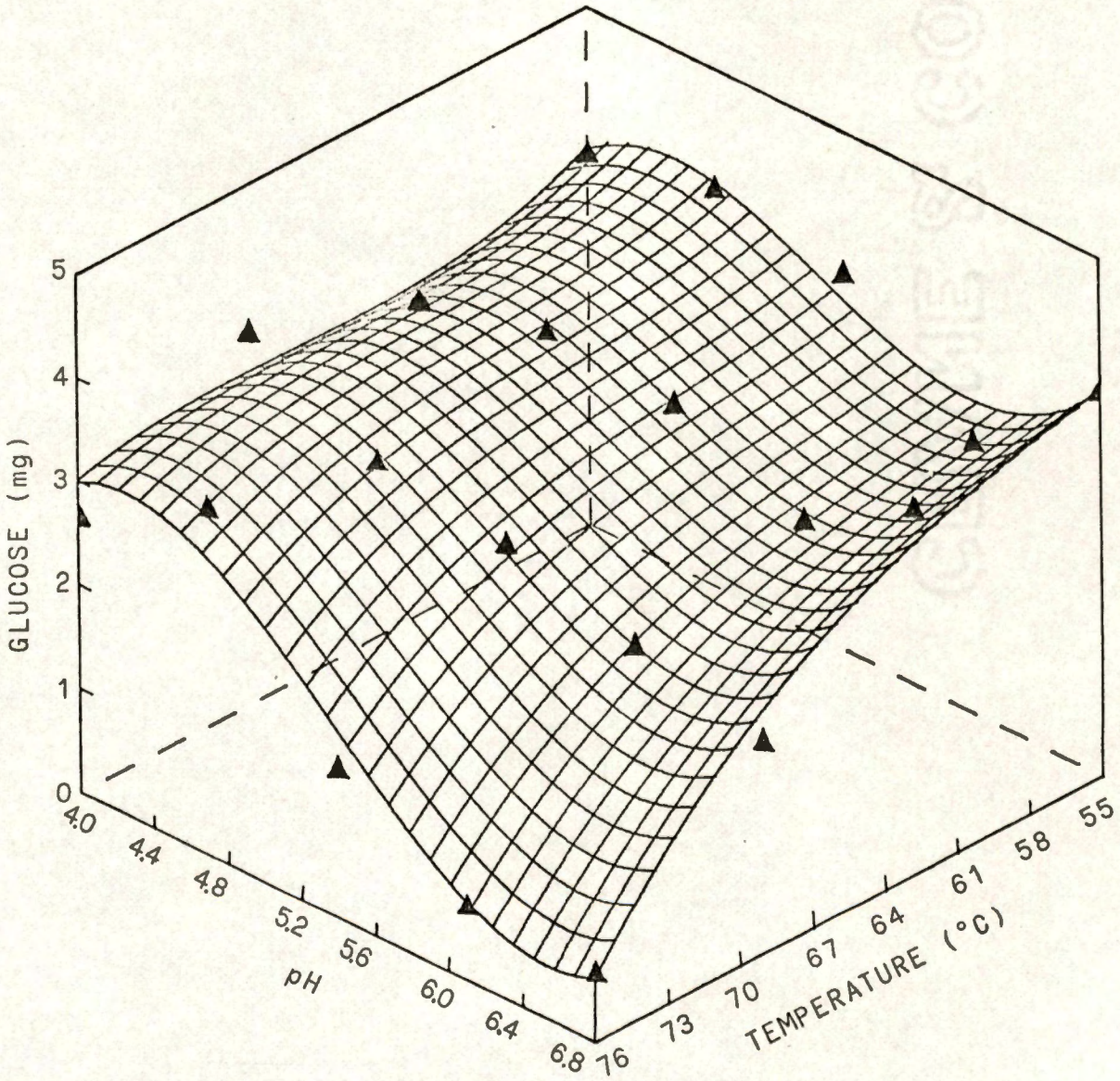


Figure 1. Response surface diagram for glucose (mg/g hydrolysate) found in baked sweet potato puree hydrolysate of the Jewel variety.

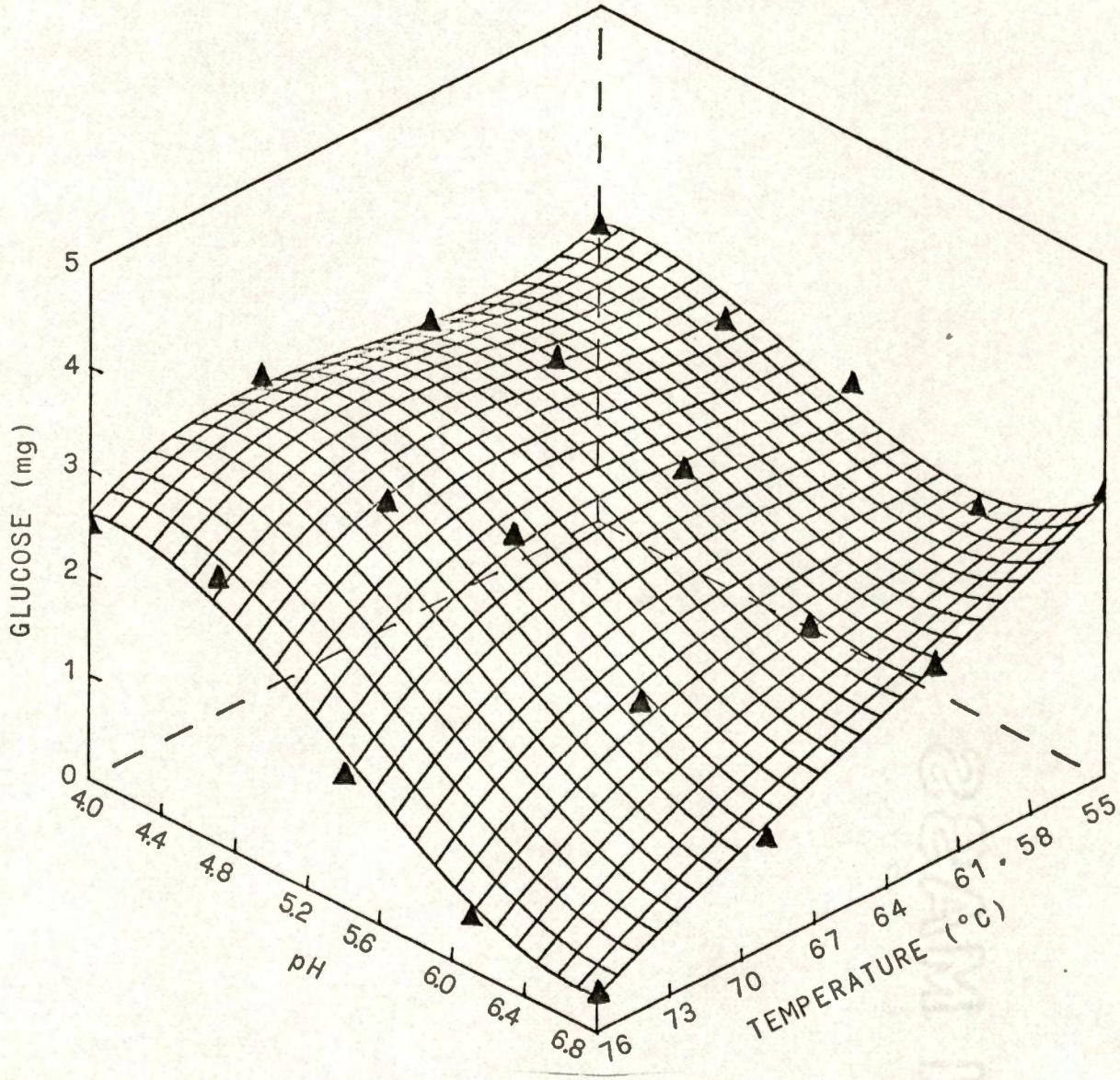


Figure 2. Response surface diagram for glucose (mg/g hydrolysate) found in baked sweet potato puree hydrolysate of the Jasper variety.

present in the hydrolysate of Jewel variety than in that of Jasper variety. Since a greater amount of fructose, also, was present in the Jewel variety, as will be shown below, this is an indication that amyloglucosidase may have had greater activity in the Jewel variety.

The analysis of variance for the effect of experimental conditions of the amount of maltose in the hydrolysate is presented in Table III. The amount of maltose was significantly affected by pH, temperature, and variety. Also, pH × temperature, and temperature × variety interactions were significant. The factor affecting maltose to the greatest extent was temperature.

Table IV (Jewel variety) and Table V (Jasper variety) lists the mean values for two observations of maltose. Since zero values for maltose content were found at all pH levels for 55°C and 62°C and at pH 4.0 to pH 5.4 for 69°C, no response surface diagrams were produced for maltose. Of interest is the effect of the highest temperature and pH levels on maltose found in the hydrolysate. The presence of maltose only at these values is probably due to heat denaturation of amyloglucosidase which converts maltose to glucose.

The analysis of variance for the fructose content of the sweet potato hydrolysate is presented in Table VI. The varietal component had a significant effect on the amount of fructose. The effect of pH, temperature, pH × temperature interaction, and the pH × variety interaction were significant at the 1% level of probability. The major effect was due to pH. The pH × variety interaction was significant, but the temperature × variety interaction was not significant indicating

TABLE III

ANALYSIS OF VARIANCE FOR THE ENZYMATIC PRODUCTION OF MALTOSE IN BAKED SWEET POTATO PUREE

	Source	D.F.	S.S.	M.S.	F-ratio	Probability
A.	Total	79	35.07	0.44		
B.	pH	4	5.10	1.28	62.58	**
C.	Temperature	3	20.62	6.87	337.12	**
D.	pH × Temperature	12	8.50	0.71	34.74	**
E.	Replications within pH and Temperature[a]	20	0.41	0.02		
F.	Variety	1	0.06	0.05	10.31	**
G.	pH × Variety	4	0.03	0.01	1.44	N.S.
H.	Temperature × Variety	3	0.15	0.05	8.87	**
I.	pH × Temperature × Variety	12	0.09	0.01	1.42	N.S.
J.	Residual[b]	20	0.11	0.01		

N.S. Not statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

[a]Item E is the error term for testing items B, C, and D.

[b]Item J is the error term for testing items F, G, H, and I.

