Quality Factors of Tomato Pastes Made at Several Break Temperatures

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Tomato pulps were made from M-32 tomatoes at break temperatures of 148, 171, 212, and 220 °F respectively on a pilot scale. A Pfaudler wiped-film continuous vacuum evaporator was used to concentrate the pulp to pastes of 26% soluble solids. Pectin retention decreased as the break temperature was lowered from 220 to 148 °F. The phenomenon can be explained by the activation of pectic enzymes of polygalacturonase and pectin esterase when the fruits were macerated at lower break temperatures. Tomatoes macerated at 220 °F were lower in acidity and higher in pH than those at lower temperatures. The phenomenon is explained by the formation of pectic acids, oligouronic, and galacturonic acids due to the action of pectic enzymes on pectic materials during maceration. The effect of break temperature on color and consistency of the pastes after reconstitution into sauce of 12° Brix solids is reported.

Tomatoes (*Lycopersicum esculentum*) are grown throughout the United States and in many regions of the world (Gould, 1974). In 1975, more than seven and a half million tons of canning tomatoes were mechanically harvested and processed in California. This is more than 78% of the total U.S. production of canning tomatoes. More than 95% of the canning tomato crop is harvested mechanically (Luh and Kean, 1975). The tomatoes for processing should ripen uniformly, and be able to withstand handlng by the mechanical harvester, as well as bulk handling (O'Brien, 1974). Needed for these objectives are tomato varieties bred for fruits of firm texture which will withstand mechanical handling (Hanna, 1966). The plants must also be resistant to fusarium and verticillium wilt, and yield fruits high in solids, rich in carotenoid pigments, good in flavor, and high in yields of acceptable fruit.

Crandall and Nelson (1975) studied the consistency of tomato juice and purée as affected by preparation and milling. Foda and McCollum (1970) reported on the viscosity of tomato juice as influenced by its constituents. Luh and Daoud (1971) reported on the effect of break temperature and holding time on pectin and pectic enzymes in tomato pulp (1971). Pectins, minerals, and amino acids in pastes made from five tomato varieties were reported by Luh and El-Tinay (1966).

Ascorbic acid in tomatoes has been studied by Kitagawa (1973) and Madamba et al. (1974). Stephens et al. (1970) studied pectic substances and viscosity of juices prepared from four tomato varieties.

This work investigates the properties of canned and frozen pastes of 26% soluble solids made at different break temperatures from M-32 tomatoes which are prospective for commercial processing.

MATERIALS AND METHODS

Tomato Paste. Six hundred pounds of M-32 tomatoes (*Lycopersicum esculentum*) were hand harvested at canning ripeness from the University Farm. The tomatoes were washed thoroughly in running water and sorted to remove defective and off-colored fruits. The sorted fruits were divided equally into four lots of 128 lb each, and stored at 41 °F overnight. The tomatoes were hand fed at a rate of 9 lb/min into a Rietz disintegrator equipped with an 8 mesh screen. Steam was injected directly into the macerates at different rates in order to achieve the desired breaking temperatures (Luh and Daoud, 1971). The heated pulp was held 40 s in a 25 ft long, 0.902 in. i.d. holding tube. The exit temperatures of the pulps were at 220, 212, 171, and 148 ± 2 °F, respectively. The macerate then entered a Brown fruit-juice finisher with a 0.033-in. screen to remove skin and seeds. The tomato pulp was cooled to 130–140 °F through a swept-film heat exchanger and collected in a stainless steel container. Each sample, with continuous mixing, was fed into a continuous Pfaudler centrifugal swept-film evaporator and concentrated under 28-in. vacuum (Hg) to a soluble solid content of 26° Brix. The product was mixed well and filled into 5.5-oz enameled cans with a head space of $^3/_8$ in. The cans were sealed under steam injection, and then divided into two equal parts. One-half of the cans were heat processed in boiling water for 30 min, and then rapidly cooled in crushed ice. The remaining cans were cooled in crushed ice without heat processing and deep frozen at −10 °F. The canned products were stored at 68 °F, and the frozen products at −10 °F. They were evaluated 2–4 months after processing.

Tomato Sauce. The pastes were reconstituted with a sufficient amount of distilled water to yield a sauce of 12° Brix at 68 °F for chemical analysis and quality evaluation.

