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Shrimp taste and vitamin content did not differ markedly in thermal and microwave processing tests.

Thermal and Microwave Energy for Shrimp Processing

M. R. R. RAO and A. F. NOVAK

INTRODUCTION

Development of new methods of processing foods inevitably encourages consumers as well as scientists to question the effects of the method on the nutrient composition of foods. Microwave cookery is actually the first totally different method of heating foods since the discovery of the attributes of fire. Since the inception of cooking by high-frequency radio waves (about 1944) scientists have attempted to elucidate its effects on food composition and total biological systems with no conclusive results.

Thermal and nonthermal effects of microwaves on microorganisms and organic chemicals were studied by Olsen, Drake, and Bunch (1966). Lacey et al. (1965) reported considerable reduction in microbial counts and even sterility in some cases when bacteria were subjected to comparatively lower levels of heat by microwaves rather than by conventional heat treatments. Proctor and Goldblith (1948) studied radar energy and its effects on the vitamin content of food products. Since then, considerable effort has resulted in numerous investigations with a great variety of conclusions. The problems seem to involve a lack of uniformity in methods of analyses, cooking times, and processing temperature.

Although much work has been done on vitamin analyses of vegetables cooked by microwaves and conventional means, literature is insufficient on proteins, and no data has yet been reported on the effects of processing methods on vitamin content of Gulf Coast shrimp.

The purpose of this study was to determine the vitamin content of shrimp processed by microwave cooking and conventional boiling and to compare these values to an uncooked (raw) control. Cooking times were established by sensory evaluation to insure that products were cooked uniformly. This method compensated for the lack of temperature measuring devices in the microwave oven. Care was taken to prevent overheating in certain areas of the microwave cavity, termed hot spots, by employing periodic stirring. Vitamins selected for this study were those which had been reported in previous microwave research, and standard methods of analyses were used for all determinations.

Microwave processing is a well-established method in the food industry and is now spreading to many different fields. Due to its greater efficiency, economical superiority, and extreme speed it has become a multimillion dollar industry within the past 10 years. It has undoubtedly influenced major changes in industrial processes, procedures, equipment, and products. Familiarity with its capabilities and potential uses in food processing industries has become increasingly vital.

MATERIALS AND METHODS

Samples

Three different sets of shrimp were obtained for analyses. Lot I was received 10 August 1969, from a large fisheries dealer (Booth Fisheries[1], Brownsville, Tex.) and consisted of one case of peeled and deveined shrimp (12/12 oz). Lot II consisted of 3 lb headless shrimp purchased 27 October 1969, from a local retailer in Baton Rouge, La. This lot was washed and treated by each processing method before being packaged and sealed in plastic bags. Lot III was obtained from a commercial dealer in New Orleans, La., 26 November 1969, and immediately transported to the Food Science Department, Louisiana State University, where the shrimp were headed, washed, and treated by each processing method before being heat-sealed in plastic bags.

Processing Methods and Equipment

Raw Samples

After each lot was washed, the control samples were packaged in 50 g quantities in heat-sealable plastic bags.

Boiled Samples

One hundred grams of shrimp were placed in an aluminum pot containing 1 liter of boiling water and 5 g salt. After 3 min and 45 sec the water returned to a boil and the shrimp were then cooked for 5 min and 30 sec at 101°C. They were then allowed to cool before peeling and packaging 50 g quantities in heat-sealable plastic bags.

Microwave Samples

One hundred grams of shrimp were placed in a heat resistant Nalge container with 1 liter of tap water (26°C) and 5 g salt and cooked with a microwave oven for 3 min, allowed to set for 10 sec, processed 30 sec, allowed to cool 10 sec, and then cooked an additional 30 sec (101°C). These time lags were to prevent boil-over. The oven used in this experiment was the Superange 2500 and its specifications are given in Table 1. Both magnetrons were used in all experiments producing 2,500 W. All samples, having been processed and packaged, were rapidly frozen to −20°C for storage until needed for analyses.

Sensory Evaluation

The organoleptic panel consisted of 10 graduate students, 9 males and 1 female. The panelists ranged in age from approximately 20 to 31 years. No

[1]Mention of trade names, commercial products, or firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

M. R. R. Rao is Associate Professor and A. F. Novak is Professor and Head, Department of Food Science, Louisiana State University, Baton Rouge, LA 70803.

Table 1.—Specifications of Superange 2500.