TABLE IV

MEAN VALUES OF MALTOSE[a] IN BAKED SWEET POTATO PUREE ENZYMATIC HYDROLYSATE WITH RESPECT TO pH AND TEMPERATURE FOR JEWEL VARIETY

	pH				
Temperature (°C)	4.0	4.7	5.4	6.1	6.8
			Maltose (mg)		
55	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00
69	0.00	0.00	0.00	0.21	0.92
76	0.35	0.35	1.61	2.17	2.15

[a]mg maltose/gram (wet weight) of hydrolysate.

TABLE V

MEAN VALUES OF MALTOSE[a] IN BAKED SWEET POTATO PUREE ENZYMATIC HYDROLYSATE WITH RESPECT TO pH AND TEMPERATURE FOR JASPER VARIETY

	pH				
Temperature (°C)	4.0	4.7	5.4	6.1	6.8
			Maltose (mg)		
55	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00
69	0.00	0.00	0.00	0.24	0.82
76	0.39	0.24	1.35	1.77	1.87

[a]mg maltose/gram (wet weight) of hydrolysate.

TABLE VI

ANALYSIS OF VARIANCE FOR THE ENZYMATIC PRODUCTION OF FRUCTOSE IN BAKED SWEET POTATO PUREE

	Source	D.F.	S.S.	M.S.	F-ratio	Probability
A.	Total	79	8.73	0.11		
B.	pH	4	4.78	1.20	110.98	**
C.	Temperature	3	0.57	0.19	17.62	**
D.	pH × Temperature	12	1.59	0.13	12.31	**
E.	Replications within pH and Temperature[a]	20	0.22	0.01		
F.	Variety	1	0.61	0.61	43.36	**
G.	pH × Variety	4	0.30	0.08	5.37	**
H.	Temperature × Variety	3	0.10	0.03	2.26	N.S.
I.	pH × Temperature × Variety	12	0.28	0.02	1.67	N.S.
J.	Residual Error[b]	20	0.28	0.01		

N.S. Not statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

[a]Item E is the error term for testing items B, C, and D.

[b]Item J is the error term for testing items F. G, H, and I.

the relative importance of pH over temperature in this system. Figure 3 (Jewel variety) and Figure 4 (Jasper variety) present the response surface diagrams for fructose in the hydrolysate. The Appendix includes the regression equations used to produce these diagrams. As the temperature was increased beyond 67°C the amount of fructose produced decreased rapidly for both varieties. This may indicate heat denaturation of the enzymes at the higher temperatures and pH levels studied. Figures 3 and 4 indicate that the maximum amount of fructose was produced at approximately 64°C and at pH 6.8 under the specified conditions of this study. Under these conditions a much greater amount of fructose was produced by the enzyme system from the Jewel variety than from the Jasper variety. The optimum pH for production of fructose is beyond the upper limit of the pH range utilized as evidenced by the increase in amount of fructose as the pH reached the range limit.

If the enzyme preparations added to the puree were free of other enzyme contaminants the sucrose content in the hydrolysate should have been unaffected by the three added enzymes. The analysis of variance for the effect of variables on the sucrose content of sweet potato puree hydrolysate is presented in Table VII. Both pH and temperature had a significant effect on the sucrose content in the hydrolysate, but pH had the greater influence. The varietal component was not significant, but the pH × variety interaction was significant due to the strong effect of pH. The response surface diagrams for sucrose in the hydrolysate are presented in Figure 5 (Jewel variety) and Figure 6 (Jasper variety). The appendix includes the regression equations used to produce these

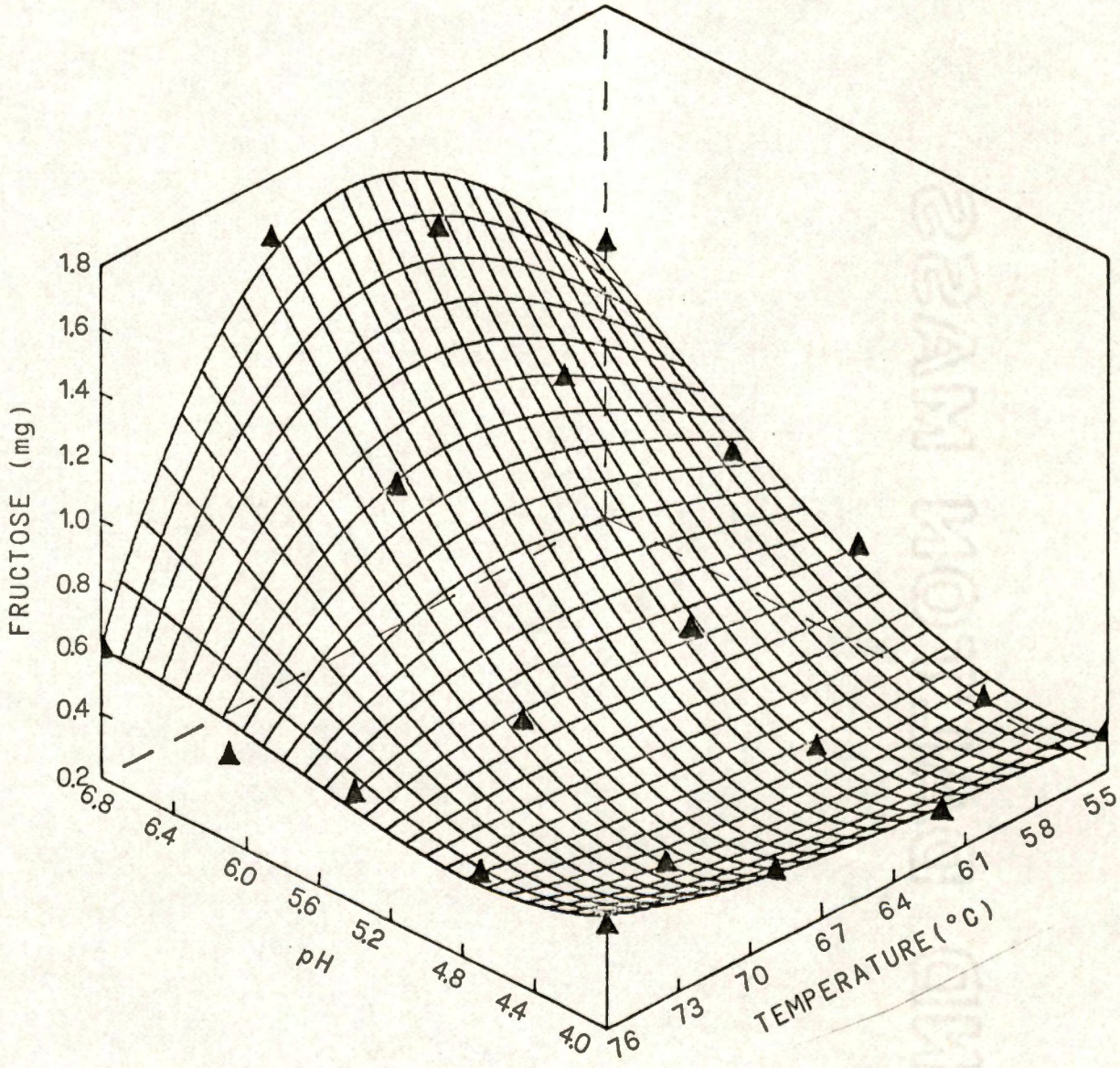


Figure 3. Response surface diagram for fructose (mg/g hydrolysate) found in baked sweet potato puree hydrolysate of the Jewel variety.

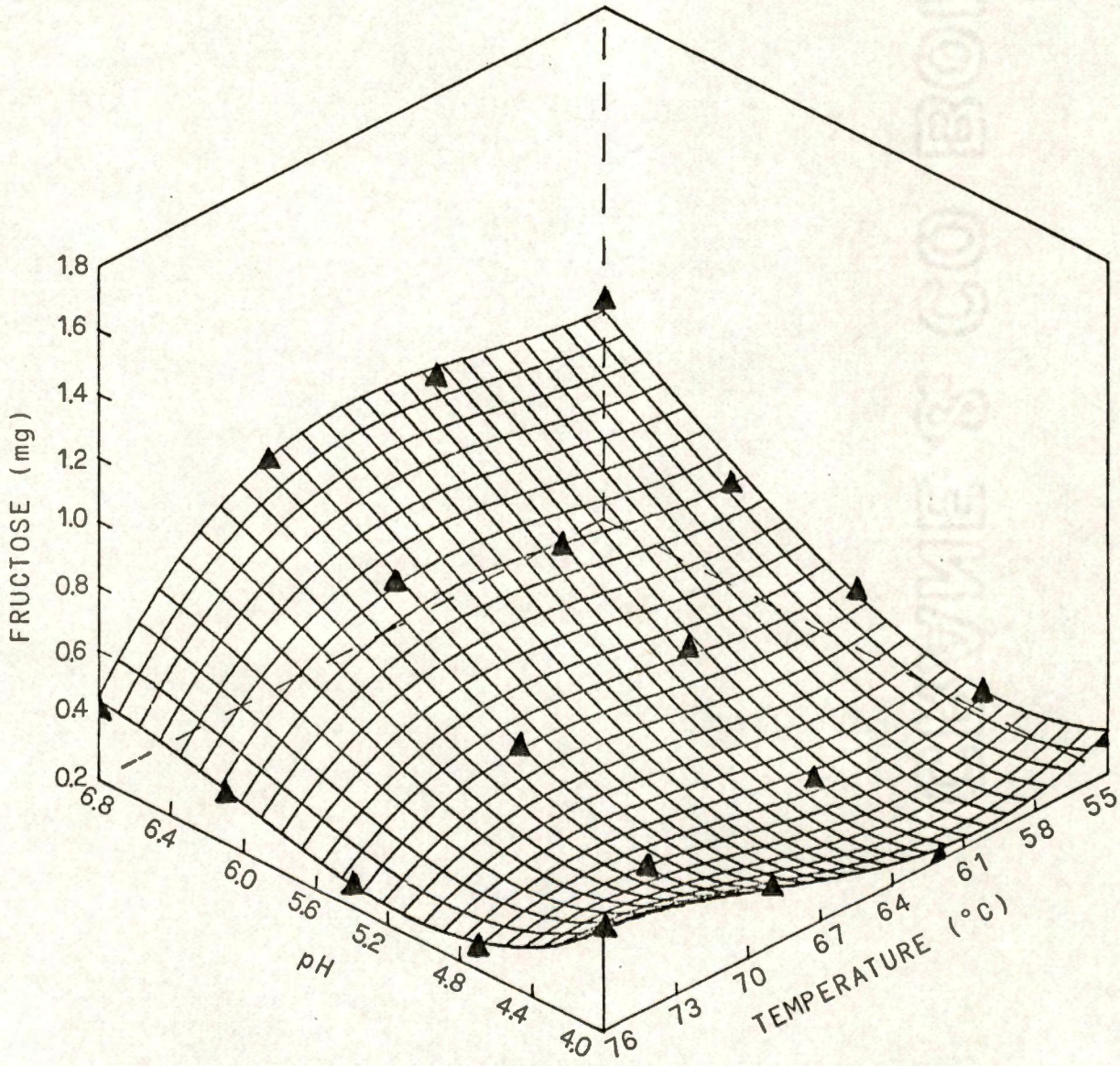


Figure 4. Response surface diagram for fructose (mg/g hydrolysate) found in baked sweet potato puree hydrolysate of the Jasper variety.