Color. The color of macerated tomatoes and the pastes was measured with an Agtron E-5 Colorimeter (Magnuson Engineers, San Jose, Calif.), and also with a Hunter Color/Difference Meter, Model D25D2. A porcelain plate for tomato products (L = 26.4; a_L = +32.1; b_L = +13.2) was used as a reference. Both Agtron and Hunter readings were made on the reconstituted tomato sauce at 12° Brix.

Soluble Solids. A Zeiss-Opton refractometer was used to determine the soluble solids. Results are expressed as degrees Brix at 68 °F.

pH Value. A Beckman Zeromatic glass electrode pH meter was used to determine the pH of the macerated fresh tomatoes, and the pastes after dilution to 12° Brix.

Titratable Acidity. Fresh tomato pulp (30 g) or 10 g of sauce at 12° Brix was mixed with 90 ml of water. The resulting mixture was titrated with 0.1 N NaOH solution to pH 8 using a Beckman Zeromatic glass electrode pH meter. The results are reported as percent citric acid.

Total Solids. The AOAC (1975) vacuum oven method was used with some modifications. Diatomaceous earth (0.5 g) was dried in an aluminum weighing dish for 30 min at 110 °C in a convection oven. The weighing dishes were cooled in a desiccator for 30 min and weighed on a Mettler Analytical Balance. About 12 g of the fresh tomato pulp or 5 g of the paste was weighed accurately (±0.001 g) into an aluminum weighing dish. The samples were mixed with

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Table I. Characteristics of M-32 Tomatoes at Canning Ripeness

Analyses	Results
Total solids, %	5.50
Soluble solids, °Brix at 68 °F	5.0
pH	4.40
Titratable acidity as citric acid, %	0.238
Agtron E-5 colorimeter reading	21.5
Hunter color difference meter reading, Model D25D2	L = 23.3 a_L = +32.4 b_L = +10.7
Average wt/fruit, g	85 ± 15
Yield, tons/acre	30.8

the diatomaceous earth and placed on a steam bath until the mixture became almost dry. Drying was completed in a vacuum oven after 2 h at 70 °C (158 °F) under a pressure of 50 Torr. The dried samples were allowed to cool in a desiccator for 30 min and then weighed again. The percent total solids in the tomato products was calculated.

Total Pectin. The total pectin in the concentrate was determined by the versenepectinase carbazole method described by McCready and McComb (1952) and Luh and Daoud (1971). The results are expressed as mg of pectin per 100-g sample.

Protopectin. The carbazole method described by Kanujoso and Luh (1967) was used for determination of protopectin in the pastes.

Ascorbic Acid. The 2,6-dichlorophenolindophenol visual titration method (Association of Vitamin Chemists, 1966) was used to determine the ascorbic acid in the paste. The pastes were extracted with 8% acetic acid. After centrifugation, an aliquot was diluted with water and titrated with the blue dye solution to a pink color which lasts for 15 s. The results are expressed as mg per 100-g sample, or as percent retention.

Consistency. A Bostwick consistometer was used to determine the consistency at 68 °F of the tomato sauce reconstituted from the pastes to 12° Brix. The results are reported as distance in centimeters in 30 s.

RESULTS

Characteristics of Fresh Tomatoes. The characteristics of the M-32 tomatoes at canning ripeness are presented in Table I. The variety has a high yield of 30.8 tons/acre, and is comparatively lower in titratable acidity. The variety is suitable for mechanical harvest and bulk handling because of its firmer texture and smaller fruit size.

Pectin Retention. The effects of break temperature on total pectin retention in the pastes are presented in Figure 1. It is apparent that pectin retention was highest at 220 °F and lowest at 148 °F. Pectin retention decreased as the break temperature decreased. The phenomenon may be explained by the rapid inactivation of the pectic enzyme polygalacturonase (PG) and pectin esterase (PE) (Luh and Daoud, 1971). PG in tomatoes are rapidly inactivated when macerating the fruit at 212 or 220 °F. The M-32 variety appears to contain a normal amount of total pectin for paste manufacture. The frozen paste contained more total pectin than the canned product made at the same break temperature. It appears that enzymic breakdown and thermal degradation of pectin occurred during maceration, and also during heat processing. The frozen pastes were kept at −10 °F after vacuum concentration without heat treatment, resulting in a higher total pectin in the final product. The protopectin contents of the frozen and canned pastes are presented in Figure 2. It was observed that the major portion of the pectic