Net weight	190 lb
Power required	208 or 240 volts AC, 3-wire, single-phase 30 amp circuit, 60 hertz
Power consumption	5,450 watts (both magnetrons) 3,010 watts (single magnetron) 550 watts (idle)
Power output	2,500 watts (both magnetrons) 1,250 watts (single magnetrons)
Frequency	2,450 megahertz
Power cord	6-foot, 3-wire grounding type with standard 30 amp connector
Cavity dimensions	Height 15⅛ in Width 20 5/16 in Depth 16⅜ in
Door dimensions	Height 17 5/16 in Width 22⅝ in Depth 1¼ in

effort was made to select panelists for their sensory acuity, since organoleptic differences detectable by the average untrained person were desired.

Hedonic, paired-comparison tests were used to determine the cooking times given above. The samples of cooked shrimp were scored on a 5 point hedonic scale with 1 representing poor and 5, excellent. When the hedonic scores indicated that the thermal and microwave products were equivalent in organoleptic values and palatability scores, the cooking times were recorded and used for preparing the samples used in vitamin assays.

The total cooking time for the boiled samples was 9.25 min at 101°C; that for the microwave samples was 4 min with no prior heating of the water. The final temperature of the microwave samples was 100°C and was determined immediately after the power was turned off.

Vitamin Analyses

For each vitamin assay, a 50 g sample package of each processing method and the raw control were allowed to thaw and then homogenized in a Sorvall Omni-Mixer with the proper solvent for that test. All microbiological assays were carried out according to Difco Manual (1967). Preparations of samples for analyses were according to procedures listed in Association of Official Agricultural Chemists (AOAC) (1960).

Vitamin A and ß-carotene

Procedures found in AOAC (1960), with modifications, were followed in the analyses of Vitamin A and ß-carotene. One-tenth gram of USP vitamin A and 1 g Crisco oil were weighed and treated as a 10 g simulated shrimp sample. Twenty-five grams of each shrimp sample were also weighed and a 3 to 1 volume/volume solution of ethanol and potassium hydroxide (50 g diluted in 100 ml distilled water) were added to each sample in a 4 to 1 volume/weight ratio. All samples were refluxed 30 min, cooled, and filtered through glass wool. After the volume of each sample was read, they were washed with hexane 3 times in separatory funnels and the hexane phase retained. The hexane phase was washed with water in separatory funnels until it was neutral to phenolphthalein. The vitamin A standard was diluted to 250 ml with hexane while the other samples were evaporated to dryness in a Rinco Rotary evaporator.

Columns for column chromatography were prepared as directed in AOAC (1960). ß-carotene was eluted with 30 ml of 4 percent acetone in hexane (35 ml). For vitamin A analysis, suitable aliquots were evaporated to dryness in Spectronic 20 tubes and 1 ml of choloroform was added. After 4 ml antimony trichloride (Carr-Price) reagent was added to sample tubes they were read immediately for maximum deflection due to rapid fading. The amount of vitamin A was determined by using a standard curve prepared by increasing the concentration of the vitamin A standard. A standard ß-carotene curve was prepared by using a series of dilutions of ß-carotene in hexane and plotting absorbance against μg carotene. Vitamin A was read at 620 mμ on a Bausch and Lomb Spectronic 20 and carotene was read at a wavelength of 440 mμ.

Stock Cultures for Microbiological Assay of Vitamins

Cultures of *Lactobacillus arabinosus* 17-5 ATCC 8014 (plantarum), *Lactobacillus fermentum* 36 ATCC 9833, and *Lactobacillus casei e* ATCC 7469 were received in July 1969 and were revived 5 September 1969 by placing them in Bacto-Micro Inoculum Broth and incubating them 48 h at 37°C. Stabs were then made in triplicates in Bacto-Micro Assay Culture Agar and after 48 h incubation, were stored in a refrigerator at 2-6°C. Stock cultures were transferred each week for 1 month and thereafter were transferred each month. A gram stain and streak plate were made of all stabs to insure pure cultures.

Riboflavin

The test organism in this assay was *Lactobacillus casei e* (7469). Assay standard and sample tubes were set up according to Difco Manual (Difco Laboratories, 1967) and after 18 h were read turbidometrically by a Bausch and Lomb Spectronic 20. Extraction procedures were those of AOAC (1960) with modifications. Ten grams of each sample were hydrolyzed in 150 ml 0.1 N hydrochloric acid and autoclaved 30 min at 121°C, 15 lb pressure, and then adjusted to a pH of 6.8 with 1 N sodium hydroxide. The volume was then brought to 200 ml with distilled water and centrifuged in 50 ml tubes to rid the solution of the protein precipitate. One, two, three, etc., ml of the sample were added to sample tubes and then all tubes were inoculated and incubated for 18 h.

