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Effect of microwave cooking on different masses of roast

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전자렌지에 의한 고기 조리시 전자파가 크기가 다른 고기에 미치는 영향

조경희

Abstract

본 실험은 4가지의 다른 무게를 가진 고기(0.1 kg, 0.5 kg, 1 kg, 1.5 kg)를, 3가지의 다른 출력의 전자파(40 %, 60%, 100%)로 조리시 나타나는 조리조건(오븐의 효율성, 대기시간, 대기시 상승온도)과 물리 화학적인 변화(수분, 단백질, 지방, vit B_1의 함량, 콜라겐의 용해도, 보수력, texture)를 관찰하였다. 고기의 무게가 증가할수록 전자렌지의 효율성은 낮아졌으며, 단위 무게당 조리시간은 고기의 무게가 증가할수록 길어졌다. 화학적 성분들에 있어서는 지방과 콜라겐의 용해도를 제외하고는 처리구간에 유의적인 차이를 보이지 않았다. 지방과 콜라겐의 용해도는 전자파의 출력차이에 의한 유의적인 차이는 나타나지 않았으나, 고기 무게가 증가할수록 지방의 함량의 증가와 콜라겐의 용해도는 증가하였다. Texture를 측정한 항목들에 대해서는 고기의 무게에 따른 유의적인 차이는 나타나지 않았으나 전자파의 출력에 의한 차이를 나타내었다.

I. Introduction

There are many studies comparing microwave with conventional cooking. The results from these studies are not consistent. It is not easy to recommend which cooking method is better. Each study used different sizes of meat, different internal temperature, different cooking treatments and different types of microwave ovens. These variations may be the cause of the inconsistent results in the comparisons of microwave and conventional cooking. Especially, Schiffmann[1] emphasized the importance of the load factor in using microwave ovens.

Therefore, the purpose of this study was to investigate 1) any differences in characteristics of different sizes of roasts and different microwave power levels during microwave heating of meat and 2) the relationship of collagen solubilization and textural characteristics because an increment of collagen solubilization was expected as masses of meat were increased, due to longer cooking time.

II. Materials and Methods

1. Microwave oven and load factor test

The microwave oven which was used in this experiment was Amana Radarange Model RS 458P with nominal power of 700 Watts. The size of interior of the oven was 3.6×10^4 cm^3, 39.4 cm(deep)×34.3 cm(wide)× 26.7 cm(high).

Power outputs of the microwave oven at different power levels were measured by the method decribed by Schiffmann[1].

For the load factor test of different meat masses, the oven was prewarmed for 1 min. with 250 ml of water. And four different sizes of meat (0.1 kg, 0.5 kg, 1 kg and 1.5 kg) were heated to an internal temperature of 70℃ including post processing temperature rise (PPTR). Dimensions of meat samples of 0.1 kg, 0.5 kg, 1 kg and 1.5 kg were about 3 cm×3 cm×1.2 cm, 10.5 cm×6.5 cm×9 cm, 16 cm×6 cm×9 cm, 17 cm×9 cm ×10 cm, respectively. Each heating rate was calculated by the increased temperature over heating time. Power output was calculated by the increased temperature over heating time. Power output was calculated by applying the formular P=specific heat of meat×Wt× ΔT/Time, where P=measured power output expressed in watts, specific heat of meat (3.2 KJ/Kg, ℃) was used for calculation, as suggested by Ohlsson[2], Wt= the weight of meat heated, ΔT=the temperature rise of the load and Time=the time heated in sec. The efficiency of the oven was calculated by the power output measured over the nominal power of the oven.

2. Preparation of meat cuts

Nine whole semimembransous beef muscles were purchased from Meat Science Laboratory, University of Illinois, Urbana. All muscles were obtained from USDA Choice Grade carcasses. Muscles were vacuum packed in plastic bags and were frozen in a freezer at −20℃ until needed for testing. All frozen roasts were thawed in a refrigerator at 4℃ for 3 days until an internal temperature of 4℃ was reached before cooking. All visible fat and almost all epimysium was removed. The whole muscle was cut into four different sizes (four −0.1 kg and each 0.5 kg, 1 kg and 1.5 kg).