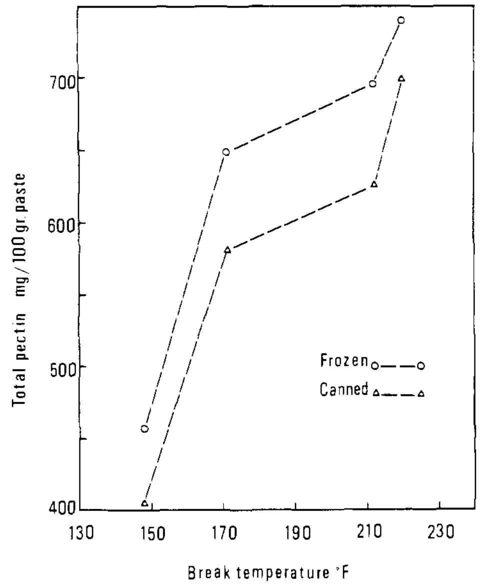

Figure 1. Effect of break temperature on pectin retention in canned and frozen tomato pastes.

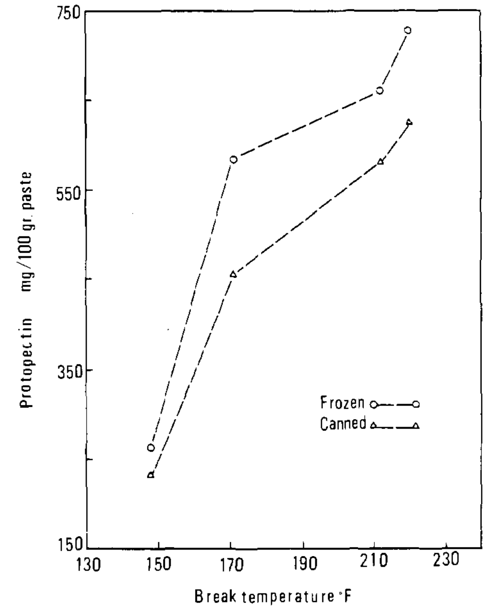

Figure 2. Effect of break temperature on protopectin retention in canned and frozen tomato pastes.

material in M-32 tomatoes is present as protopectin. This is different from the Pearson tomatoes which contained less protopectin (Luh et al., 1960). Thus, both varietal characteristics and break temperature are important factors influencing pectin content of tomato pastes.

Ascorbic Acid Retention. The effect of break temperature on ascorbic acid retention in tomato pastes is presented in Figure 3. The fresh tomatoes used in this investigation contained 32.5 mg/100 g of fruit on a fresh basis. Ascorbic acid retention decreased as the break temperature increased. The frozen paste contained slightly higher ascorbic acid than the corresponding canned sample preheated at the same break temperature. The phenomenon may be explained by oxidation and thermal degradation of ascorbic acid at higher processing temperatures.

Titratable Acidity and pH. The titratable acidity and pH of the pastes after diluting to 12° Brix are presented in Table II. The titratable acidity decreased when the break temperature increased. On the other hand, the pH

Table II. Effect of Break Temperature on Chemical and Physical Properties of Tomato Sauce (12° Brix) Reconstituted from Canned Pastes

Break temp, °F	Titrable acidity as % citric acid	pH	Hunter color difference meter L	Hunter color difference meter a_L	Hunter color difference meter b_L	Agtron E-5 colorimeter reading	Bostwick consistometer (12° Brix at 68 °F), cm
220	0.480	4.60	25.6	33.5	13.5	31.0	5.2
212	0.493	4.57	25.9	34.1	13.6	30.5	5.1
171	0.624	4.40	24.7	33.0	13.3	26.5	7.8
148	0.670	4.30	24.9	33.5	13.0	28.5	8.2