Niacin

Procedures given in the Difco Manual (Difco Laboratories, 1967) were used for the microbiological assay of niacin. *Lactobacillus arabinosus* (8014) (plantarum) was the test organism and was incubated for 24 h at 37°C in Bacto-Micro Inoculum Broth before inoculation. Samples were prepared by hydrolyzing 20 g of each sample 30 min after adding 125 ml of 1 N sulfuric acid. After cooling, the pH was adjusted to 6.8 by adding 1 N sodium hydroxide. Samples were diluted to 1,000 ml and then centrifuged with the resulting solution further diluted 1 to 10 with distilled water. The assay was sterilized by autoclaving 10 minutes at 15 lb pressure (121°C), inoculated, and allowed to incubate 18 h at 37°C. The tubes were read turbidometrically with a Bausch and Lomb Spectronic 20 at a wavelength of 650 mμ.

Thiamine

Lactobacillus fermentum (9833) was used for this assay. It was found that stock cultures must be incubated a full 48 h to produce proper results in this assay. Preparation of samples was carried out according to AOAC (1960) with slight modifications. Twenty grams were hydrolyzed in 150 ml of 0.1 N hydrochloric acid by autoclaving 30 minutes at 121°C. The pH was adjusted to 6.5 with 1 N sodium hydroxide, and the sample was then diluted to 250 ml with distilled water, centrifuged, and then further dilutions were made to attain

proper readings. Because of possible destruction of thiamine, the assay was steam sterilized at 100°C for 15 minutes before cooling and inoculating.

Pantothenic Acid

After preliminary investigations it was found that stock cultures of *Lactobacillus arabinosus* (8014) should be incubated 36 h instead of 48 h to produce proper responses. Samples were prepared by adding 220 ml of distilled water to 20 g of the sample shrimp. The pH was adjusted to 5.65 with an acetate buffer (10 ml 0.2 N acetic acid, 100 ml of 0.2 N sodium acetate in 1 liter of distilled water). After autoclaving for 7 min at 121°C the pH was adjusted with 1 N sodium hydroxide to 6.8 and the solution was diluted to 2,000 ml before centrifuging. After increasing amounts of the solution were pipetted into each tube, the assay was autoclaved 10 min at 15 lb pressure (121°C). Throughout all microbiological assays, the stock solutions of each vitamin were stored in a refrigerator at 2-6°C under toluene. All determinations were carried out by plotting a standard curve for each assay and comparing growth of sample tubes using turbidometric readings (Difco Laboratories, 1967).

Table 2.—Analysis of variance for appearance, texture, taste, and overall organoleptic scores.

Organoleptic Quality	Source of variation	Degrees of freedom	Mean square	*F* value
Appearance	Total	39		
	Judges	9	2.2472	[1]3.39
	Process	1	0.0250	0.04
	Replicas	1	0.2250	0.34
	Replicas × Process	1	0.6250	0.94
	Error	27	0.6620	
Texture	Total	39		
	Judges	9	1.5694	1.42
	Process	1	0.2250	0.20
	Replicas	1	0.0250	0.02
	Replicas × Process	1	1.2250	1.11
	Error	27	1.1028	
Taste	Total	39		
	Judges	9	2.1694	[2]2.26
	Process	1	0.2250	0.23
	Replicas	1	3.0250	3.14
	Replicas × Process	1	0.0250	0.03
	Error	27	0.9620	
Overall	Total	39		
	Judges	9	11.500	[1]5.68
	Process	1	1.000	0.49
	Replicas	1	1.600	0.79
	Replicas × Process	1	3.600	1.78
	Error	27	2.026	

[1]$P<0.01$
[2]$P<0.05$
Critical values at *d.f.* 9/27 $F_{0.05} = 2.25$, $F_{0.01} = 3.15$
Critical values at *d.f.* 1/27 $F_{0.05} = 4.21$, $F_{0.01} = 7.68$

Table 3.—Individual mean scores of the 10 judges in order of increasing rank for appearance, taste, texture, and overall scores.