TABLE VII

ANALYSIS OF VARIANCE FOR THE PRESENCE OF SUCROSE IN BAKED SWEET POTATO PUREE

Source	D.F.	S.S.	M.S.	F-ratio	Probability
A. Total	79	3.93	0.05		
B. pH	4	2.46	0.62	26.57	**
C. Temperature	3	0.23	0.08	3.98	**
D. pH × Temperature	12	0.53	0.04	1.91	N.S.
E. Replications within pH and Temperature[a]	20	0.46	0.02		
F. Variety	1	0.02	0.02	3.88	N.S.
G. pH × Variety	4	0.06	0.01	2.86	*
H. Temperature × Variety	3	0.01	0.00	0.45	N.S.
I. pH × Temperature × Variety	12	0.68	0.01	1.17	N.S.
J. Residual Error[b]	20	0.10	0.00		

N.S. Not statistically significant at the 0.05 level of probability.

*Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

[a]Item E is the error term for testing items B, C, and D.

[b]Item J is the error term for testing items F, G, H, and I.

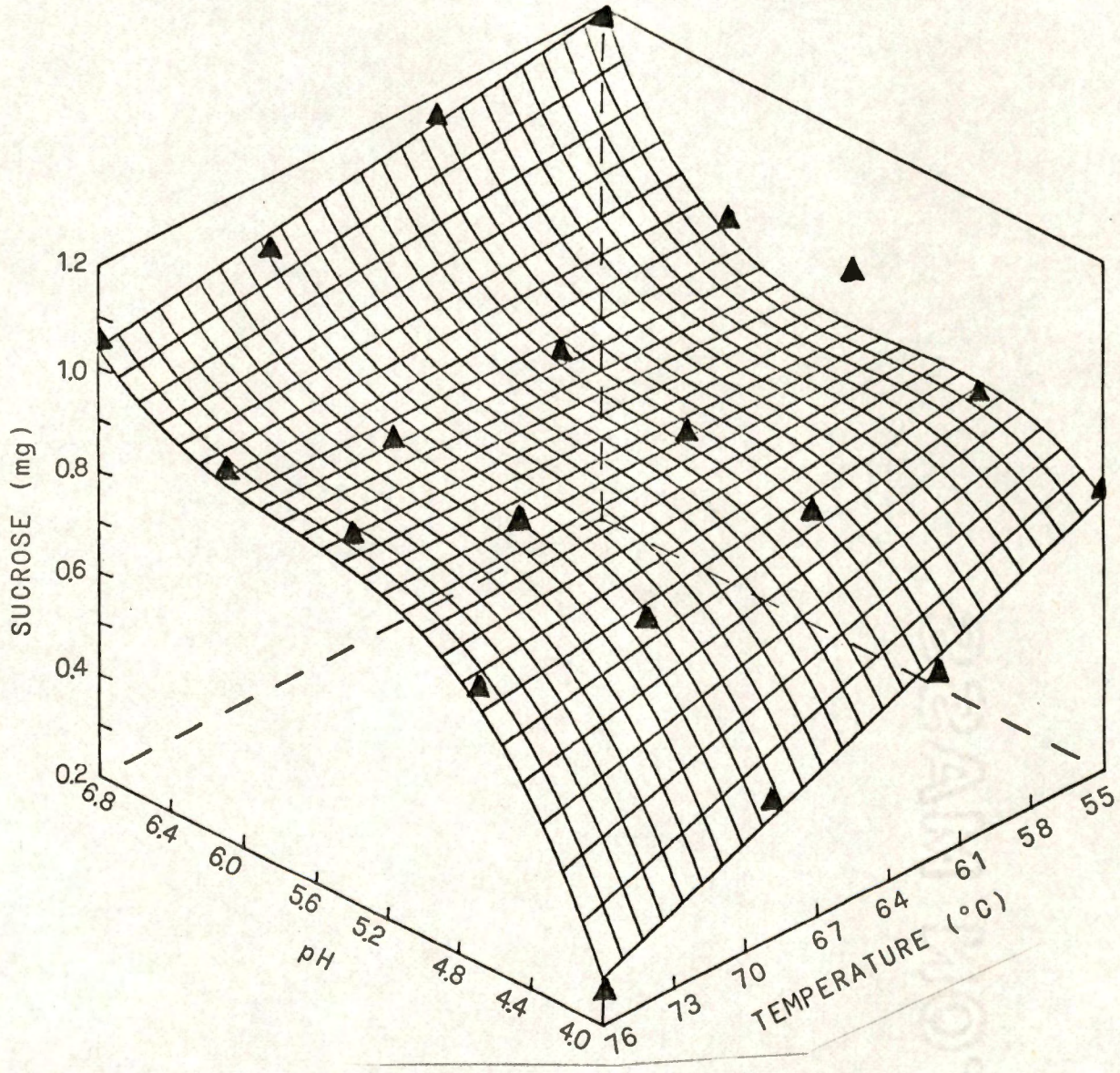


Figure 5. Response surface diagram for sucrose (mg/g hydrolysate) found in baked sweet potato puree hydrolysate of the Jewel variety.

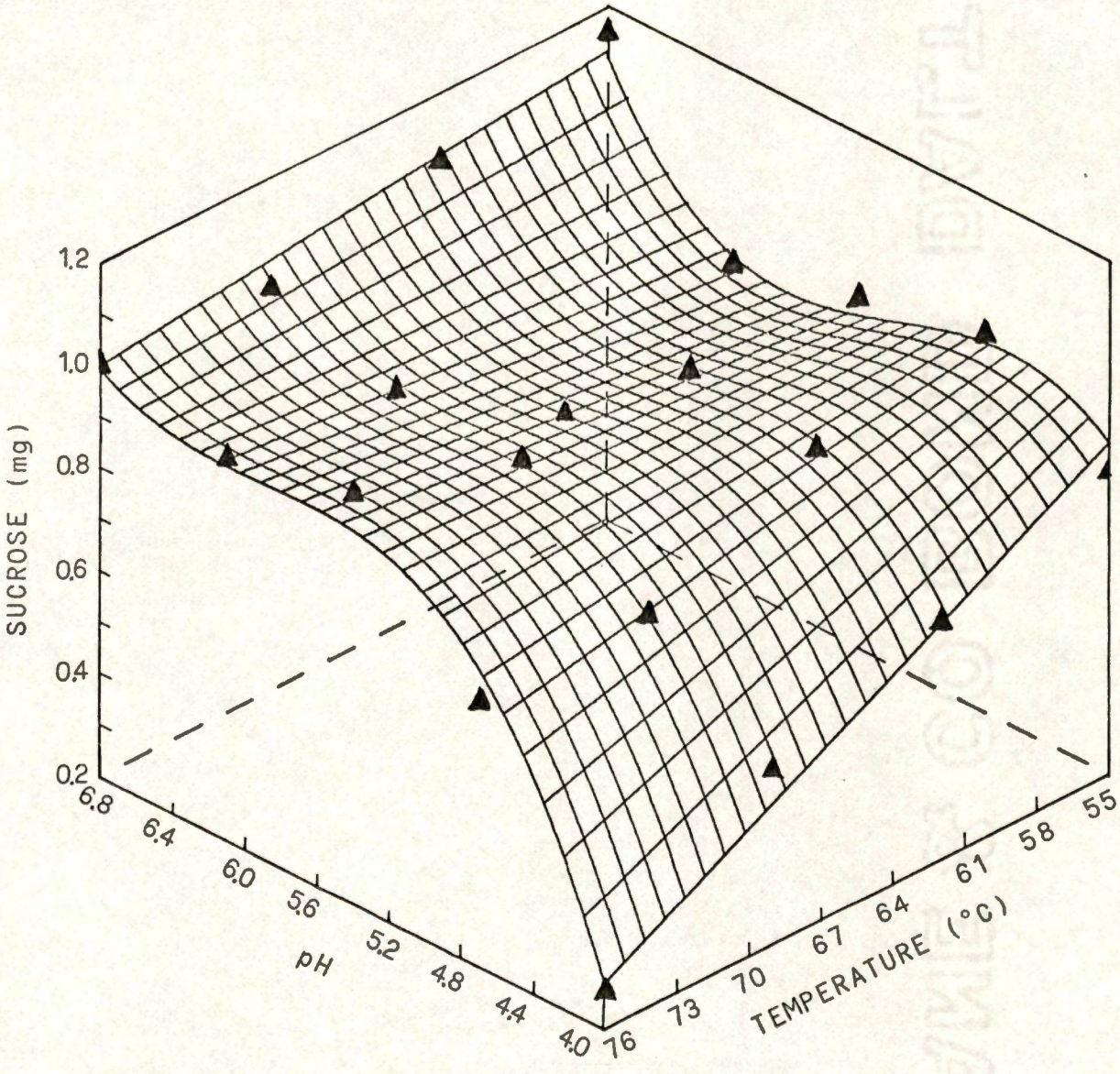


Figure 6. Response surface diagram for sucrose (mg/g hydrolysate) found in baked sweet potato puree hydrolysate of the Jasper variety.

diagrams. As the temperature increased the sucrose concentration decreased. Since sucrose is supposedly unaffected by the added enzymes, one possible explanation for the reduction of sucrose in the hydrolysate is that at the lower limit of the pH range inversion of sucrose molecules occurred. Inversion should have increased as the temperature was increased.

The analysis of variance for the Hunter L color values is presented in Table VIII. Temperature and pH were significant, but temperature had the greater influence on the Hunter L values. A Hunter L value of zero indicates black and a value of 100 indicates white. The large effect of temperature caused the interactions of pH × temperature, temperature × variety, and pH × temperature × variety to be significant also. Differences in variety did not significantly affect the darkening of the hydrolysate.

