Family and Consumer Sciences Research Journal

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Family and Consumer Sciences Research Journal 1982; 11; 149
DOI: 10.1177/1077727X8201100205

Home Economics Research Journal December 1982, Vol. 11, No. 2

Microwave Blanching Of Vegetables For Frozen Storage

The quality of five vegetables, blanched using either microwave or hot water methods currently recommended to the American consumer, was examined after one, two, four, and six months of frozen storage. The vegetables were analyzed for residual peroxidase activity immediately after blanching. Storage stability of cooked and uncooked vegetables was determined by examining various quality factors after each period of frozen storage. Quality factors included color, texture, flavor, and overall acceptability of the vegetables as measured using objective methodology and sensory evaluation. Broccoli and zucchini retained high levels of peroxidase activity after microwave blanching. Broccoli and green beans blanched with microwave energy retained less chlorophyll ($p \leq 0.05$), had higher shear force values ($p \leq 0.05$), and received lower sensory evaluation scores than the water blanched vegetables ($p \leq 0.05$) for quality factors commonly used by consumers. The texture of zucchini blanched with microwave energy was limp as measured by shear force and by sensory evaluation. No significant differences ($p \geq 0.05$) were found in the quality of carrots or cauliflower blanched by the two methods. Instructions currently available for microwave blanching of vegetables for home freezing do not result in a quality product for all vegetables.

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Introduction

Freezing has long been considered to be one of the best methods of preserving vegetables from one harvest season to the next. Freezing is our closest approach to preserving fresh quality in foods, and if proper technologies are applied, vegetables after blanching, freezing, and cooking should not be different from those freshly cooked (Olson and Dietrich, 1969). If stored at low enough temperatures, the initial quality of frozen vegetables can be protected and maintained over long periods of time (Olson and Dietrich, 1969).

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An essential step in the preparation of vegetables for freezing is the process of blanching, or heating, the vegetables before packing. Blanching is necessary to denature and inactivate enzymes that are present in fresh vegetables (USDA, 1976; Baardseth, 1978). Enzymes which have not been inactivated contribute to undesirable changes in color, texture, and flavor of frozen vegetables (Baardseth, 1978).

Traditionally, vegetables have been blanched in boiling water for times specified by the United States Department of Agriculture to inactivate destructive enzymes (USDA, 1976). A few vegetables, such as pumpkin, sweet potatoes, and winter squash, can also be blanched successfully by steam or by heating in a pressure cooker or oven (USDA, 1976). However, these are isolated instances, and the majority of blanching by the American consumer has been done with boiling water.

Recently, home blanching with microwave energy has been publicized as an alternative to the conventional boiling water method. Microwave oven manufacturers are promoting this method of blanching to the consumer stating that, with a microwave oven, blanching can be accomplished with a minimum of time and effort and with the elimination of pots of boiling water that require constant attention and heat up the kitchen (General Electric Co., 1977).

The consumer has used procedures based on data generated by the Agricultural Research Service of the United States Department of Agriculture in home preservation of food by freezing. At the present time no data on microwave blanching are available from USDA, and only two sources have published information on blanching vegetables in a microwave oven (General Electric Co., 1977; Whirlpool Corporation, 1978). These instructions were later published in a regional women's magazine ("Blanch Vegetables," 1980). This information is based on minimal initial studies which involved various times for blanching vegetables in a microwave oven and subsequent sensory evaluations on these vegetables six months later (General Electric Co., 1977). General Electric (1977) does indicate that more extensive testing is desirable and that the consumer will be advised of any adjustments necessary in current recommendations. Further information is not available to the consumer at the present time.

Microwave blanching has the potential to make a substantial impact on home blanching of vegetables for frozen storage if it can be demonstrated that the same quality results for microwave blanched vegetables as for hot water blanched vegetables. There is a definite need for information on the quality attributes of vegetables blanched with microwave energy (Quenzer and Burns, 1981). The present study was designed to compare microwave and conventional hot water blanching methods currently recommended to the American consumer by testing their effects on quality factors of broccoli, carrots, cauliflower, green beans, and zucchini squash.