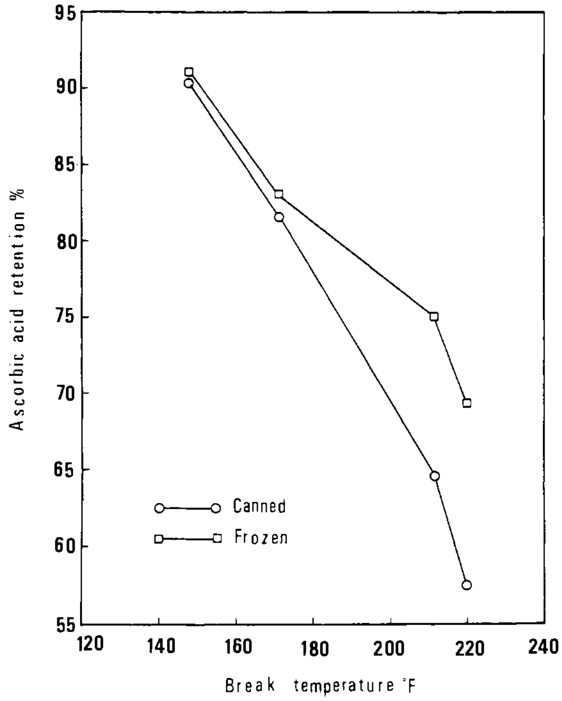

Figure 3. Effect of break temperature on ascorbic acid retention in tomato pastes.

value increased with an increase in break temperature. The higher acidity in the samples macerated at 148 and 171 °F may be related to the activation of PE and PG in tomatoes during maceration. These enzymes cause formation of pectic, oligouronic, and galacturonic acids from pectic materials, contributing to higher acidity and lower pH in the product.

Color. The effect of break temperature on color of tomato pastes was evaluated. The pastes were first diluted with distilled water to 12° Brix at 68 °F. The results are presented in Table II. There were small differences in Hunter color difference meter readings among the samples. A slightly higher L value (brightness) was observed in samples macerated at 212 and 220 °F than at 171 and 148 °F. Table II indicated a lower b_L (yellowness) in samples macerated at lower break temperatures. Thus, a slightly better color was observed in the samples with lower break temperatures. The Agtron E-5 colorimeter also showed a slightly better color (lower Agtron E-5 readings) in the samples macerated at 171 and 148 °F. In the temperature range used in this investigation, the color difference between the samples was not readily discernible by visual evaluation.

Consistency. A Bostwick consistometer was used to study the effect of break temperature on consistency of the pastes after dilution to 12° Brix. It is shown in Table II that a higher break temperature results in a thicker consistency. The phenomenon is related to heat inactivation of PG during maceration. The consistency of the product decreases when the break temperatures are favorable to PG and PE activity (Luh and Daoud, 1971). The property was retained when the tomato pulp was concentrated into pastes, and when reconstituted into sauce.

DISCUSSION

The major breakthrough of the last 10 years in the production of processing tomatoes has been the advent of once-over machine harvest. The mechanization program in California, which is essentially all mechanized, is a milestone in horticulture production. The success is attributed largely to the close coordination of the varietal and the machine development programs in an area of extremely favorable climate for tomato production. Development of improved varieties of processing tomatoes through breeding is an important subject of interest to the food processing industry. This involves many characters such as plant habit, disease resistance, fruit color, yields, solids, nutritive value, and suitability for mechanical harvest and bulk handling. For mechanical harvest, a tomato variety should have the following characteristics: (a) the fruit should ripen uniformly to permit high yield for a once-over harvest; (b) the plants should not have excessive foliage because vegetative growth interferes with the separation of fruit from the vine; (c) the tomato pedicel (stem) should be jointless so that the fruits are not punctured in handling; (d) the fruits should be firm and crack-resistant; (e) the tomato should have good vine-storage ability in the field after maturity; and (f) fruit should be firm and resistant to machine damage. The M-32 tomato appears to be suitable for mechanical harvest and has good prospect for commercial production.

The pectins and cellulose present in the tomato are responsible for the firm texture of the fresh fruit, and high viscosity in the finished product (Miladi et al., 1969). Pectin and protopectin are the major components in the middle lamella of the cell walls cementing the cells together. As the tomatoes ripen, more protopectin is changed into pectin which still holds the cells in place but less rigidly, so that the fruit is no longer hard. Riper tomatoes yield juices of thinner consistency, because during ripening the pectins in the cell walls are degraded into soluble compounds which have little binding power (Luh et al., 1960). The break temperature also affects the consistency of the canned pastes greatly. One should use an efficient hot break process in order to have better retention of consistency and pectin in the final product.