The response surface diagrams for the Hunter L values are presented in Figure 7 (Jewel variety) and Figure 8 (Jasper variety). The Appendix includes the regression equations used to produce these diagrams. The Hunter L values decreased as the temperature increased, indicating a pronounced darkening of the hydrolysate. The greater effect of temperature on the darkening of sweet potato puree should not overshadow the significant effect of pH on the Hunter L values. The natural pH of the sweet potato purees was pH 5.8. Lowering the pH much from pH 5.8 caused a pronounced visual lightening of the yellow-orange color of the puree. Raising the pH above pH 5.8 caused a pronounced visual darkening of the puree. The darkening could not be reversed after hydrolysis by

TABLE VIII

ANALYSIS OF VARIANCE FOR HUNTER L VALUES OF ENZYMATICALLY HYDROLYZED BAKED SWEET POTATO PUREE

	Source	D.F.	S.S.	M.S.	F-ratio	Probability
A.	Total	79	1414.12	17.90		
B.	pH	4	98.00	24.50	14.91	**
C.	Temperature	3	1154.05	384.68	234.15	**
D.	pH × Temperature	12	89.43	7.45	4.54	**
E.	Replications within pH and Temperature[a]	20	32.86	1.64		
F.	Variety	1	0.00	0.00	0.01	N.S.
G.	pH × Variety	4	3.44	0.86	1.68	N.S.
H.	Temperature × Variety	3	7.50	2.50	4.88	*
I.	pH × Temperature × Variety	12	18.61	1.55	3.03	*
J.	Residual Error[b]	20	13.04	0.65		

N.S. Not statistically significant at the 0.05 level of probability.

*Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

[a]Item E is the error term for testing items B, C, and D.

[b]Item J is the error term for testing items F, G, H, and I.

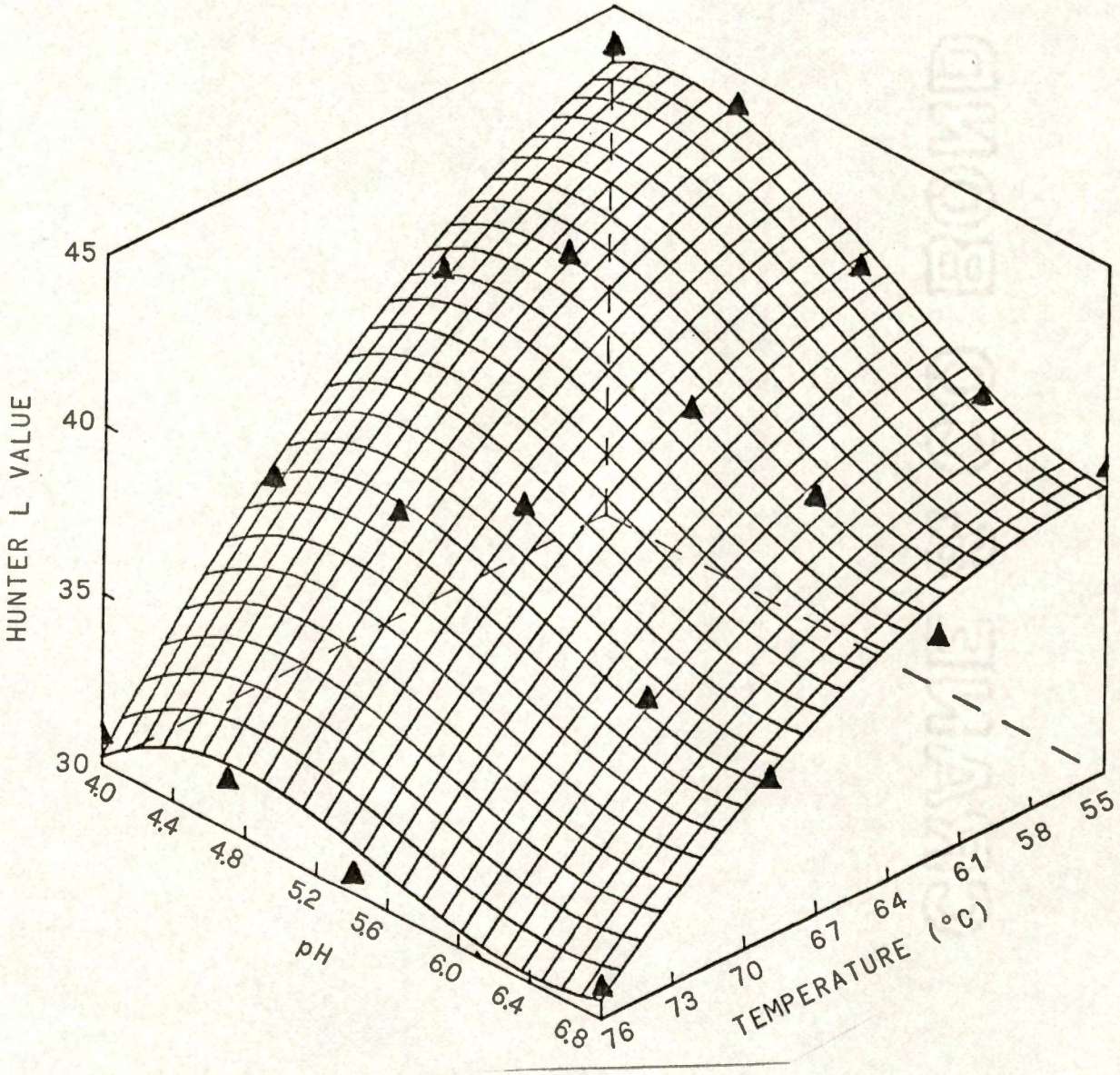


Figure 7. Response surface diagram for Hunter L values of baked sweet potato puree hydrolysate of the Jewel variety.

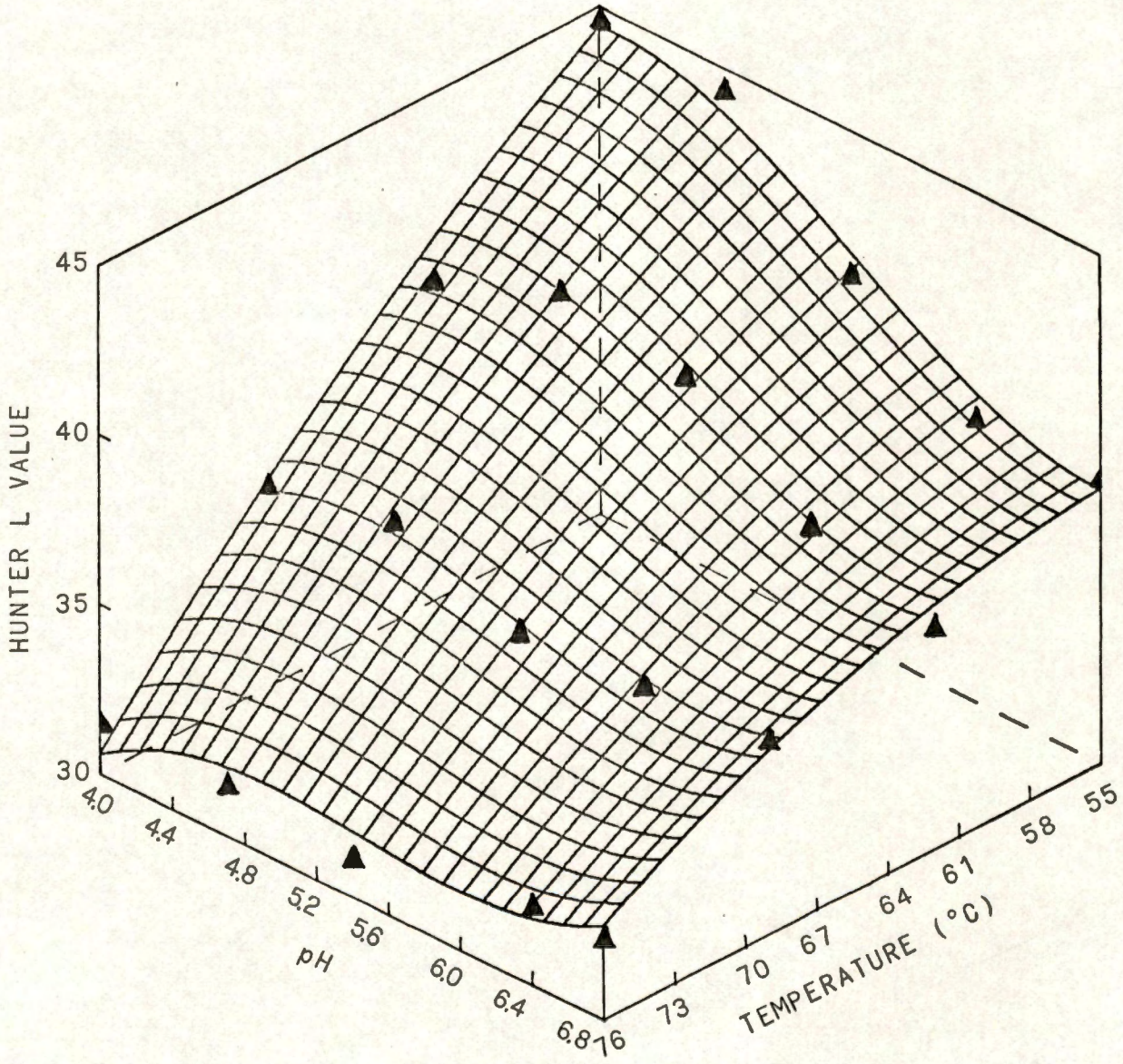


Figure 8. Response surface diagram for Hunter L values of baked sweet potato puree hydrolysate of the Jasper variety.

readjusting the pH back to pH 5.8, probably due to the pronounced and irreversible effects of the heat induced carbonyl-amine browning. Carbonyl-amine browning is the probable reason for temperature having such a pronounced effect on Hunter L values.

The analysis of variance for the Hunter a values is presented in Table IX and the response surface diagrams for the Hunter a values are presented in Figure 9 (Jewel variety) and Figure 10 (Jasper variety). The Appendix includes the regression equations used to produce these diagrams. As the Hunter a value decreased the red component of the puree's color decreased toward gray. Both temperature and variety and the pH × temperature and temperature × variety interactions were significant. The temperature component had the larger influence on the Hunter a value. The varietal difference is evident by comparing the values of the two figures. Of interest is the increase in the redness of the puree from 55°C to about 60°C.