Materials and Methods

Acquisition and Storage of Vegetables

Broccoli, carrots, cauliflower, green beans, and zucchini squash were purchased from a local retail market in 35 or 50 pound lots. Vegetables selected were examined carefully for freshness and absence of defects. After transportation to the laboratory, vegetables were stored in a two-door, home-size refrigerator (about 1° C) until time for processing. No vegetables were held longer than 48 hours prior to processing.

Preparation of Vegetables

All vegetables were washed, trimmed, and cut with stainless steel knives into the desired shapes for freezing. Broccoli was cut into one-inch stem pieces and flowerets. Green beans were cut into one-inch segments. Carrots and zucchini were sliced into pieces one-fourth and one-half inch thick, respectively. Cauliflower was frozen as flowerets.

Blanching Procedures

Vegetables were weighed on a Mettler P1000 top-loading balance. A 454 g sample of each vegetable was blanched conventionally in boiling deionized water for the maximum time recommended (USDA, 1976). A stainless steel four-quart blanching kettle with a basket and cover was used. A second 454 g sample of each vegetable was blanched in a microwave oven at high power (600 watts) for the maximum recommended time (General Electric, 1977) because preliminary tests indicated that peroxidase activity was high after shorter blanching times. Deionized water in the amount recommended (1/4 or 1/2 cup) was added to cover the vegetables, spread evenly in a two-quart covered glass casserole dish. The microwave oven used was a Sears Kenmore Dual Power (120 volts, 2450 MHz, Model No. R626BA-808). Vegetables blanched by either method were plunged into iced deionized water immediately after blanching and allowed to cool for the same length of time they were heated.

Frozen Storage

The vegetables were placed in plastic freezer bags, heat sealed, and stored in a walk-in freezer at −18° C for one, two, four, and six months.

Peroxidase Activity

Percent residual peroxidase activity was determined immediately after blanching for duplicate samples of all vegetables. Inactivation of peroxidase, a heat-resistant enzyme, indicates inactivation of enzymes which may contribute to poor color, texture, and flavor of most frozen vegetables. The procedure followed was a modification of Masure and Campbell (1944). Samples were filtered through S and S #589 Black Ribbon filter paper with suction rather than through cotton milk filters as described by Masure and Campbell. Absorbance of the extract was read in a Bausch and Lomb Spectrophotometer 21 at 420 nm every 10 seconds for two minutes. Peroxidase activity was expressed as divisions of color per minute (D/M). Percent residual peroxidase activity was determined by dividing the D/M of the blanched vegetable by the D/M of the raw vegetable and multiplying by 100.

Cooking Procedure

After frozen storage, and prior to analysis of quality factors, vegetables were cooked in one-quart saucepans on a household Frigidaire 30-inch Electric Range (Model RSE3-36W) using procedures recommended by the U.S. Department of Agriculture (1971). Precise cooking times (Table 1) to produce vegetables that were tender, but crisp, were determined prior to the first test period and used throughout the study.

TABLE 1
Cooking times for vegetables[a] after frozen storage

Vegetable	Minutes
Broccoli	8
Carrots	7
Cauliflower	6
Green Beans	8
Zucchini	6

[a] 454 g vegetable in 125 ml water

Chlorophyll Determination

Percent total chlorophyll retention was determined before and after cooking for frozen broccoli and green beans using the procedure described by Vernon (1960) with the exception that each sample was filtered twice with suction through a large Kim-Wipe and then through S and S #589 Black Ribbon filter paper. Absorbance was measured with a Bausch and Lomb Spectrophotometer 21 at 536, 558, and 700 nm. The 700 nm wavelength was used to determine the clarity of the samples; a reading of 0.012 or less was considered to be optically clear. Percent total chlorophyll retention was calculated using the formula:

$$\frac{2.10 - A536/A558}{1.26} \times 100$$

Color Analysis

Color difference between the microwave and conventionally blanched samples of each vegetable was measured with a Hunter Color Difference Meter. Twenty grams of each vegetable were blended with 50 ml of water in a Sunbeam Solid State blender on the "liquefy" setting for one minute (Guerrant, 1958). Zucchini slices were blended with the flesh and skin intact. Duplicate samples of the slurries for each vegetable were analyzed in petri dishes, using a Hunter Meter, calibrated with a green standard plate (**L** = 60.7, **a** = −15.9, **b** = +7.3) for broccoli, green beans, and zucchini; a yellow standard plate (**L** = 83.2, **a** = −3.7, **b** = +25.4) for carrot samples; and a white standard plate (**L** = 91.8, **a** = −0.7, **b** = −0.7) for cauliflower. After the first reading for each vegetable, the petri dish was turned 90°, read on the Hunter Meter again, and the average value of the two readings was used.

Texture Analysis

The Warner-Bratzler Shear Press was used to determine resistance to shear (tenderness) of each cooked vegetable after one, two, four and six months of frozen storage. Eight replications were measured for each vegetable. Stem pieces of broccoli, stems of cauliflower just beneath the floweret, half slices of carrots and zucchini, and intact cuts of green beans were measured with Vernier calipers for

TABLE 2
Residual peroxidase activity (RPA) in vegetables immediately after blanching[a]

	Blanching Method			
	Boiling Water		Microwave	
Vegetable	Time[b] min.	RPA %	Time[c] min.	RPA %
Broccoli	0.2	2.4	5.0	22.1
Carrots	0.4	0.8	5.0	0.8
Cauliflower	0.1	2.1	5.0	0.2
Green Beans	0.1	1.8	5.5	2.4
Zucchini	0.3	4.8	4.0	54.2

[a] Mean values of duplicate samples
[b] Blanching time (USDA, 1976)
[c] Maximum blanching time specified (General Electric Company, 1977)

selection of uniform pieces. The dimensions of the vegetable pieces analyzed for tenderness with the Warner-Bratzler Shear Press were: broccoli, 2.54 cm long, 0.62 cm wide; carrots, 0.50 cm thick, 1.84 cm diameter; cauliflower, 1.47 cm diameter; green beans, 2.54 cm long, 0.85 cm diameter; and zucchini, 0.71 cm thick, 3.61 cm diameter.

Sensory Evaluation

A 15-member sensory evaluation panel was selected from among graduate students and faculty of the department. Each individual was instructed in the evaluation procedures to be used. Evaluations were conducted in individual booths, painted gray, and lit with cool-white fluorescent lights, 15 watts. Microwave and conventional blanched samples of each vegetable were presented to the judges immediately after cooking. Two vegetables were evaluated at each session. Samples were presented on bone-colored plastic plates, 24 cm in diameter. A glass of water at room temperature was given to each evaluator to clear the palate between samples. The judges rated the coded, unseasoned vegetable samples for color intensity, lightness/darkness of color, color acceptability, tenderness, texture (limpness/firmness), texture acceptability, flavor, and overall acceptability, using a 5-point hedonic scale, with a score of 5 representing the highest quality. Judges were also asked which of the two unidentified samples (microwave or conventional blanch) they preferred overall.

Statistical Analysis

To determine whether significant differences in quality factors of the vegetables blanched by the two methods existed, the t-test for unequal standard deviations was used to analyze the Warner-Bratzler Shear Press values. The t-test for matched pairs was used to analyze chlorophyll data. Sensory data were analyzed using the Wilcoxon Signed-Ranks Test for Matched Pairs (Siegel, 1956, p. 75).

Results and Discussion

Peroxidase Activity

A value of one to five percent residual peroxidase activity after blanching was deemed acceptable, as it has been demonstrated that peroxidase present in this amount will not cause deterioration in frozen vegetables (Burnette, 1977; Masure and Campbell, 1944). By this standard all of the vegetables blanched in boiling water were adequately blanched (Table 2). Carrots, cauliflower and green beans were the only vegetables blanched with microwave energy that showed residual peroxidase activity within this range. Levels of residual peroxidase activity ranging between 22–54 percent were found in broccoli and zucchini blanched with microwave energy.