3. Cooking method

Each roast was cooked by dry heat, using three different power levels in the microwave oven (40%, 60% and 100%) until it reached an internal temperature of 70℃, including PPTR. The roast was turned over in the middle of cooking time. The roast was removed from the oven at lower temperature which was estimated during preliminary test to reach the same final internal temperaure. Internal temperature was measured by a Dickson Temprobe 500. All treatments were replicated three times.

4. Sample preparation for chemical and physical analysis

Raw samples were removed from each end of an individual muscle on the day cooking. After cooking, 2.5 cm thick slices were taken from the cooked roast samples and eight 2.5 cm cores parallel to the muscle fibers were taken from those slices. Four cores were used for shear measurement and four cores were used for compression measurement. Tissue remaining after the removal of the cores for compression measurement were ground and used for chemical determinations.

5. Cooking time, standing time and post-processing temperature rise.

After cooking, the cooking time was calculated per kg without including standing time. Also standing time and post-processing tmeperature rise to get final internal temperature were muasured.

6. Cooking losses

Drip, evaporation and total cooking losses were determined by weighing drippings and all roasts before and after cooking.

7. Moisture, fat and protein determinations

Percent moisture, protein and fat were determined in duplicate in all samples. Percent moisture was determined by loss of weight after samples were dried in an oven at 105℃ for 24 h. Percent fat was determined after extracting from the moisture free samples with repetitive washes of chloroform: methanol(2 : 1) over a 24 h period. Protein content was analyzed by Kjeldahl method[3].

Protein contet were calculated from nitrogen concentration, using a factor of 6.25.

8. Thiamin determination

Thiamin content was determined by a modification of thiochrome assay method[4]. Thiamin content of duplicate samples was calculated in mg per 100 g sample on the moisture and fat free basis. The apparent percent retention of thiamin was calculated by dividing the thiamin content of cooked meat by that of raw meat.

9. Water Holding Capacity

A Carver laboratory press was used to determine the water holding capacity (WHC) based on a method described by Miller and Harrison[5]. WHC was determined in triplicate in all samples. Ground meat samples (300 mg) were placed between plexiglass plates and subjected to 906 kg of hydraulic pressure per 6.4 cm^2 over a 5 min. peiod. Samples were air dried and the areas of the meat and juice were determined using a Hi-Pad digitizer. Water holding capacity was calculated

WHC = (whole juice area − meat area) ÷ whole juice area

10. Instrumental test for textural characteristics

Instrumental tests for textural chatacteristics were done using an Instron Universal testing machine model 1132. Shear measurement was conducted using a Warner Bratzler shear attachment with Instron. A 50 kg load cell was used with cross head and chart speeds of 20 cm/min. Four cores(25 cm diameter) per roast and two shears per core were sheared by cutting across the fibers with a Warner Bratzler shear attachment. Properties of firmness and cohesiveness of shear were measured from the shear deformation curve. For the compression measurement, cores were compressed twice to 75% of their height using a flat plunger 5.7 cm dia. For 100 g samples, four 100 g samples, four 100 g smaples were cooked at each replication to get eight cores for shear and compression measurement. Properties of hardness, springiness and cohesiveness of compression were evaluated from the resulting 2 bite curve.