Appearance									
Mean score	1.00	2.00	2.25	2.50	3.00				
Judge no.	4,10	3,9	1	2,7	5,6,8				
	F = [1]3.39								
Texture									
Mean score	1.25	1.75	2.00	2.25	2.50	2.75	3.25		
Judge no.	10	4	3	8,9	1,2	7	5,6		
	F = 1.42								
Taste									
Mean score	1.50	2.00	2.25	2.50	2.75	3.25	3.75		
Judge no.	5	3	4,9	10	1,8	6	2,7		
	F = [2]2.26								
Overall									
Mean score	4.75	6.00	6.50	7.50	7.75	8.00	8.75	9.00	9.50
Judge no.	4,10	3	9	1	5	8	2	7	6
	F = [1]5.68								

[1]$P<0.01$
[2]$P<0.05$
Critical value at *d.f.* 9/27, $F_{0.05} = 2.25$, $F_{0.01} = 3.14$

RESULTS AND DISCUSSION

Organoleptic Results

The organoleptic data were subjected to standard analyses of variance which examined the effects on appearance, texture, taste, and overall values of two processes and two replicas. The results of the analyses of variance are presented in Table 2.

The mean scores of the different judges are listed in Table 3 in order of increasing rank. These ranged from 1.0 to 3.0 for appearance, from 1.25 to 3.25 for texture, and from 1.50 to 3.75 for taste. The overall organoleptic scores (sum of values for appearance, texture, and taste) were highly individualistic, ranging from 4.75 to 9.50, with only 2 judges, No. 4 and No. 10, scoring the same total. The 4 calculated F values for differences among the means for the 10 judges were: appearance, 3.39, highly significant; texture, 1.42, insignificant; taste, 2.26, significant; and overall, 5.68, highly significant. The critical values at *d.f.* 9/27 are $F_{0.05} = 2.25$, and $F_{0.01} = 3.14$.

Cooking Processes

The mean organoleptic scores and standard deviations associated with the thermal and microwave processes are given in Table 4. For both processes the mean scores for appearance, texture, taste, and overall values were almost identical. The calculated F values for differences between the thermal and microwave samples were very small and insignificant, ranging from 0.04 for appearance to 0.49 for overall values. The critical value at *d.f.* 1/27 is $F_{0.05} = 4.21$.

Replicas

The mean organoleptic scores and standard deviations associated with the 2 replicas are shown in Table 5. There

Table 4.—Mean scores and standard deviations for appearance, texture, and taste among processes.

	Microwave		Boiled		*F* values
	Mean	S.D.	Mean	S.D.	
Appearance	2.20	1.06	2.25	0.96	0.04
Texture	2.45	1.10	2.30	1.08	0.20
Taste	2.60	1.10	2.75	1.17	0.23
Overall	7.20	2.01	7.30	2.13	0.49

Critical value at *d.f.* 1/27, $F_{0.05} = 4.21$, $F_{0.01} = 7.68$

Table 5.—Mean scores and standard deviations for appearance, texture, and taste among replicas.

	First replica		Second replica		*F* values
	Mean	S.D.	Mean	S.D.	
Appearance	2.30	1.13	2.15	0.88	0.34
Texture	2.35	1.18	2.40	0.99	0.02
Taste	2.40	1.04	2.95	1.14	3.14
Overall	7.05	2.23	7.45	1.88	0.79

Critical value at *d.f.* 1/27, $F_{0.05} = 4.21$, $F_{0.01} = 7.68$

appeared to be a trend toward a preference for the second replica samples in overall scores and this was especially evidenced in taste scores for which the F value was 3.14. The second replica samples were scored higher in texture, taste, and overall, with appearance being slightly higher in the first replica. The critical value at $d.f.$ 1/27 is $F_{0.05} = 4.21$.

Interactions Between Processes and Replicas

The mean scores for the interaction, process × replica, with respect to appearance, texture, taste, and overall values of the shrimp sample are given in Table 6. The critical values of F at $d.f.$ = 1/27 for the above interactions were $F_{0.05} = 4.21$ and $F_{0.01} = 7.68$. The interactions between processes and replicas for each of the four organoleptic attributes all had insignificant F values. This indicated that the processes and replicas were consistent in their relationships with respect to the preferences of the judges.

Table 6.—Interactions—mean organoleptic scores of shrimp.