Chlorophyll Retention

Broccoli and green beans blanched with microwave energy retained less total chlorophyll than the samples blanched with boiling water both immediately after blanching and after all periods of frozen storage (Table 3). There were differences between the average percent total chlorophyll retention in broccoli blanched by the two methods both for the uncooked and for the cooked vegetable ($p \leq 0.05$.) The difference between the average percent total chlorophyll retention in green beans blanched by the two methods was significant only for the uncooked vegetable ($p \leq 0.05$).

The amount of water in which the vegetables were blanched could have been a factor contributing to the difference in chlorophyll retention. Eheart and Gott (1965) found that

TABLE 3
Chlorophyll retention[a] of frozen broccoli and green beans

Vegetable	Storage time months	Water blanched Uncooked %	Water blanched Cooked %	Microwave blanched Uncooked %	Microwave blanched Cooked %
Broccoli	0	81.75*	—	78.57	—
	1	80.95	61.11*	75.40	47.62
	2	73.81	53.17	72.22	41.27
	4	73.81	41.27	71.43	34.13
	6	73.02	38.89	61.90	20.63
Green beans	0	78.57*	—	71.43	—
	1	71.43	39.68	70.63	34.92
	2	57.94	36.51	50.00	28.57
	4	57.14	32.54	51.59	25.40
	6	61.90	31.75	50.00	7.94

[a] Mean values of duplicate samples
* Difference between means of the same vegetable at the same preparation stage (uncooked or cooked) significant at $p \leq 0.05$

green vegetables cooked in a 4:1 water to vegetable ratio retained chlorophyll better than those cooked without water in a microwave oven. They attributed this effect to the diluting action of water on the plant acids. In the present study 454 g of vegetables in 4 L of water was used in the conventional procedure. The same amount of vegetables in 125 ml of water was used for the microwave procedure.

Chlorophyll was more unstable in green beans than in broccoli (Table 3). This difference could have been due to the presence of larger amounts of the enzyme lipoxygenase in green beans than in broccoli (Baardseth, 1978).

TABLE 4
Mean[a] Hunter color difference meter values for vegetables cooked after frozen storage

Time	Broccoli M[b]	Broccoli W[c]	Carrots M	Carrots W	Cauliflower M	Cauliflower W	Green Beans M	Green Beans W	Zucchini M	Zucchini W
One month										
L[d]	32.96	39.00	34.58	35.29	49.24	50.98	32.90	31.90	30.26	33.64
a[e]	−5.22	−7.70	+18.52	+20.18	−3.65	−3.45	−5.50	−6.00	−7.45	−6.70
b[f]	+15.70	+15.05	+20.60	+20.72	+3.32	+2.79	+14.95	+13.95	+15.31	+17.12
Two months										
L	36.42	37.20	34.70	34.33	47.99	47.44	36.92	30.38	31.26	31.79
a	−8.41	−8.68	+19.42	+19.05	−3.87	−3.61	−7.08	−8.52	−9.46	−8.01
b	+16.96	+15.96	+21.18	+20.72	+2.71	+3.96	+16.96	+14.33	+15.60	+16.24
Four months										
L	35.71	38.97	35.18	34.37	50.09	50.95	32.59	32.94	31.27	31.55
a	−7.40	−10.18	+18.62	+18.98	−3.80	−3.60	−6.40	−8.60	−9.18	−9.02
b	+17.67	+16.18	+21.44	+20.53	+3.08	+3.48	+15.41	+14.32	+15.90	+16.03
Six months										
L	41.07	37.62	35.51	34.50	47.70	52.24	36.53	32.32	27.52	30.91
a	−6.72	−8.36	+17.02	+16.72	−3.62	−3.34	−6.30	−8.19	−9.20	−8.92
b	+18.14	+17.27	+21.80	+20.98	+3.16	+3.02	+16.60	+15.25	+14.54	+15.68