11. Analysis of percent solubilized collagen

Meat samples were treated by the procedure described by Zayas and Naewbanji[6]. Three grams of round raw meat samples were introduced into 50 ml test tube with teflon coated cap and hydrolyzed by adding 30 ml 6 N HCl. The samples were sealed with teflon tape and hydrolyzed for 12 h at 118℃. Cooked ground samples were homogenized with 50 ml of distilled water by using Virtis 45 homogenizer. The samples were separated into residue and supernatant by centrifugation at 4000 rpm for 10 min. The residue of cooked samples was hydrolyzed by the same method. Hydroxyproline from each hydrolyzate was assayed using the method of Wossener[7]. Collagen content was calculated by multiplying the amount of hydroxyproline by a factor of 7.25. Solubilized collagen content was calculated with total contents of collagen in the total residues of cooked roasts divided by total amounts of collagen in raw samples.

12. Statistical analysis

Data were subjected to analysis of varience using Statview 512+(Brainpower, Inc., Calabases, CA) on the Macintosh computer. When F values were significant

Table 1. Load factor test with meat with including PPTR

Masses (g)	Heating (min.)	ΔT (℃)	Heating rate (℃/sec)	Power output (watts)	Efficiency (%)
	with 100% power				
100	1.34	69.08	0.860	291.17	41.60
500	10.92	66.93	0.102	168.31	24.04
1000	17.34	63.20	0.061	185.42	26.49
1500	34.36	66.56	0.032	148.27	21.18
	with 60% power				
100	2.05	69.83	0.570	192.15	45.75
500	16.29	68.61	0.070	119.75	28.51
1000	31.54	67.85	0.036	118.15	28.13
1500	50.91	64.04	0.021	101.25	24.11
	with 40% power				
100	2.95	66.86	0.378	123.58	44.14
500	20.01	67.49	0.056	93.74	33.48
1000	39.26	66.00	0.028	83.66	29.88
1500	65.40	67.68	0.017	79.07	28.24

Table 2. Load factor test with meat without including PPTR

Masses (g)	Heating (min.)	ΔT (℃)	Heating rate (℃/sec)	Power output (watts)	Efficiency (%)
	with 100% power				
100	1.34	57.40	0.710	240.69	34.37
500	10.92	51.25	0.078	128.52	18.36
1000	17.34	51.26	0.049	148.94	21.28
1500	34.36	50.70	0.025	112.94	16.13
	with 60% power				
100	2.05	63.67	0.520	175.20	41.72
500	16.29	57.23	0.058	99.74	23.75
1000	31.54	56.65	0.030	98.25	23.39
1500	50.91	51.44	0.017	81.19	19.33
	with 40% power				
100	2.95	59.98	0.340	110.87	39.60
500	20.01	58.71	0.049	81.57	29.13
1000	39.26	56.86	0.024	72.08	25.74
1500	65.40	60.40	0.015	70.56	25.20

($p<0.05$), mean separation was determined Fisher PLSD at the 5% level.

III. Results and Discussion

1. Load factor test with different meat masses

The results of load fator test of different meat masses are shown in Table 1 and the results of load factor test of meat which was calculated without including PPTR are shown in Table 2. Heating rates were decreased with increasing load of meat. However, power output and efficiency of the oven were decreased with increasing load of meat. Some articles[2,8] showed the efficiency of the oven is increased as food items are bigger. But they did not mention what the food item was. The efficiency at the 40% power level was higher than at higher power levels. The power output of the microwave oven was measured based on specific heat of food items. The power output would vary for different food items because of the differences in specific heat of foods. These factors should be considered for microwave cooking to get desirable final products. Power output and efficiency of the oven when PPTR was excluded were lower than those when PPTR was included. When power output and efficiency of the oven is calculated, it should be considered that PPTR is included or excluded.