The analysis of variance for the Hunter b values is presented in Table X. Significant effects on the Hunter b values were contributed by pH, temperature, and variety as well as the interactions of pH × temperature, temperature × variety, and pH × temperature × variety. The major effect was that of temperature. Response surface diagrams for the Hunter b values are presented in Figure 11 (Jewel variety) and Figure 12 (Jasper variety). The Appendix includes the regression equations used to produce these diagrams. In general, the Hunter b values decreased from approximately 25 to approximately 17 as the

TABLE IX

ANALYSIS OF VARIANCE FOR HUNTER a VALUES OF ENZYMATICALLY HYDROLYZED BAKED SWEET POTATO PUREE

	Source	D.F.	S.S.	M.S.	F-ratio	Probability
A.	Total	79	389.57	4.93		
B.	pH	4	22.76	5.69	2.69	N.S.
C.	Temperature	3	164.27	54.76	25.84	**
D.	pH × Temperature	12	96.73	8.06	3.80	**
E.	Replications within pH and Temperature[a]	20	42.39	2.12		
F.	Variety	1	3.16	3.16	4.85	*
G.	pH × Variety	4	2.22	0.55	0.85	N.S.
H.	Temperature × Variety	3	31.05	10.35	15.88	**
I.	pH × Temperature × Variety	12	13.95	1.16	1.78	
J.	Residual Error[b]	20	13.04	0.65		

N.S. Not statistically significant at the 0.05 level of probability.

*Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

[a]Item E is the error term for testing items B, C, and D.

[b]Item J is the error term for testing items F, G, H, and I.

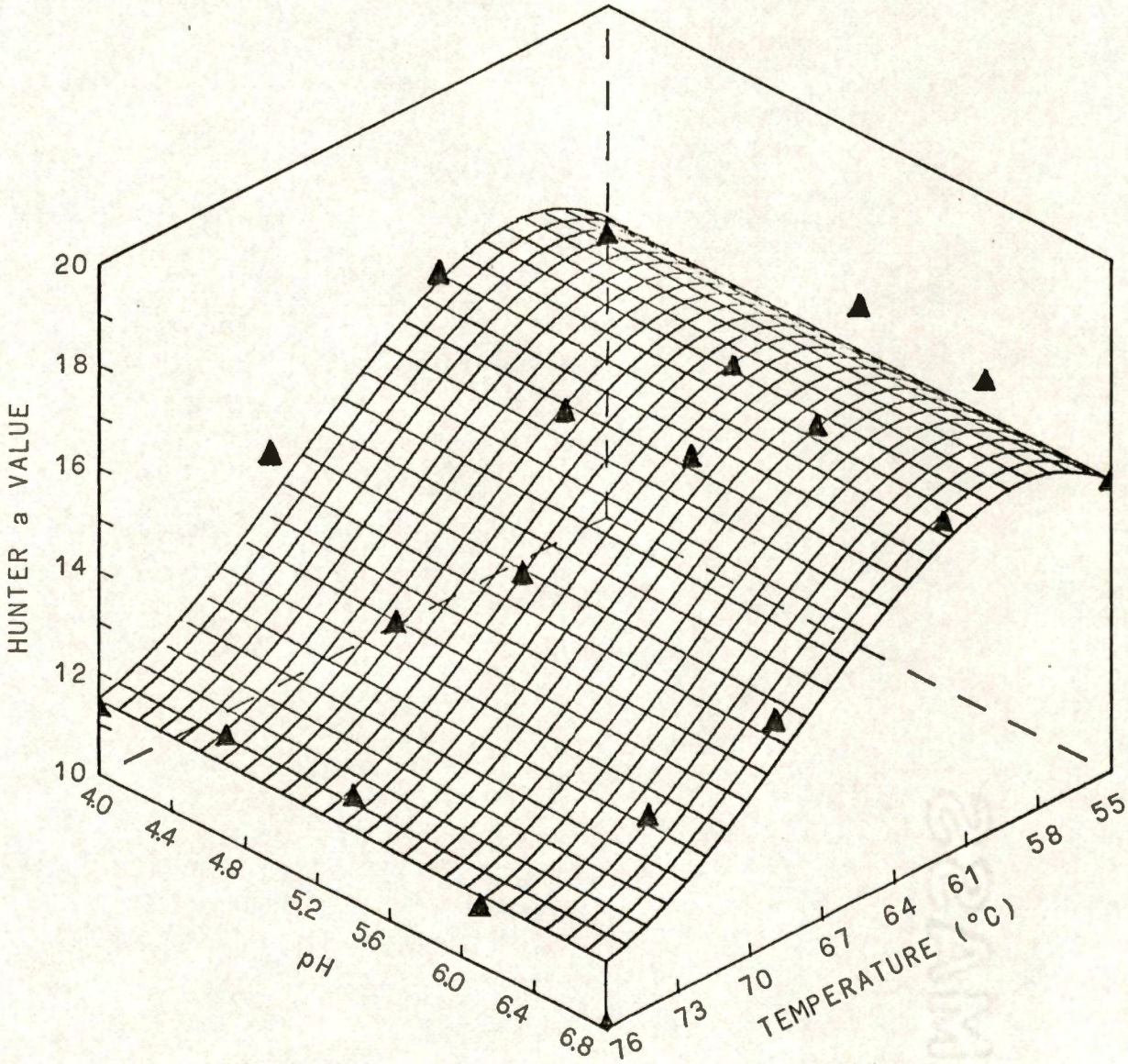


Figure 9. Response surface diagram for Hunter a values of baked sweet potato puree hydrolysate of the Jewel variety.

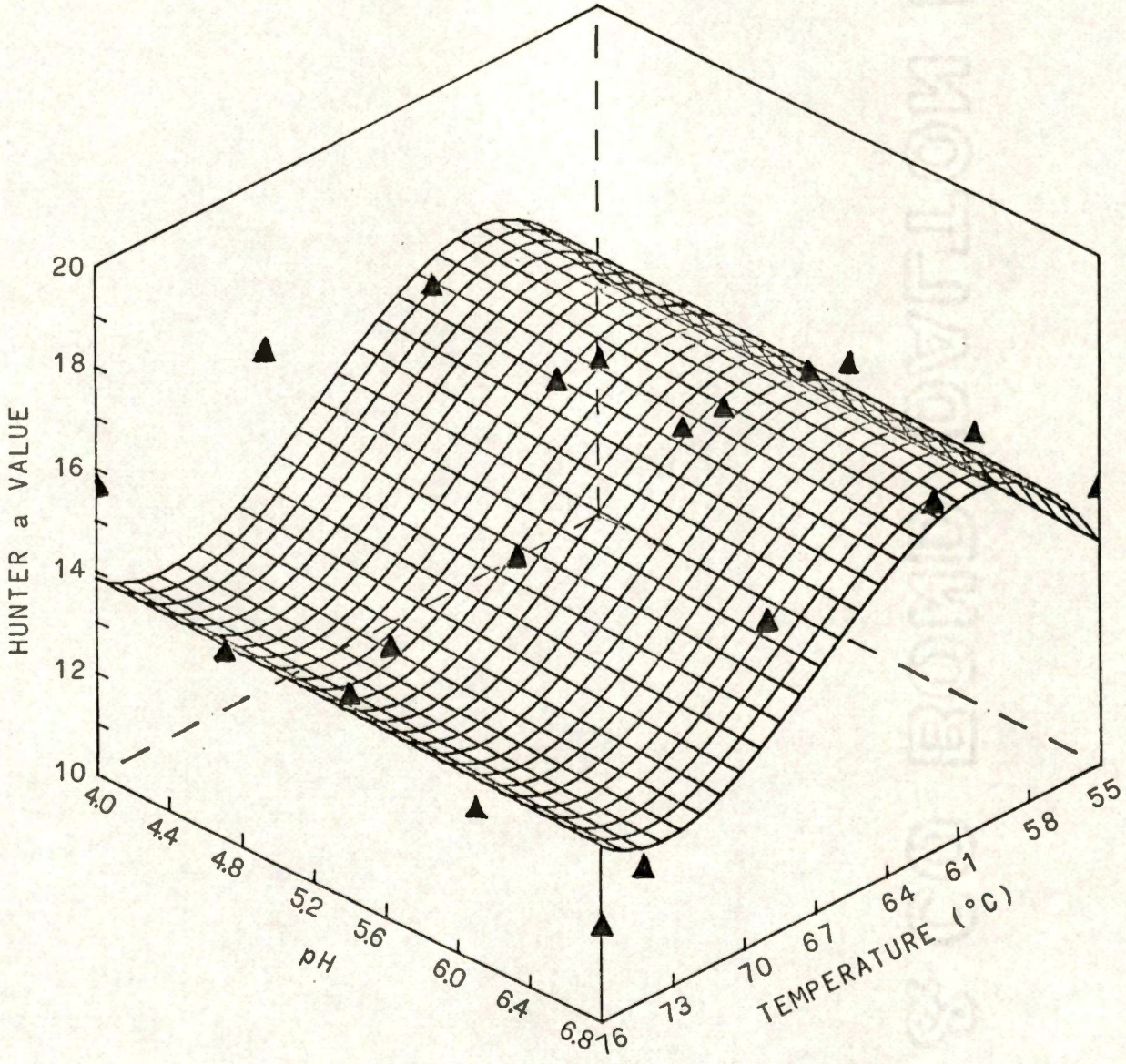


Figure 10. Response surface diagram for Hunter a values of baked sweet potato puree hydrolysate of the Jasper variety.

TABLE X

ANALYSIS OF VARIANCE FOR HUNTER b VALUES OF ENZYMATICALLY HYDROLYZED BAKED SWEET POTATO PUREE

	Source	D.F.	S.S.	M.S.	F-ratio	Probability
A.	Total	79	673.35	8.52		
B.	pH	4	31.07	7.77	11.86	**
C.	Temperature	3	530.89	176.97	270.23	**
D.	pH × Temperature	12	71.28	5.93	9.07	**
E.	Replications within pH and Temperature[a]	20	13.10	0.65		
F.	Variety	1	1.83	1.83	7.32	*
G.	pH × Variety	4	2.78	0.70	2.79	N.S.
H.	Temperature × Variety	3	4.15	1.38	5.54	**
I.	pH × Temperature × Variety	12	13.24	1.10	4.05	**
J.	Residual Error[b]	20	5.00	0.25		

N.S. Not statistically significant at the 0.05 level of probability.

*Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

[a]Item E is the error term for testing items B, C, and D.

[b]Item J is the error term for testing items F, G, H, and I.