[a] Mean values of duplicate samples
[b] Blanched with microwave energy
[c] Blanched with boiling water
L[d] scale—higher numbers indicate a lighter color; lower numbers indicate a darker color
a[e] scale—more negative numbers indicate a greener color; more positive numbers indicate a more red color
b[f] scale—more negative numbers indicate a bluer color; more positive numbers indicate a more yellow color

Since the peroxidase in the samples blanched with microwave energy was not completely inactivated (Table 2), lipoxygenase activity may also have been present. Axelrod (1974) implicated lipoxygenase in the breakdown of chlorophyll as a result of a coupled reaction with lipid oxidation catalyzed by the enzyme. The difference in chlorophyll retention between beans and broccoli may also be attributed to the lower natural pH of green beans (Eheart and Gott, 1965; Sweeney and Martin, 1961). Another factor in this study contributing to the relatively low chlorophyll retention in the green beans was the condition of the fresh vegetable (Sweeney and Martin, 1961). The intense heat and lack of moisture during the summer of 1980 made it a poor growing season. The fresh green beans available showed a great deal of variation in color.

Color

Because variance in measurement was small, all differences in **L**, **a**, and **b** readings between microwave and hot-water blanched vegetables were statistically significant ($p \leq 0.05$, using the t-test) (Table 4). Hunter Color Difference Meter measurements indicated that broccoli and green beans blanched with boiling water were more green (lower **a** values) and less yellow (lower **b** values) than the samples blanched with microwave energy. Quenzer and Burns (1981) reported that water-blanched spinach was darker and had lower **a** and **b** values than samples blanched with microwave energy. The Hunter Meter values coincide with measured chlorophyll retention of the broccoli and green beans; greener color was associated with greater chlorophyll retention and a more yellow color with greater conversion of chlorophyll to pheophytin.

A difference of 0.27 on the **a** scale between the broccoli samples blanched with boiling water and with microwave energy and stored two months was perceived by the sensory evaluation panel as a difference ($p \leq 0.01$) in color intensity (Table 5). In green beans a difference of 0.50 on the **a** scale represented a perceptible difference ($p \leq 0.01$) in color intensity between beans blanched by the two methods and stored one month (Table 5).

Color differences between carrots blanched with boiling water and with microwave energy were small and varied from one test period to another. Differences as high as 1.01 on the **L** scale, 1.66 on the **a** scale, and 0.91 on the **b** scale were not perceived by the sensory panel.

Cauliflower blanched with microwave energy was darker (lower **L** values) and more green (lower **a** values) than cauliflower blanched with boiling water at every test period. These differences were not perceived by the sensory panel. Cauliflower blanched in the microwave oven turned green during the blanching treatment and remained that way throughout frozen storage. Although any green color that could be detected visually disappeared on cooking, the greenness of the samples blanched with microwave energy was detected by the colorimeter. No explanation for "greening" was explored, but it is possible that the microwave heat initiated formation of a chlorophyll-metal complex causing a "regreening" that has been noted in other vegetables (Eskin, 1979, p. 13).

Zucchini blanched with boiling water was measured with the Hunter Meter as being consistently lighter (higher **L** values), less green (higher **a** values), and more yellow (higher **b** values) than its counterpart blanched with microwave energy. The sensory panel did not detect these differences.

Texture

Blanching with microwave energy resulted in a firmer, tougher product than that obtained by blanching with boiling water in every vegetable except zucchini, as determined by Warner-Bratzler Shear Press values (Table 6). Zucchini squash was more limp after blanching with microwave energy than after blanching with boiling water, and it remained so through six months of frozen storage.

Differences in texture between broccoli and green beans blanched by the two methods were significant ($p \leq 0.05$) at the four test periods and for zucchini at the last three test periods. Sensory evaluators perceived the difference (Table 5) for tenderness (tender vs. tough) ($p \leq 0.05$) but not for texture (firm vs.