Factors affecting nutrient concentrations in fresh tomatoes include heredity, soil and plant nutrition, cultivation, and handling practices and maturity. Ascorbic acid content of tomatoes has been shown to vary with varieties (Stevens and Dickinson, 1974). Many of the processing tomato varieties have ascorbic acid contents ranging from 20 to 32 mg/100 g. The M-32 tomatoes used in this investigation contained 32.5 mg of ascorbic acid per 100 g. This is very desirable from the point of view of nutritive value. Maintenance of high levels of ascorbic acid in foods has received considerable emphasis by the food processors and consumers. In the manufacturing process, ascorbic acid may be oxidized to dehydroascorbic acid which can be further oxidized to degradation products with no vitamin C activity. The rate of oxidation is dependent on availability of oxygen and the break temperature. The longer the paste is held at higher temperature, the lower will be the retention of ascorbic acid in the product.

The organic acid in tomatoes is largely citric acid (Ukai and Luh, 1972). Acetic, formic, pyrrollidone carboxylic, malic, phosphoric, and galacturonic acids were also found in canned tomato juice. Miladi et al. (1969) have separated eight organic acids from tomato juice. Malic acid was found to be the second major organic acid in fresh juice, whereas pyrrollidone carboxylic acid was found to be the second major organic acid in the processed juice. The present work found a higher acidity in the pastes made at break temperatures of 148 and 171 °F. The phenomenon may be explained by the formation of galacturonic and oligouronic acids in the product when the pectic enzyme PG was activated to hydrolyze the pectic materials during maceration (Garces and Luh, 1972). Higher break temperatures result in rapid inactivation of the pectic enzymes, resulting in a lower acidity in the product (Luh and Daoud, 1971). Loss of volatile acids and carbon dioxide at higher break temperatures may also contribute to the difference in acidity between the samples.

Low acids and the resultant high pH in certain varieties of tomatoes are considered a weak point for processing. This occurred because thick-walled, firm-fruited lines had been used in breeding for new varieties for mechanical harvest. The average acidity of processing tomatoes is about 0.35% as citric acid. However, if the solids content is increased considerably, it may be desirable to increase the acidity level through breeding. The M-32 tomatoes appear to be comparatively low in acidity for processing. Research has shown that decreased phosphorus in the fruits helps to alleviate high pH problems in low acid lines (Stevens and Dickinson, 1974).

Consistency is one of the criteria for quality of pastes used in reprocessing into ketchup and sauce. It is demonstrated that pectic retention and consistency of the tomato pastes are influenced by the break temperature. The M-32 tomatoes appear to be excellent in their character except for their lower acidity.

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Processing of Fresh Artichoke Trimmings for Use in Animal Feeds

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Fresh artichoke waste trimmings were dehydrated in a pilot scale Arnold dehydrator with and without prior mechanical dewatering. Dewatering increased the quantity of meal produced per cubic meter of gas consumed by up to 80%. The protein content of the dehydrated meal ranged from 14.2 to 23.1%; dewatering and dehydration resulted in a slight reduction of protein and an increase in crude and acid-detergent fiber, acid-detergent lignin, and cellulose in the meal. The carotene and xanthophyll contents of the dried meals were less than that required for a poultry pigmentation source. Although the lysine, methionine, and arginine content of freeze dried artichoke meal was comparable to that of dehydrated alfalfa or bermuda grass meal, the quantities of lysine and methionine were decreased during dehydration, as was in vitro crude protein digestibility.

Fresh artichoke trimmings produced at the packing shed are an example of a waste product which may be converted to a useful animal feed. Previous experience in the processing and dehydration of fresh alfalfa (Spencer et al., 1971; Livingston et al., 1968), turf grass clippings (Livingston et al., 1971c), cauliflower (Livingston et al., 1972), and pimento (Livingston et al., 1974) trimmings suggested possible grinding, dewatering, and drying procedures that

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