2. Cooking time, standing time and PPTR

Final internal temperature, cooking time, standing time and PPTR of meat are shown in Table 3. The final internal temperature was reached after standing time. The goal was to cook all roasts to 70℃. Cooking time was calculated as min. per kg without including standing time. There were significant differences in cooking times among different power levels. As expected, cooking time for full power level was shorter than that for reduced power. For the 40% power level, the cooking time was significantly different among four different sizes of meat. This suggests that when reduced power is used, the cooking time should be considered carefully, depending on the sizes of meat so as not to overcook. As sizes of roast were increased, the cooking times were increased. It took longer for a larger mass of meat to heat to a given temperature. Most recipes presenting the cooking time for roasting mention the time per unit of weight. If cooking time for roasting beef is affected by load, more careful recom-

Table 3. Final internal temperature, cooking time, standing time and PPTR of different sizes of meat masses at three different microwave power levels

Characteristics		40% power	60% power	100% power	SF
Final internal Temp (℃)	100 g	70.86± 0.44	73.83± 1.59	73.08α	ns
	500 g	71.49± 1.13	72.61± 1.31	70.93± 1.59	ns
	1000 g	70.00± 0.32	71.85± 2.20	67.20± 0.65	ns
	1500 g	71.68± 2.53	68.04± 2.51	70.56± 2.63	ns
	SF	ns	ns	ns	
Cooking Time (min./kg)	100 g	28.90± 0.11aA	19.38± 0.02bA	13.22αc	*
	500 g	38.38± 0.02aB	30.44± 1.13bB	21.20± 2.72c	*
	1000 g	42.07± 0.70aC	30.75± 0.87bB	18.75± 0.42c	*
	1500 g	45.65± 2.13aC	33.79± 3.85bB	23.94± 0.78c	*
	SF	*	*	ns	
Standing time (min.)	100 g	1.51± 0.25A	1.72± 1.05A	2.50α	ns
	500 g	9.67± 1.20AB	7.00± 0.58AB	14.33± 4.84	ns
	1000 g	11.67± 0.88B	11.67± 2.40B	15.33± 2.33	ns
	1500 g	12.67± 5.21B	17.50± 4.41B	16.00± 2.52	ns
	SF	*	*	ns	
PPTR (℃)	100 g	6.88± 0.58	6.16± 3.54	11.48α	ns
	500 g	8.78± 0.67a	11.38± 1.46a	15.68± 1.68b	*
	1000 g	9.14± 0.49	11.20± 2.96	11.94± 0.37	ns
	1500 g	7.28± 2.26a	12.60± 0.28a	15.86± 1.31b	*
	SF	ns	ns	ns	

SF: Significance of F value, *: significant at 0.05 level, ns: not significant. α: This figure represents only one replication. Small letters show significant differences by different power levels. Capital letters show significant differences by different meat masses.

mendation of cooking time is required.

Standing time, which is the time between removal of the food from the oven until it finishes cooking, did not differ significantly among three different power levels. However, there were significant differences in standing time due to different meat masses except at 100% power levels. When total cooking time is considered as the cooking time plus standing time, for the larger sizes, longer cooking time (min./kg) required.

There were some differences in PPTR among microwave power levels. The higher power level was used, PPTR was higher. Kylen *et al.*[9] reported cooking time of 34.6 min./kg and 20± 0.5 min. of standing time for roasts weighing 1.5 kg and 10.5℃ of PPTR to reach an internal temperature of 74.4℃. Korschgen *et al.*[10] reported 13± 1 min./kg of cooking time, 53± 11 min of total preparation time and 25℃ of PPTR of roasts of 1 kg cooked with 1054 watts of microwave power and 26± 3 min./kg of cooking time and 54± 4 min./kg of total cooking time and 15℃ of PPTR of roasta of 1 kg cooked with 492 watts of microwave power. Starrak[11] suggested that the cooking time of beef top round roast at 650 watts is 19.87 min./kg and at 325 watts is 26.49 min./kg and at 200 watts is 44.15 min./kg to reach an internal temperature of 64℃. She also mentioned that PPTR depends upon the power at which the meat was cooked. She showed, in general, roasts rose 8.3 to 11.1 ℃ when cooked on high; about 5.6℃ on medium and 2.8℃ on low power setting. In this study, no significant difference was seen among power levels, even though there was a trend of increasing PPTR as power increased.