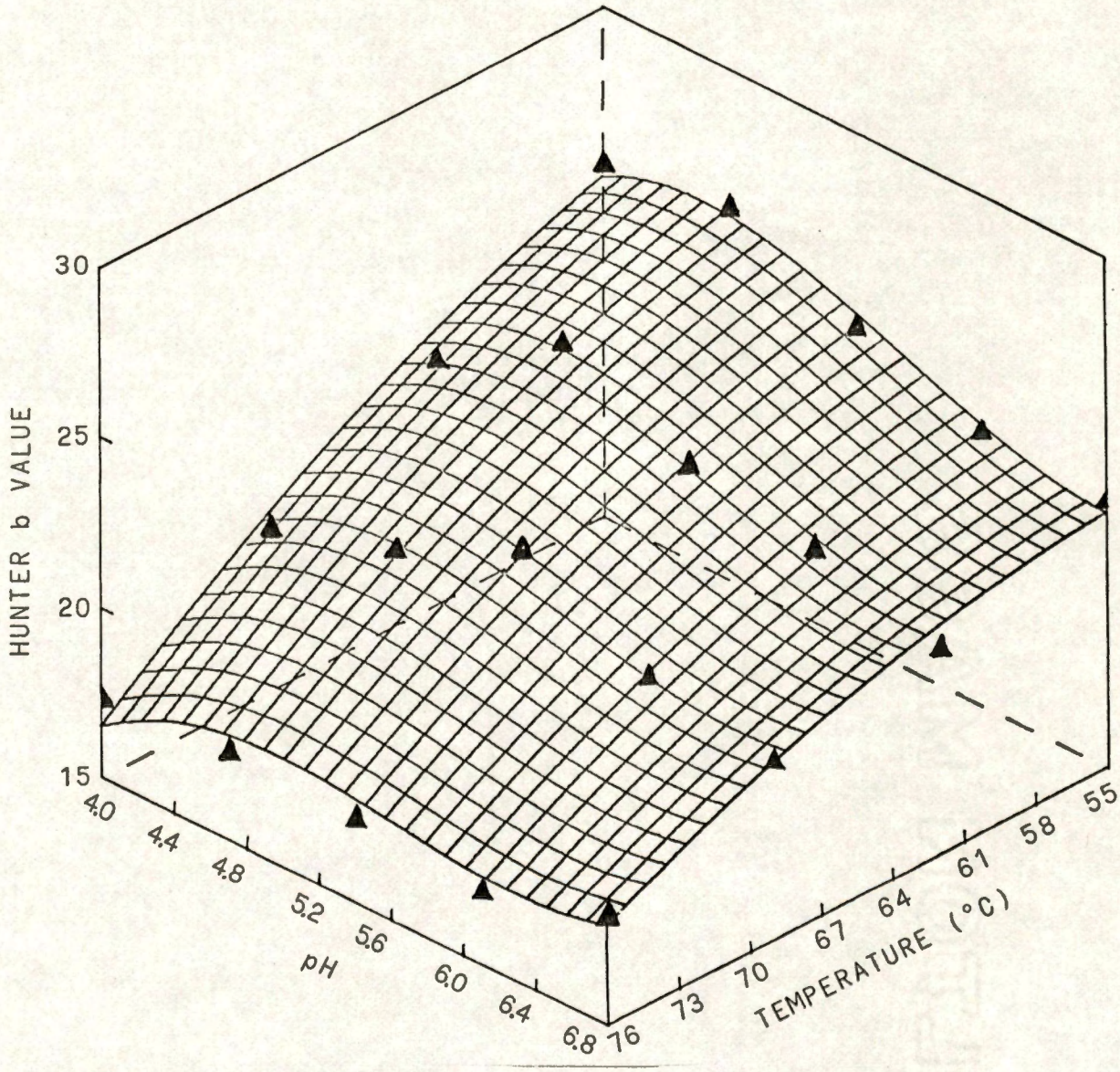


Figure 11. Response surface diagram for Hunter b values of baked sweet potato puree hydrolysate of the Jewel variety.

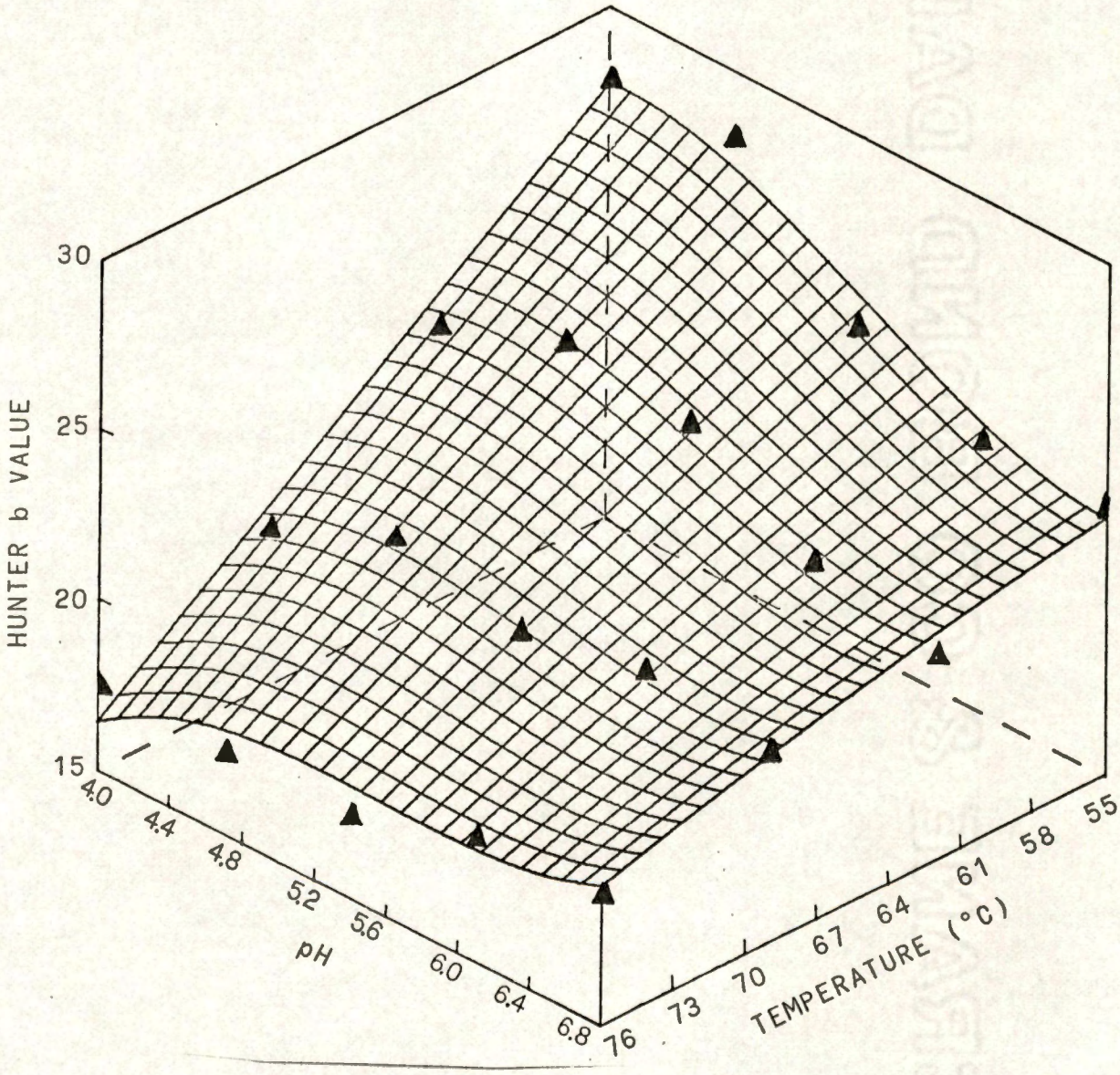


Figure 12. Response surface diagram for Hunter b values of baked sweet potato puree hydrolysate of the Jasper variety.

temperature was increased from 55°C to 76°C. This shift in Hunter b value indicates a color change from yellow toward gray.

Although the optimum pH and temperature for production of fructose by this enzymatic system was pH 6.8 at 64°C, color, flavor, and odor considerations were given equal importance in choosing the pH and temperature combination that was used to produce hydrolysate for the subsequent sensory panel. The highest pH (6.8) was chosen because it represented a dramatic increase in fructose content in the hydrolysate. The lowest temperature (55°C) was chosen in order to reduce the strong effect of temperature on the color of the hydrolysate. Also, hydrolysates which were produced at the higher temperatures had a bitter aftertaste.

The time (28 hours) of the hydrolysis chosen for the panel was decided by a 61 hour time trial. After 28 hours, the flavor and odor of the hydrolysate were becoming objectionable. Therefore, a 28 hour period was selected for hydrolysis. The difference in the amount of fructose found in the hydrolysate after 28 hours and the next sampling time at 36 hours was 0.0138 mg/gram of puree (Jewel variety) and 0.0120 mg/gram of puree (Jasper variety). These differences (less than 2%) were quite small for an additional eight hours of hydrolysis.

II. TASTE PANEL

Table XI and Table XII presents the analysis of variance for the added levels of sucrose and hydrolysate, respectively. The varietal component was not significant indicating that the panel members were

TABLE XI

ANALYSIS OF VARIANCE FOR TASTE PANEL SCORES FOR BAKED SWEET POTATO PUREE WITH ADDED SUCROSE

	Source	D.F.	S.S.	M.S.	F-ratio	Probability
A.	Total	399	640.68	1.60		
B.	Variety	1	0.90	0.90	0.58	N.S.
C.	Panel	19	235.93	12.42	7.94	**
D.	Error A	58	90.74	1.56		
E.	Replication[a]	1	11.90	11.90		
F.	Level	4	11.39	2.85	3.11	*
	Linear	1	0.02	0.02	0.02	N.S.
	Quadratic	1	9.66	9.66	10.54	**
	Cubic	1	1.71	1.71	1.87	N.S.
	Quartic	1	0.00	0.00	0.00	N.S.
G.	Variety × Level	4	4.01	1.00	1.09	N.S.
H.	Error B	312	285.80	0.92		

N.S. Not statistically significant at the 0.05 level of probability.

*Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

[a]No legitimate error term exists with which to test replication.

TABLE XII

ANALYSIS OF VARIANCE FOR TASTE PANEL SCORES FOR BAKED SWEET POTATO PUREE WITH ADDED HYDROLYSATE

	Source	D.F.	S.S.	M.S.	F-ratio	Probability
A.	Total	399	622.39	1.56		
B.	Variety	1	1.96	1.96	1.66	N.S.
C.	Panel	19	234.09	12.32	10.41	**
D.	Error A	58	68.65	1.18		
E.	Replication[a]	1	0.49	0.49		
F.	Level	4	129.59	32.40	54.31	**
	Linear	1	126.40	126.40	211.91	**
	Quadratic	1	3.00	3.00	5.04	*
	Cubic	1	0.15	0.15	0.25	N.S.
	Quartic	1	0.03	0.03	0.05	N.S.
G.	Variety × Level	4	1.49	0.37	0.62	N.S.
H.	Error B	312	186.12	0.60		

N.S. Not statistically significant at the 0.05 level of probability.

*Statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

[a]No legitimate error term exists with which to test replication.

unable to indicate a significant difference in their preference for sweetness between the two varieties. The panel term was significant at the 1% level of confidence indicating that individual panel members scored the samples differently from other panel members. Figures 13 and 14 present the regression curves for the panel scores of puree with added sucrose and hydrolysate, respectively. The Appendix includes the regression equations used to produce these curves. Since the varietal component was not significant, the regression curves were drawn from the composite means of the two varieties. The regression curve in Figure 13 was significantly quadratic in structure. The maximum panel score (calculated value) was for puree with 14.86% added sucrose. The regression curve in Figure 14 was significantly linear at the 1% confidence level and significantly quadratic at the 5% confidence level.

It is clearly demonstrated in Figure 14 that as the level of added hydrolysate was increased, the mean panel score decreased. It would seem, however, that the theoretical sweetness value would have increased. This apparent contradiction may best be explained in light of the following observations. Even though comments were not solicited, almost all of the panel members indicated a strong dislike for the samples containing the added hydrolysate. The hydrolysate itself had an unusual blend of odor and taste resembling that of overcooked and perhaps slightly decaying sweet potatoes. Since the panel members were specifically asked to judge the samples on sweetness only and not on their overall opinion of the samples, it is likely that the poor odor and taste imparted by the added hydrolysate masked the sweetness of the

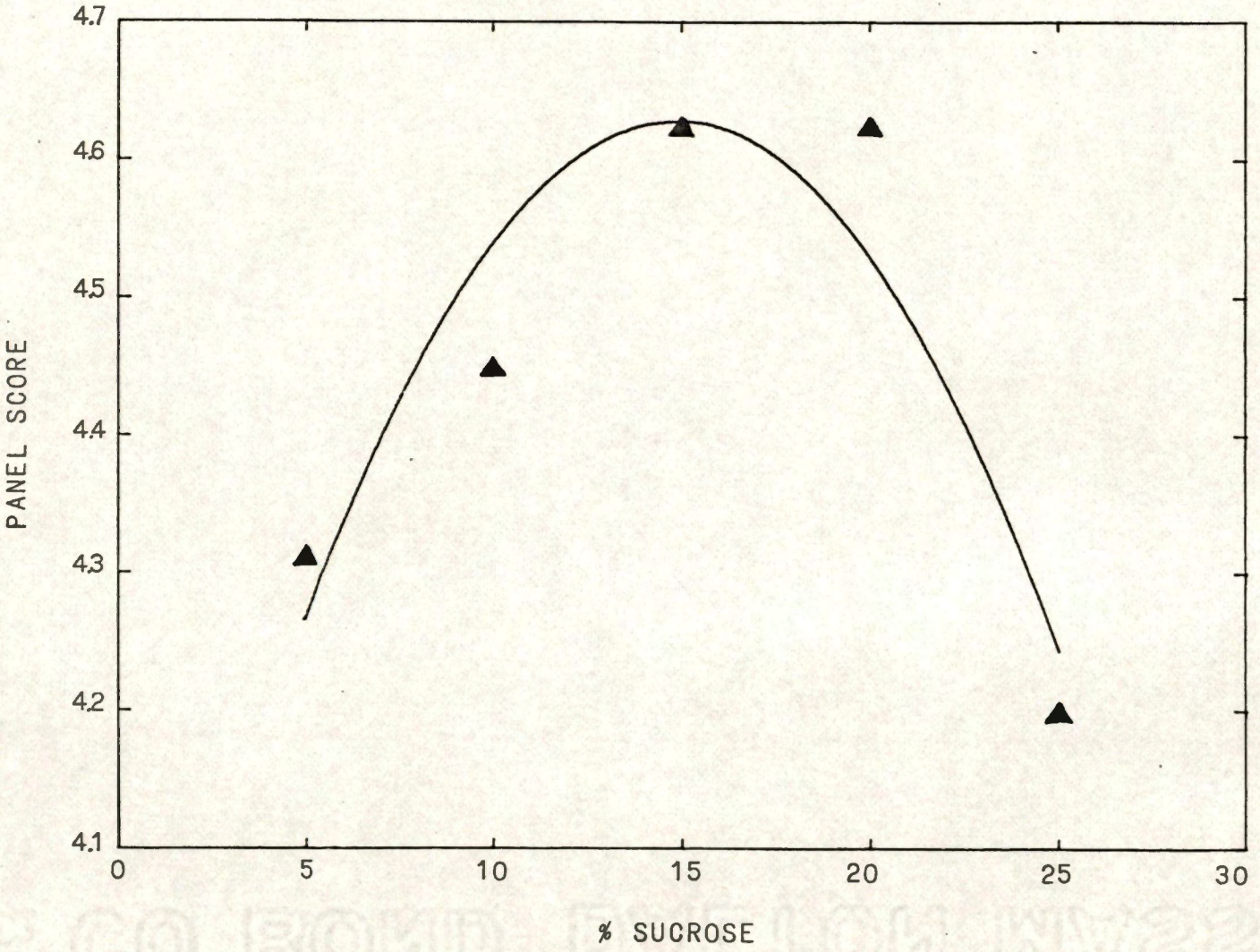


Figure 13. Regression curve of the taste panel scores for added sucrose to baked sweet potato puree (mean of two replications).

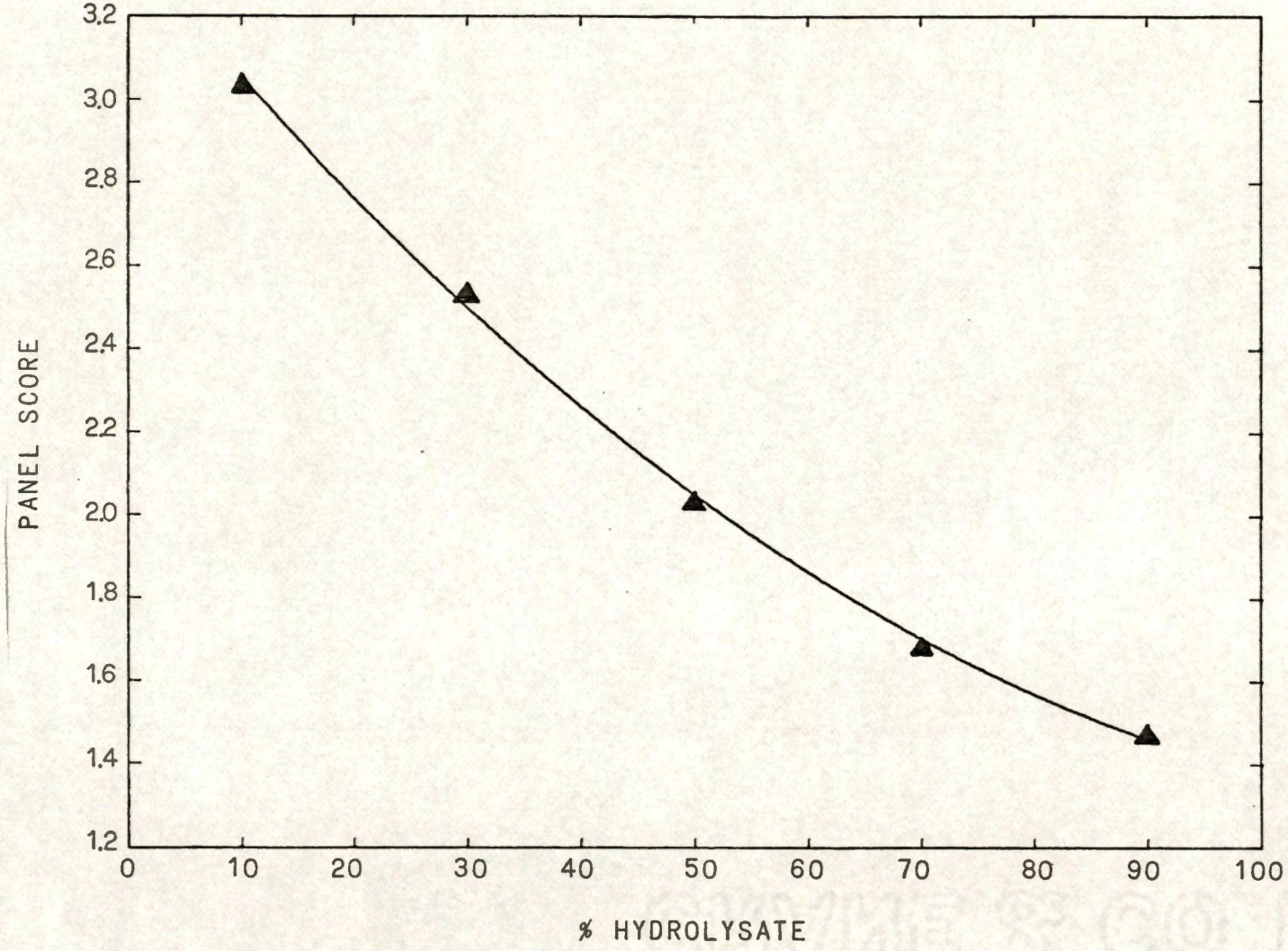


Figure 14. Regression curve of the taste panel scores for added hydrolysate to baked sweet potato puree (mean of two replications).

samples which resulted in the decreasing trend of the mean panel scores as shown in Figure 14.

The panel members were able to indicate a significant preference among the levels of added sucrose and hydrolysate. The levels component of the analysis of variance was significant at the 1% confidence level for the added hydrolysate and at the 5% confidence level for the added sucrose. This indicates that it was more difficult for the panel members to distinguish between the levels of sucrose than between the levels of hydrolysate. It is, however, very likely that due to the more pronounced difference in flavor of the hydrolysate containing samples, the panel members tended to score preferences for the samples with hydrolysate on a broader subjective scale than they scored the samples sweetened with sucrose. This would have tended to artificially increase the F-ratio of the level component of the hydrolysate containing samples.

III. CALORIC DETERMINATION

Table XIII presents the analysis of variance for the caloric content of baked sweet potato puree with added sucrose which was scored by the sensory panel. The variety, replication, and variety × level interaction were all not significant. The level component was the only significant term tested. The addition of sucrose to the baked sweet potato puree produced a highly significant increase in caloric content of the puree. Table XIV presents the mean caloric content for the levels of added sucrose. Calories increased from approximately 130 to approximately 227 per 100 grams.