Qualities	Replica 1	Replica 2
Appearance		
Thermal	2.20	2.30
Microwave	2.40	2.00
$F = 0.94$		
Texture		
Thermal	2.10	2.50
Microwave	2.60	2.30
$F = 1.11$		
Taste		
Thermal	2.50	3.00
Microwave	2.60	2.30
$F = 0.03$		
Overall		
Thermal	6.80	7.80
Microwave	7.30	7.10
$F = 1.78$		

Critical value at $d.f.$ 1/27, $F_{0.05} = 4.21$, $F_{0.01} = 7.68$

Correlation Coefficients

In Table 7 the values of the Pearson product-moment coefficients of correlation are given for all 6 possible pairs of organoleptic attributes (appearance vs. texture, appearance vs. taste, appearance vs. overall, texture vs. taste, texture vs. overall, and taste vs. overall) and these are categorized according to processes and replicas.

The correlations between appearance and texture were positive in all 4 categories but they were not significant ($P>0.05$). The correlations between appearance and taste were positive for the first replica and the thermal process and were significant ($P<0.05$), whereas in the two other categories the correlations were negative and not significant. The correlations between texture and taste were negative in all 4 categories but they were not significant, whereas correlations between overall scores and appearance were positive and highly significant in all 4 categories ($P<0.01$). The correlations between overall scores and texture were positive in all categories and significant in one category (first replica) and highly significant in the three other categories: those between overall scores and taste were positive in all categories; they were significant in two categories, second replica and microwave process, and highly significant in the two other categories.

The analyses of the data indicate there were no significant differences between the microwave and boiled processes and between replicas. Significant differences were found among judges at the 0.01 level. Samples of shrimp processed according to these procedures were then analyzed for vitamin A, ß-carotene, niacin, thiamine, riboflavin, and pantothenic acid.

Table 7.—Correlation coefficients of appearance, texture, and taste for the replicas and processes.

Correlations	$d.f.$	Replicas		Process	
		First	Second	Microwave	Boiled
Texture vs Appearance	18	0.114	0.351	0.190	0.227
Taste vs Appearance	18	[1]0.472	−0.202	−0.064	0.339
Taste vs Texture	18	−0.077	−0.074	−0.061	−0.063
Overall vs Appearance	18	[2]0.786	[2]0.566	[2]0.623	[2]0.754
Overall vs Texture	18	[1]0.551	[2]0.688	[2]0.646	[2]0.576
Overall vs Taste	18	[2]0.666	[1]0.500	[1]0.491	[2]0.669

[1]Significant at $P<0.05$
[2]Significant at $P<0.01$
Critical value at $d.f.$ 18, $F_{0.05} = 0.444$, $F_{0.01} = 0.561$

Vitamin Analyses

After three assays of each vitamin had been carried out, Table 8, mean values, Table 9, were calculated for the

Table 8.—Results of vitamin analysis.

Vitamin	Replicas	Process		
		Raw	Microwave	Boiled
		Micrograms per gram		
Niacin	1	12.37	13.33	15.27
	2	27.30	18.40	18.02
	3	19.88	14.40	15.75
Thiamine	1	0.95	0.82	0.81
	2	0.91	1.09	0.95
	3	0.52	0.81	0.54
Riboflavin	1	0.59	0.40	0.52
	2	1.03	0.65	0.61
	3	0.37	0.51	0.53
Pantothenic acid	1	1.50	1.47	1.30
	2	1.47	1.47	1.73
	3	2.65	3.10	1.60
ß-carotene	1	0.048	0.046	0.060
	2	0.093	0.065	0.044
	3	0.078	0.099	0.138

Table 9.—Mean vitamin content of shrimp samples.

Vitamin	Replicas			Process		
	First	Second	Third	Boiled	Microwave	Raw
			Micrograms per gram			
Niacin	13.66 $F = 4.11$	21.24	16.68	16.35 $F = 1.56$	15.38	19.85
Thiamine	0.860 $F = 8.14$[1]	0.983	0.623	0.767 $F = 1.34$	0.970	0.793
Riboflavin	0.503 $F = 2.88$	0.763	0.470	0.553 $F = 0.63$	0.520	0.663
Pantothenic acid	1.42 $F = 4.14$	1.56	2.45	1.54 $F = 0.77$	2.01	1.87
ß-Carotene	0.051 $F = 3.04$	0.067	0.105	0.081 $F = 0.12$	0.070	0.073