3. Cooking losses

Table 4 shows total losses, drip losses and evaporation losses of roasts. There were no differences in total losses of four different meat masses cooked with three different power levels. This result is consistent with Korschgen *et al.*[10] and Drew *et al.*[12] who compared different microwave power levels. However, Starrak[11] showed significant differences in total losses among three different microwave power levels. Ream *et al.*[13] showed significant differences in cooking losses on two different sizes of roast, showing the decreased cooking losses by increasing sizes of roast.

There were no significant differences in drip and evaporation losses with the three microwave power levels except the drip losses in roasts weighing 1.5 kg. The drip losses of roast of 1.5 kg decreased when power level was increased, as shown by Korschgen *et al*[10]. This is probably due to the browned surface of roast caused by longer cooking time preventing further drip losses. The results showed significant differences in drip losses and evaporation losses by different sizes. In general drip losses were decreased with larger sizes of meat, evaporation losses were increased with increasing meat masses, because of evaporation and/or spattering of drippings during the longer cooking time.

Table 4. Total losses, Drip losses and Evaporation losses of four different sizes of meat masses at three different microwave power levels

Characteristics		40% power	60% power	100% power	SF
Total losses (%)	100 g	30.66± 1.32	28.47± 0.35	26.9$^{\alpha}$	ns
	500 g	30.67± 0.25	35.16± 0.98	35.57± 1.51	ns
	1000 g	32.93± 0.85	34.10± 2.21	34.12± 2.37	ns
	1500 g	33.21± 2.08	33.39± 0.77	34.06± 1.60	ns
	SF	ns	ns	ns	
Dirp losses (%)	100 g	18.81± 0.09A	17.89± 0.80A	16.60$^{\alpha}$	ns
	500 g	12.03± 0.82B	13.80± 0.74B	11.75± 2.82A	ns
	1000 g	11.92± 1.91B	12.66± 0.84B	11.37± 1.71A	ns
	1500 g	10.21± 2.09aB	8.64± 0.40abC	5.77± 0.54bB	*
	SF	*	*	*	
Evaporation losses (%)	100 g	11.86± 1.23A	10.58± 0.46A	10.43$^{\alpha}$	ns
	500 g	18.64± 0.61B	21.36± 0.91B	23.84± 4.35A	ns
	1000 g	21.01± 0.31C	21.44± 1.31B	22.42± 0.39A	ns
	1500 g	22.99± 1.00C	21.61± 1.15B	28.29± 1.93B	ns
	SF	*	*	*	

SF: Significance of F value, *: significant at 0.05 level, ns: not significant. α: This figure represents only one replication. Small letters show significant differences by different power levels. Capital letters show significant differences by different meat masses.

4. Moisture, protein, fat and water holding capacity

Moisture, protein, fat and water holding capacity are presented in Table 5. There were no differences in moisture contents and protein content among three microwave power levels and four different sizes. Fat content had some difference by power level and by meat masses. The results showed a significant increment in fat content by meat masses can be caused by sampling in which larger roasts have more intermuscular fat. The difference of fat content by different power levels is probably due to the difference of fat content of raw samples. Kylen *et al.*[9] showed that the percentage of moisture was significant lower in electronic than in conventionally cooked product and fat content was the same after both methods of cooking. Korschgen and Baldwin[14] and Voris and Van Duyne[15] reported similar moisture, protein and fat contents of meat cooked by microwaves and conventionally.

There was no difference in water holding capacity by different power levels and meat masses. Ream *et al.*[13], Hawrysh *et al.*[16] and Moore *et al.*[17] compared the water holding capacity of microwave cooked meat with conventionally cooked meat. They showed no significant difference in water holding capacity between two cooking methods.