TABLE 5
Mean sensory scores[a] for quality factors of vegetables cooked after frozen storage

	Color intensity		Color lightness		Color accept-ability		Tenderness		Texture		Texture accept-ability		Flavor		Overall accept-ability	
Vegetable	**M[b]**	**W[c]**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**
Broccoli																
1 month	2.5**	3.7	2.3**	3.5	2.9**	4.1	2.7*	3.6	4.0**	3.2	3.5	3.7	3.5	3.5	3.3	3.7
2 months	2.6**	3.8	2.6	3.1	2.5**	3.7	2.5*	3.5	3.8	3.7	3.3*	4.1	3.0*	3.9	2.9**	3.8
4 months	2.7*	3.5	2.9	3.1	2.6**	4.4	2.6*	3.4	3.3	3.2	3.0*	3.8	2.7	3.5	2.7**	3.7
6 months	2.5**	4.1	3.1	3.1	3.9**	4.4	2.7**	4.1	3.9	3.3	3.3**	4.2	3.3**	4.1	2.9**	4.1
Carrots																
1 month	3.7	3.4	3.4	3.5	4.1	3.8	3.3	2.9	3.9	3.9	3.5	3.5	3.5	4.0	3.7	3.9
2 months	3.7	3.9	3.3	3.3	4.2	4.1	3.7	3.3	3.3	3.7	3.5	3.9	4.0	4.1	3.9	3.9
4 months	3.9	3.7	2.9	3.3	4.0	3.9	3.6	3.7	3.3	3.8	3.7	3.7	3.7	3.7	3.7	3.8
6 months	3.5	3.6	3.1	3.5	3.7	3.6	3.6	3.7	3.4	3.1	3.7	3.3	3.3	3.6	3.3	3.3
Cauliflower																
1 month	3.3	3.7	2.9*	2.1	3.5	3.8	4.1**	2.5	3.9	3.7	4.2**	3.3	3.9*	2.6	3.9*	3.0
2 months	3.0	2.9	3.1	2.4	3.5	3.5	3.7	3.6	3.7	3.1	3.7	3.9	3.3	3.3	3.3	3.3
4 months	3.0	3.3	2.6	2.3	3.9	4.1	3.3	3.9	3.3	3.3	3.7	3.5	2.9	3.5	3.3	3.5
6 months	3.0	3.5	2.6	2.5	4.0	4.3	3.6*	4.1	4.2**	3.5	3.5*	4.2	3.1	3.5	3.7	3.7
Green Beans																
1 month	2.3**	4.1	3.3	3.4	3.3**	4.4	2.2*	3.3	3.8	3.3	2.6**	3.9	2.9*	3.8	2.7*	3.7
2 months	2.7*	3.8	3.4	3.5	2.8**	4.2	2.5**	3.6	3.6	2.9	2.9	3.5	2.9**	3.9	2.7**	3.8
4 months	2.3**	3.5	3.9*	3.1	2.9**	4.3	2.9**	3.9	3.7*	3.3	2.9**	4.1	3.2	3.9	3.0**	3.9
6 months	2.4*	3.8	3.7	3.6	2.5*	3.9	1.8**	3.9	3.8	3.5	2.4**	4.1	2.9*	4.0	2.5**	3.9
Zucchini																
1 month	3.7	3.4	3.7	3.2	4.1	4.3	2.7	3.3	3.2	3.4	3.7	3.7	3.8	3.8	3.5	3.7
2 months	3.1	3.9	3.5	3.4	3.4	3.9	2.6*	3.7	2.9	3.3	3.0	3.7	2.9	3.6	3.2	3.7
4 months	3.0	3.2	3.9**	3.0	3.1*	3.8	3.2	3.1	2.3**	3.5	2.6**	3.7	2.9	3.5	2.7	3.4
6 months	3.1	3.4	3.6*	2.7	3.2*	4.0	3.7	2.9	2.3**	3.6	2.5**	3.7	3.0**	4.1	2.6**	3.7