TABLE XIII

ANALYSIS OF VARIANCE FOR THE CALORIC CONTENT OF BAKED SWEET POTATO PUREE, UNSWEETENED AND SWEETENED WITH FIVE LEVELS OF SUCROSE

Source	D.F.	S.S.	M.S.	F-ratio	Probability
A. Total	23	28333.49	1231.89		
B. Variety	1	25.90	25.90	0.60	N.S.
C. Level	5	27677.73	5535.54	128.53	**
D. Variety × Level	5	103.04	20.61	0.48	N.S.
E. Replication	1	53.07	53.07	1.23	N.S.
F. Residual Error	11	473.76	43.07		

N.S. Not statistically significant at the 0.05 level of probability.

**Statistically significant at the 0.01 level of probability.

TABLE XIV

CALORIC CONTENT OF BAKED SWEET POTATO PUREE,[a] UNSWEETENED AND CONTAINING FIVE LEVELS OF ADDED SUCROSE

Varieties	Added Sucrose (%)					
	0	5	10	15	20	25
	Calories[b,c]					
Jewel	130	155	177	195	221	226
Jasper	131	154	170	193	214	230

[a]Percent moisture = 66.91% (Jewel variety) and 67.96% (Jasper variety).

[b]Calories/100 grams (wet weight).

[c]Mean of two replications.

IV. GAS CHROMATOGRAPHIC ANALYSIS OF TASTE PANEL SAMPLES

Table XV (Jewel variety) and Table XVI (Jasper variety) present the gas chromatographic analysis of the hydrolysate and the unaltered puree. The tables also include the calculated content of sugars of the samples which were scored by the taste panel members. Fructose and sucrose were responsible for the majority of the sweetness of the puree and hydrolysate. If one adds together the weights reported in Tables XV and XVI for these two sugars, one finds that the puree which contained 15% added sucrose (preferred by the panel) had a much greater amount of fructose and sucrose than did the hydrolysate or any specific mixture of hydrolysate and puree. The puree which contained 15% added sucrose had approximately 166 mg more of these two sugars (total) than did the hydrolysate. The principle aim of this investigation was to attempt to enzymatically produce fructose in baked sweet potato puree, hopefully making it as sweet as unaltered puree sweetened to the preferred level with sucrose. If one assumes that the 166 mg of additional sugar in the sucrose sweetened puree were to be compensated for in the enzymatic hydrolysate, 92 additional mg of fructose would have to be produced in the hydrolysate (using the factor that fructose is 1.8 times as sweet as sucrose and assuming all other things equal). Only 1% of this amount was enzymatically produced in this study. It must be concluded, therefore, that the enzymatic production of fructose in baked sweet potato puree to compare in sweetness with puree which has been sweetened by sucrose to the preferred level cannot be achieved by the enzymatic system and parameters utilized in this investigation.

TABLE XV

ANALYSIS OF SUGARS[a] IN BAKED SWEET POTATO PUREE AND BAKED SWEET POTATO PUREE HYDROLYSATE, JEWEL VARIETY

Source	(mg)			
	Fructose	Sucrose	Glucose	Maltose
Puree	0.32	1.25	0.50	3.68
Hydrolysate	1.28	0.81	2.36	0.00
10% Hydrolysate 90% Puree	0.41	1.21	0.68	3.31
30% Hydrolysate 70% Puree	0.61	1.12	1.06	2.58
50% Hydrolysate 50% Puree	0.80	1.03	1.43	1.84
70% Hydrolysate 30% Puree	0.99	0.94	1.80	1.10
90% Hydrolysate 10% Puree	1.19	0.85	2.17	0.37
5% Sucrose 95% Puree	0.30	53.88	0.47	3.50
10% Sucrose 90% Puree	0.39	112.24	0.45	3.31
15% Sucrose 85% Puree	0.27	167.73	0.42	3.13
20% Sucrose 80% Puree	0.25	251.00	0.40	2.94
25% Sucrose 75% Puree	0.24	336.09	0.37	2.76

[a]mg sugar/gram (wet weight) of puree or hydrolysate.

TABLE XVI

ANALYSIS OF SUGARS[a] IN BAKED SWEET POTATO PUREE AND BAKED SWEET POTATO PUREE HYDROLYSATE, JASPER VARIETY

Source	(mg) Fructose	Sucrose	Glucose	Maltose
Puree	0.21	1.44	0.29	3.05
Hydrolysate	1.14	0.90	2.00	0.00
10% Hydrolysate 90% Puree	0.33	1.39	0.46	2.74
30% Hydrolysate 70% Puree	0.49	1.28	0.80	2.13
50% Hydrolysate 50% Puree	0.68	1.17	1.14	1.52
70% Hydrolysate 30% Puree	0.86	1.07	1.49	0.91
90% Hydrolysate 10% Puree	1.05	0.96	1.83	0.30
5% Sucrose 95% Puree	0.20	52.77	0.27	2.90
10% Sucrose 90% Puree	0.19	111.24	0.26	2.74
15% Sucrose 85% Puree	0.18	166.79	0.24	2.59
20% Sucrose 80% Puree	0.17	250.12	0.23	2.44
25% Sucrose 75% Puree	0.16	333.44	0.22	2.29

[a] mg sugar/gram (wet weight) of puree or hydrolysate.

CHAPTER V

SUMMARY

An enzyme system composed of alpha-amylase, amyloglucosidase, glucose isomerase, and appropriate cofactors was added to baked sweet potato puree and held for 21 hours at combinations of five pH levels (pH 4.0, 4.8, 5.4, 6.2, and 6.8) and four temperatures (55, 62, 69, and 76°C). The resultant hydrolysate was analyzed for fructose, glucose, sucrose, and maltose content. Hunter L, a, and b values were also measured. Optimum condition for fructose production within the range studied was pH 6.8 at 64°C. Increasing pH and temperature caused the hydrolysate to become darker, less yellow, and less red. After consideration of color, flavor, and odor, pH 6.8 at 55°C was chosen as the ideal condition for fructose production for subsequent taste panel evaluation.

A taste panel comprised of 20 university staff, employees, and students scored sweet potato puree sweetened with five levels of sucrose and hydrolysate for preference of sweetness. They preferred puree with 14.86% added sucrose and strongly disliked samples containing hydrolysate. The poor flavor and odor of the hydrolysate masked the panel's perception of sweetness in these samples. A true evaluation of sweetness in samples containing hydrolysate could, therefore, not be obtained.

The caloric value of samples sweetened with sucrose was determined. The addition of sucrose significantly increased the calorie content of

the baked sweet potato puree. The caloric value of samples containing hydrolysate was not determined due to their low panel scores.

The enzymatic production of fructose in baked sweet potato puree, under the conditions evaluated, produced an unpalatable product containing only a small percentage of the fructose needed to compare favorably in sweetness with puree sweetened to the desired level with sucrose.

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APPENDIX

TABLE XVII

REGRESSION EQUATIONS OF RESPONSE SURFACE DIAGRAMS OF SUGARS FOUND IN ENZYMATIC HYDROLYSATE OF BAKED SWEET POTATO PUREE,[a] OF HUNTER COLOR VALUES OF THE HYDROLYSATE,[a] AND OF PUREE SWEETENED WITH SUCROSE AND HYDROLYSATE

Source	Variety	Regression Equation
Glucose	Jewel	$Y = 135.52 + 10.76X - 75.22Z - 7.13X^2 + 0.52X^3 + 9.17Z^2 - 0.35Z^3 + 8.18XZ - 0.01X^3Z^2$
Glucose	Jasper	$Y = 317.12 - 37.03X - 133.91Z - 4.35X^2 + 0.52X^3 + 16.09Z^2 - 0.60Z^3 + 18.20XZ - 1.37XZ^2 - 0.02X^3Z^2$
Fructose	Jewel	$Y = -101.38 + 30.17X + 32.61Z - 1.67X^2 - 2.39Z^2 - 7.23XZ - 0.13XZ^2 + 0.06XZ^3 + 0.15X^2Z^2 - 0.02X^2Z^3$
Fructose	Jasper	$Y = 49.85 - 4.46X - 15.08Z + 0.36X^2 + 1.33Z^2 - 0.42XZ + 0.31XZ^2 - 0.04XZ^3$
Sucrose	Jewel	$Y = 2.41 + 2.35X - 2.52Z - 0.98X^2 + 0.09X^3 + 0.89XZ - 0.08X^2Z$
Sucrose	Jasper	$Y = 5.57 + 1.68X - 3.32Z - 1.03X^2 + 0.10X^3 + 1.17XZ - 0.10X^2Z$
Hunter L	Jewel	$Y = -106.83 + 69.78X + 13.96Z - 13.84X^2 + 0.82X^3 - 1.80Z^2 + 0.79XZ$
Hunter L	Jasper	$Y = -14.92 + 47.11X - 0.88Z - 10.81X^2 + 0.66X^3 - 0.89Z^2 + 1.53XZ$
Hunter a	Jewel	$Y = -489.61 + 230.43Z - 34.45Z^2 + 1.69Z^3 - 0.01XZ$

TABLE XVII (continued)

Source	Variety	Regression Equation
Hunter a	Jasper	$Y = -928.04 + 432.27Z - 65.38Z^2 + 3.26Z^3 - 0.02XZ$
Hunter b	Jewel	$Y = -78.59 + 52.75X + 6.85Z - 9.95X^2 + 0.58X^3 - 0.94Z^2 + 0.19XZ$
Hunter b	Jasper	$Y = 26.15 + 32.16X - 12.84Z - 8.40X^2 + 0.52X^3 + 2.15XZ - 0.01X^2Z^2$
Sucrose (taste panel)		$Y = 3.81 + 0.11X$
Hydrolysate (taste panel)		$Y = 3.37 - 0.03X$

[a] X = pH, Z = temperature.

VITA

The author was born in June 1947, in Chattanooga, Tennessee. He was graduated in 1965 from Chattanooga High School. After four years service in the United States Air Force he enrolled as an undergraduate student at the University of Tennessee in January 1971. He was married to the former Miss Beverly Ann Brock of Englewood, Tennessee, in July 1971. In December 1973, he received the B.S. degree in Agriculture with a major in food technology from the University of Tennessee. In January 1974, he enrolled in the graduate school of the University of Tennessee and since that time has been working to complete the requirements for the degree of Master of Science in the Department of Food Technology and Science where he holds a graduate research assistantship. He is a member of Phi Kappa Phi and Gamma Sigma Delta honor societies.