5. Thiamin content and thiamin retention

Table 6 shows thiamin content and retention of thiamin of the meat samples. Thiamin content and retention of meat samples did not show significant differences by the sizes of meat and the microwave power levels. Thomas *et al.*[18] reported less retention of thiamin in beef roasts cooked in an electronic range (63%) than in those cooked in a conventional oven (75%). Dawson *et al.*[19] reported that the thiamin retention of top rounds of beef conventionally brasied was 31% to 69%. Kylen *et al*[9] showed significant differences in mean percent retention of thiamin in meat cooked by two different cooking method. Microwave cooked meat retained 58~67% and conventionally cooked meat retained 80~86% of thiamin. Korschgen *et al.*[10] reported no differences in thiamin losses on two different microwave power levels but Korschgen and Baldwin[14]

Table 5. Moisture, protein, fat and water holding capacity (WHC) of four different sizes of meat masses at three different microwave power levels

Characteristics		40% power	60% power	100% power	SF
Moisture (%)	raw	74.24± 0.07	74.92± 0.37	73.40± 0.68	ns
	100 g	62.73± 0.47	64.01± 0.22	64.90$^{\alpha}$	ns
	500 g	63.73± 0.24	63.11± 0.95	63.91± 1.14	ns
	1000 g	61.83± 0.04	62.44± 1.05	63.07± 0.87	ns
	1500 g	62.63± 0.47	62.84± 0.78	62.34± 1.99	ns
	SF	ns	ns	ns	
Protein (%)	raw	23.66± 0.31	23.49± 0.66	22.67± 1.61	ns
	100 g	34.44± 0.91	33.26± 0.36	33.84$^{\alpha}$	ns
	500 g	35.46± 0.56	33.87± 1.53	33.08± 1.68	ns
	1000 g	34.97± 1.41	32.67± 1.81	31.85± 0.75	ns
	1500 g	32.30± 1.05	33.84± 1.47	33.27± 1.25	ns
	SF	ns	ns	ns	
Fat (%)	raw	1.82± 0.26	1.57± 0.36	2.04± 0.38	ns
	100 g	3.74± 0.03A	2.25± 0.11A	2.32$^{\alpha}$A	ns
	500 g	3.11± 0.26bAB	1.86± 0.12aA	3.37± 0.79bA	*
	1000 g	4.60± 0.63BC	3.50± 0.49B	4.22± 0.94B	ns
	1500 g	5.43± 0.55bC	3.62± 0.86aB	5.88± 0.88bB	*
	SF	*	*	*	
WHC	100 g	0.77± 0.01	0.78± 0.01	0.79$^{\alpha}$	ns
	500 g	0.74± 0.02	0.78± 0.01	0.76± 0.00	ns
	1000 g	0.75± 0.00	0.75± 0.00	0.75± 0.00	ns
	1500 g	0.76± 0.00	0.75± 0.01	0.75± 0.01	ns
	SF	ns	ns	ns	

SF: Significance of F value, *: significant at 0.05 level, ns: not significant. α: This figure represents only one replication. Small letters show significant differences by different power levels. Capital letters show significant differences by different meat masses.

Table 6. Thiamin content and thiamin retention of four different sizes of meat masses at three different microwave power levels

Characteristics		40% power	60% power	100% power	SF
	raw	0.150± 0.001	0.151± 0.001	0.143± 0.003	ns
Thiamin[a]	100 g	0.144± 0.005	0.144± 0.005	0.119[α]	ns
(mg/100 g)	500 g	0.137± 0.005	0.132± 0.007	0.117± 0.007	ns
	1000 g	0.131± 0.006	0.129± 0.008	0.120± 0.003	ns
	1500 g	0.129± 0.006	0.131± 0.001	0.122± 0.003	ns
	SF	ns	ns	ns	
	raw	0.628± 0.007	0.653± 0.040	0.583± 0.031	ns
Thiamin[b]	100 g	0.428± 0.010	0.427± 0.019	0.363[α]	ns
(mg/100 g)	500 g	0.412± 0.015	0.379± 0.031	0.362± 0.046	ns
	1000 g	0.392± 0.022	0.379± 0.012	0.367± 0.010	ns
	1500 g	0.405± 0.020	0.391± 0.013	0.386± 0.020	ns
	SF	ns	ns	ns	
Thiamin	100 g	68.86± 1.78	61.74± 4.04	62.37[α]	ns
Retention	500 g	65.58± 1.71	58.26± 5.00	61.76± 5.02	ns
(%)	1000 g	62.27± 2.78	58.31± 3.26	63.42± 4.86	ns
	1500 g	64.48± 2.87	60.45± 4.93	66.34± 1.49	ns
	SF	ns	ns	ns	