[1]Significant at $P<0.05$
Critical values at $d.f.$ 2/4, $F_{0.05} = 6.94$, $F_{0.01} = 18.00$

raw, boiled, and microwave processes, and, based on the raw values, apparent percent retentions were calculated. Niacin was retained by 77.48 percent in the microwave and 82.36 percent in the boiled samples; 115.00 and 97.00 percent of thiamine were retained in the microwave and boiled samples, respectively; 79.00 percent in the microwave and 83.00 in the boiled samples were retained of riboflavin; pantothenic acid had 107.00 and 82.00 percent retentions in the microwave and boiled processes; and ß-carotene had apparent percent retentions of 96.00 in the microwave and 110.00 in the boiled samples.

Vitamin A and ß-carotene

Preliminary analysis of vitamin A revealed no measurable amount present in the flesh of Gulf Coast shrimp. These results are in agreement with those of Fisher, Kon, and Thompson (1957) who found no vitamin A in the body of *Penaeus aztecus*. They found a total vitamin A content of .054 μg/g but this was made up entirely of vitamin A found in the eyes (4.3 μg/g).

ß-carotene was then measured because of its reported vitamin A activity. Stecher (1960) calls ß-carotene the most important of the provitamins A, having about one-half vitamin A activity. A substantial difference among replicas and samples may be explained by ß-carotene's tendency to oxidize when exposed to the air. Mean values of the three replicas and processes are presented in Table 9. The boiled samples were higher in ß-carotene than raw samples and the microwave samples retained 96.0 percent. The unusually high amounts of ß-carotene in the boiled samples might be explained by enzyme inactivation due to processing and could also be due to uneven oxidation. Results were similar to those given by Fisher et al. (1957) for carotenoid content.

Niacin

Although the amount of niacin changes from sample to sample, results are fairly consistent among each replica. Table 9 gives the mean values for the 3 replicas and processes. Samples processed by microwaves retained 77.48 percent and the boiled samples retained 82.36 percent. These figures generally agree with other results which indicate 80-90 percent retention of niacin due to processing temperatures. General vitamin content was in agreement with results shown by Heen and Kreuzer (1962) who recorded values of 11-53 μg/g for shrimp. An analysis of variance will be discussed for all vitamins following discussion of their individual characteristics.

Thiamine

This assay seemed to be the most difficult to run due to the fastidious nature of the test organisms. Results of the 3 replicas were consistent (Table 8) except for the third replica. Mean values (Table 9) once again showed a B vitamin with higher values in one of the processed samples than in the raw samples. The mean values for the microwave and boiled samples had 115.0 and 97.0 percent retention respectively. This is possibly explained by Furia (1968) when he stated that enzymes capable of destroying vitamin B_1 (thiaminase) occur in some foods—raw fish, clams, shrimp, rice polishings, beans, and mustard seed. Thiamine was found to be heat labile by Inagaki, Hishio, and Hattori (1964), Goldblith, Tannenbaum, and Wang (1968), and Causey and Fenton (1951) in meat and vegetables. When shrimp were tested the raw samples were allowed to sit at room temperature while the microwave and boiled processes were carried out. There was also a time lag for packaging all samples, and after freezer storage samples were thawed for analyses. Melnick, Hochberg, and Oser (1945) reported that within 20 min one serving of raw clams (100 g) could destroy 7.5 mg of thiamine, whereas a heated clam serving destroyed only 15 percent of the 8 mg of thiamine originally present. The thiaminase enzyme in raw clams was inactivated during processing allowing similar results in both the cooked and raw samples. The greater amount of thiamine in the microwave samples could be due to a higher degree of destruction of thiaminase than that due to just thermal energy.

Riboflavin

Results of the 3 replicas (Table 8) are inconsistent among some replicas and processes, although values agree with ranges of riboflavin in shrimp given by Heen and Kreuzer (1962). Percent retention based on mean values (Table 9) was 79.0 percent for the microwave and 83.0 percent for the boiled samples. This agrees with results cited in the literature review. Furia (1968) noted retentions of 70-90 percent in meat depending on methods of cooking and he also stressed the fact that riboflavin is light sensitive which could be a factor in some samples even though attempts were made to reduce this factor.

Pantothenic Acid

Results of the vitamin analyses (Table 8) showed a slight inconsistency in the third replica. All values were well within the range of pantothenic acid given for shrimp flesh by Heen and Kreuzer (1962), 1.2-3.8 μg/g, and values given by Orr (1969), 2.8 μg/g.