[a] Mean scores of fifteen panelists; 5 = highest score
[b] Blanched with microwave energy
[c] Blanched with boiling water
* Significantly different ($p \leq 0.05$) from same vegetable blanched with boiling water, using Wilcoxon Signed-Ranks
** Significantly different ($p \leq 0.01$) from same vegetable blanched with boiling water, using Wilcoxon Signed-Ranks

limp) in broccoli and green beans. A Warner-Bratzler value of 4.15 or above for broccoli and 1.22 or above for green beans could be interpreted as an indication of an unusually tough vegetable. In zucchini, the difference in texture between the vegetables blanched with microwave energy or with boiling water was perceived by the tasters for texture (firm vs. limp) ($p \leq 0.01$), but was not perceived for tenderness (Table 5). These results imply that a Warner-Bratzler reading of 0.36 or below could be used as an indicator of unusually limp zucchini.

Although there was a tendency for carrots and cauliflower blanched with microwave energy to be more firm than those blanched with hot water, tenderness differences measured by the Warner-Bratzler Shear Press disappeared after four months of frozen storage (Table 6). The sensory panel did not perceive differences in any of the factors describing texture in carrots at any time and only at the first and last test periods for cauliflower (Table 5).

A possible explanation for the significant difference in texture observed in broccoli is that microwave blanching activated the enzyme pectin methylesterase (PME). The incomplete inactivation of peroxidase by microwave blanching in this vegetable (Table 2) leads to the conclusion that some sections of the vegetable may have become just warm enough to activate PME but not hot enough for inactivation. Lee, Bourne, and Van Buren (1979) reported that low temperature blanching produced firmer canned carrots than did high temperature blanching. They concluded that this could have been the result of PME activation in the product blanched at low temperatures. Van Buren (1974) reported more in-

TABLE 6
Mean Warner-Bratzler shear values[a] of vegetables cooked after frozen storage

Time	Broccoli		Carrots		Cauliflower		Green Beans		Zucchini	
	M[b]	W[c]	M	W	M	W	M	W	M	W
1 month	4.50*	1.94	0.36*	0.20	2.09	1.75	3.59*	0.59	0.38	0.49
2 months	4.88*	1.69	0.48*	0.18	2.22*	0.81	1.71*	0.63	0.36*	0.96
4 months	4.15*	1.88	0.26	0.19	2.31	1.41	1.22*	0.69	0.35*	0.59
6 months	4.16*	1.28	0.28	0.21	2.38	1.56	1.78*	0.56	0.35*	1.00

[a] Each value is the mean of eight replications
[b] Blanched with microwave energy
[c] Blanched with boiling water
* Significantly different ($p \leq 0.05$) from same vegetable blanched with boiling water, using *t*-test

soluble pectic substances present in cherries heated to 65°C than in fruit heated to 43°C or 95°C. A firmer texture was noted in fruit subjected to 65°C, the temperature which activated PME, than in fruit heated to the other two temperatures.

Immediately after blanching, the zucchini blanched with microwave energy had the appearance of a cooked vegetable and was more limp than its counterpart blanched with boiling water. Microwave blanching apparently caused a greater amount of textural damage in this vegetable than in any other, possibly due to its parenchymatous nature. Schrumpf and Charley (1975) found that vegetables with a large proportion of parenchyma cells were more subject to cell separation and collapse caused by the heat transfer of microwave cooking than were vegetables containing a larger proportion of sclerenchyma cells.

Flavor

The sensory evaluation panel rated the flavor of the broccoli blanched by microwave lower ($p \leq 0.05$) than that of the conventionally blanched broccoli after two and six months of frozen storage (Table 5). The flavor scores of the carrots blanched by the two methods were not significantly different ($p \geq 0.05$) at any of the test periods. Cauliflower blanched with microwave energy was given higher flavor ratings than the cauliflower blanched with boiling water after one month of storage. At later test periods there were no significant differences ($p \geq 0.05$). The panel rated the flavor of green beans blanched by microwave significantly lower ($p \leq 0.05$) than that of green beans blanched with boiling water at all test periods except one. Flavor scores for zucchini blanched with microwave energy were significantly lower ($p \leq 0.05$) than the scores for zucchini blanched with boiling water after six months of storage.