[a]: Wet basis. [b]: Moisture and Fat free basis SF: Significance of F value at 0.05 level, ns: not significant. α: This figure represents only one replication.

Table 7. Shear and Compression measurement of different sizes of meat masses at three different microwave power levels

Characteristics		40% power	60% power	100% power	SF
Shear	100 g	9.86± 1.18ab	11.06± 0.26bBC	8.35[α]a	*
Cohesiveness	500 g	9.65± 0.79a	14.87± 3.07bC	7.70± 0.67a	*
(kg)	1000 g	11.05± 0.81a	8.48± 0.93bA	8.59± 0.36a	ns
	1500 g	9.94± 1.28ab	10.74± 1.42bAB	8.11± 0.78a	*
	SF	ns	*	ns	
Shear	100 g	72.15± 11.24ab	83.25± 7.78aA	54.21[α]b	*
Firmness	500 g	86.26± 13.45b	129.36± 27.61abB	66.11± 10.68a	*
(kg/min.)	1000 g	90.38+13.78b	78.91± 6.47abA	69.66± 8.09a	ns
	1500 g	84.03± 6.39ab	101.06± 13.44bA	68.89± 9.55a	*
	SF	ns	*	ns	
Compression	100 g	44.83	ND	ND	
Hardness	500 g	33.93± 5.48a	30.36± 2.38ab	29.13± 2.65b	*
(kg)	1000 g	36.05± 2.39b	36.50± 3.63ab	32.16± 2.70a	*
	1500 g	37.67± 3.97a	36.23± 3.28ab	30.79± 3.09b	*
	SF	ns	ns	ns	
Compression	100 g	0.033	ND	ND	
Springiness	500 g	0.028± 0.004a	0.027± 0.001a	0.037± 0.001b	*
(min./cm)	1000 g	0.027± 0.001a	0.032± 0.001b	0.033± 0.001b	*
	1500 g	0.029± 0.001a	0.032± 0.005ab	0.036± 0.001b	*
	SF	ns	ns	ns	
Compression	100 g	0.39	ND	ND	
Cohesivenss	500 g	0.37± 0.076	0.44± 0.065	0.34± 0.056	ns
	1000 g	0.39+0.038	0.35± 0.026	0.43± 0.035	ns
	1500 g	0.34± 0.023	0.33± 0.029	0.37± 0.066	ns
	SF	ns	ns	ns	

SF: Significance of F value, *: significant at 0.05 level, ns: not significant. α: This figure represents only one replication. ND: not determined. Small letters show significant differences by different power levels. Capital letters show significant differences by different meat masses.

showed significant differences in the retention of thiamin of meats cooked by microwaves and conventionally when they cooked the roasts to an internal temperature of 98℃. They showed that the thiamin retention of microwave cooked meat was higher (25% vs 19%) than that of meat cooked conventionally. Their explanation was that since there was longer heating and more browning of the conventional oven, there was more destruction of thiamin. Voris and Van duyne[15] showed no significant differences in thiamin retention due to cooking methods. It seems that the destruction of thiamin is not related to heating rates by the result of this experiment.