Table 9 shows mean values of the 3 replicas to be similar in relationship to those of thiamine. Microwave samples retained 107.0 percent and the boiled samples retained 82.0 percent when compared to the raw control. Furia (1968) shows a 7-10 percent loss of pantothenic acid when meat is cooked, but also states that there is usually only 70 percent retention when foods are cooked in an excess amount of water due to the vitamin's hygroscopic nature. The greater amounts of pantothenic acid in the microwave sample could be due once again to enzymatic action in the other samples, experimental error for the method of assay, or microbiological activity.

Analysis of Variance

Table 10 gives an analysis of variance for all vitamins previously discussed, along with ß-carotene, the provitamin

Table 10.—Analysis of variance on vitamin composition due to replicas and processes.

Vitamin	Source of variance	Degrees of freedom	Mean square	*F* value
Niacin	Total	8		
	Replicas	2	43.730	4.11
	Processes	2	16.612	1.56
	Error	4	10.650	
Thiamine	Total	8		
	Replicas	2	0.1004	[1]8.14
	Processes	2	0.0166	1.34
	Error	4	0.0123	
Riboflavin	Total	8		
	Replicas	2	0.0774	2.88
	Processes	2	0.0169	0.63
	Error	4	0.0268	
Pantothenic acid	Total	8		
	Replicas	2	0.9349	4.14
	Processes	2	0.1747	0.77
	Error	4	0.2260	
ß-Carotene	Total	8		
	Replicas	2	0.00228	3.04
	Processes	2	0.000091	0.12
	Error	4	0.000749	

[1]Significant at $P<0.05$
Critical value at d.f. 2/4, $F_{0.05} = 6.94$
$F_{0.01} = 18.00$

A. The sources of variation for each vitamin were the 3 replicas and the 3 processes. The only significant difference, which was found in the replicas for thiamine, was significant at the 5 percent level. The *F* values were consistently higher for replicas than for processes. The small number of replicas and the large differences between them undoubtedly contributed to the finding of only insignificant differences among the raw and processed samples of shrimp.

As discussed in sections covering individual vitamins, many of these differences in replicas could be caused by several factors. Novak, Fieger, and Bailey (1956) offered experimental error, microbiological activity (synthesis of additional vitamins), enzymatic degradation, and sampling errors as reasons for fluctuation of vitamin content.

An evaluation of findings in this study indicates that no difference in sensory evaluation and no significant differences in vitamin retention between the microwave and thermal methods are evident. Therefore, it is concluded that the faster, labor saving method of microwave cookery could be utilized with no sacrifice of nutritional or organoleptic qualities to the consumer. It is hoped that this present study will add to the knowledge being accumulated on microwave cookery.

High frequency cooking has a definite place in the future, and restaurants are now operating with complete precooked, frozen, and microwave-thawed gourmet dinners. With institutional, industrial, and domestic uses increasing each day, there is no doubt that microwave cooking will play an important part in the food industry of the future.

SUMMARY

Gulf Coast shrimp were processed by 2450 MHz microwave energy and conventional boiling to determine if differences existed in organoleptic evaluation and vitamin retention. Since no satisfactory method was available for measuring the temperature of products while being cooked by microwave energy, hedonic test panels were employed to insure compatible cooking times for the two methods. A 10-member panel evaluated these methods by scoring a 5-point hedonic test for appearance, texture, and taste.

Chemical tests for vitamin A and ß-carotene, and microbiological assays for niacin, thiamine, riboflavin, and pantothenic acid were used to determine vitamin retention. Statistical analyses of all results were accomplished with the use of a 360 IBM computer. Results of the organoleptic tests showed no significant difference between the two processes; the only significant difference was among the judges, showing evidence of an untrained test panel which is typical of the consuming public.

Vitamin A was not found in the tail-meat and thereafter samples were analyzed for ß-carotene, one of the most important provitamins A. Apparent percent retentions were calculated from the mean values of the replicas for each vitamin and varied between 77.48 and 115.0 percent for different vitamins and processes and were based on values found for the raw control. The highest value, 115.0 percent, was found in the microwave samples assayed for thiamine, and was probably caused by thiaminase found in raw shrimp, which is responsible for destruction of thiamine.

Analysis of variance for vitamin composition showed no significant difference between processing methods, although there was a significant difference at the 0.05 level for replicas in the thiamine assay.

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