Although there has been little study of isolated, specific enzymes in connection with flavors (Chase, 1974), some undesirable flavor changes in vegetables have been attributed to enzymes, e.g., lipoxygenase (Axelrod, 1974). The less desirable flavors of the microwave-blanched vegetables may have been due to residual activity of enzymes as suggested by residual peroxidase activities of these vegetables.

Overall Acceptability

Only one vegetable blanched with microwave energy was rated higher ($p \leq 0.05$) than the water-blanched counterpart in overall acceptability by the sensory evaluation panel (Table 5). After one month of frozen storage the panel's mean overall acceptability score for cauliflower blanched with microwave energy was higher than that for the cauliflower blanched with the boiling water. At later test periods no significant differences for cauliflower were reported. The panel gave significantly higher ratings of overall acceptability to broccoli blanched with boiling water at each test period after two months of storage (Table 5) and preferred the broccoli blanched with boiling water to the broccoli blanched with microwave energy at every test period (Table 7). The carrots blanched by the two methods were not rated significantly different for over-

TABLE 7
Preference of fifteen sensory panelists for microwave vs. hot water blanched vegetables after frozen storage

	Broccoli		Carrots		Cauliflower		Green Beans		Zucchini	
Storage Time	M[a]	W[b]	M	W	M	W	M	W	M	W
1 month	2*	13	7	8	12*	3	2*	13	8	7
2 months	2*	13	7	8	7	8	1*	14	4	11
4 months	2*	13	7	8	6	9	1*	14	3*	12
6 months	1*	14	7	8	7	8	1*	14	6	9

[a] Blanched with microwave energy
[b] Blanched with boiling water
* Significantly different ($p \leq 0.05$) from vegetable blanched with boiling water using "Significance in Paired Sensory Tests" table (Roessler, Baker, and Amerine, 1956)

all acceptability (Table 5) or preference (Table 7) by the panel. The panel preferred the green beans blanched with boiling water at all test periods. Although the difference in the overall acceptability scores of the zucchini after four months' storage was not statistically significant ($p \geqslant 0.05$) (Table 5), more of the sensory panel preferred the vegetable blanched with boiling water (Table 7). After six months' storage the overall acceptability scores of the zucchini blanched with boiling water were higher.

Conclusions

Residual peroxidase activity of all conventionally hot water blanched vegetables was less than five percent. Blanching with microwave energy at times commonly in use by the consumer produced this acceptable level of enzyme inactivation only in cauliflower carrots, and green beans.

Quality factors of cauliflower and carrots blanched by microwave heat were not significantly different from those of these two vegetables blanched conventionally in boiling water. The sensory evaluation panel rated broccoli and green beans blanched with microwave energy lower in color, texture, flavor, and overall acceptability than the same vegetables blanched with boiling water. Lower chlorophyll values, lower green and higher yellow values as indicated with a Hunter Meter, and higher shear force values obtained for the broccoli and green beans blanched with microwave energy confirmed the sensory evaluation scores. After four months or longer of frozen storage, sensory evaluation scores and shear force values were lower for zucchini blanched with microwave energy than for zucchini which was conventionally blanched in hot water.

Further research is indicated to identify microwave blanching times which effectively decrease peroxidase activity and to determine whether such blanching times would indeed produce acceptable vegetables after frozen storage. It may be that adequate blanching times in the microwave oven would essentially cook the vegetable. The zucchini in this study blanched with microwave energy was limp. Blanching for a time sufficient to inactivate peroxidase undoubtedly would produce an overcooked vegetable. Some vegetables, then, may be unsuitable for blanching by this method. The instructions currently available for microwave blanching of vegetables for home freezing do not result in a quality product for all vegetables.

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Received February 25, 1982; accepted May 19, 1982.