6. Shear and compression measurement

Table 7 shows the shear and compression measurement of different sizes of meat masses at three different microwave power levels. Shear cohesiveness, which is called "shear values" in most reports, showed some inconsistent trend among three different power levels. Shear cohesiveness and firmness values of meat cooked at full power are low and 60% power showed highest for all meat masses. There were no differences in shear cohesiveness due to mass differences except at 60% power. Voris and Van Duyne[15], Fulton and Davis[20] and Howat *et al.*[21] showed no differences in peak shear force in meat with two different methods of cooking. Korschgen *et al.*[10] and Drew *et al.*[12], who used different power levels, did not show any dignificant differences in shear values. Only Korschgen and Baldwin[14] and Hawrysh *et al.*[16] showed significant differences in shear values of roasts cooked with microwaves and conventional cooking method. Shear firmness showed the same trend as shear coheisveness.

There were significant differences in compression hardness and springiness at the different power levels. The values of compression hardness of roast cooked at full power level were lower than those of reduced power levels and the values of compression springiness of roast cooked at full power level were higher than those of reduced power levels. The values of compression cohesiveness by the diffferent power levels and by different masses were not significantly different. There was no reference showing compression values of microwave cooked meat. Lower values of shear cohesiveness and compression hardness of meat cooked with 100% microwave power level than with lower power levels might be caused by the effect of intense microwaves on meat, giving more structural damage in muscle and collagen fibers.

7. Percent solubilized collagen

Table 8 shows the percentage of solubilized collagen of different meat masses cooked with three different

Table 8. Percentage of solubilized collagen of four different meat masses cooked with three different microwave power levels

Treatment	40% power	60% power	100% power	SF
100 g	14.02± 4.43a	ND	16.43$^{\alpha}$	ns
500 g	16.44± 2.35ab	ND	10.48± 0.35a	ns
1000 g	17.73± 1.84ab	18.79± 2.48	24.86± 1.15b	ns
1500 g	27.12± 13.59b	24.59± 1.88	26.85± 0.89b	ns
SF	*	ns	*	

SF: Significance of F value, *: significant at 0.05 level, ns: not significant. α: This figure represents only one replication. Small letters show significant differences by different power levels.

Table 9. Correlation of collagen solubility and Instron measurement of different meat masses cooked with three different microwave power levels

masses	power	SC	SF	CH	CS	CC
1 g	40%	0.948	-0.972	-0.911	0.998	0.195
	60%	0.480	0.906	0.063	-0.746	0.992
	100%	-	-	-	-	-
1.5 kg	40%	-0.401	-0.165	0.594	0.483	0.646
	60%	-0.054	-0.074	0.127	0.379	0.379
	100%	-0.406	-0.352	-0.033	-0.567	-0.751

SC: Shear cohesiveness. SF: Shear firmness. CH: Compression hardness. CS: Compression springiness. CC: Compression cohesiveness.

microwave power levels. Percentage of collagen solubility showed great variation among replications and no significant difference was seen among different power levels. However, there was an increasing trend in collagen solubility as meat mass increases. The correlation coefficients between collagen solubility and Instron measurement are shown in Table 9. There was no correlation between Instron tenderness measurements and collagen solublity.

IV. Conclusion

1. Time is the most important factor to cook foods in a microwave oven. The cooking time by using a microwave oven is depend on several factors such as specific heat of food, size of food, power output of a microwave oven, etc. By the result of load factor test of this experiment, cooking time of meat calculated as per unit weight should not be applied uniformly to any sizes of meat.

2. Because of the characteristics of rapid heat transfer of microwaves, standing time and post processing temperature rise should be carefully considered to determine the cooking time. There were significant differences in cooking time and post processing temperature rise among the three different microwave power levels (40, 60, 100%).

3. There were no significant differences in total losses of cooking among treatments. However, as sizes of meat masses were increased, drip losses of cooking were decresed and evaporation loses of cooking were increase.

4. There were no significant differences in moisture, protein, water holding capacity and thiamine content and retention among treatments. The difference of fat content by increasing the meat masses was considered to be caused by sampling in which larger roasts have more intermuscular fat.

5. For the measurement of texture, shear cohesiveness, shear firmness, compression hardness, compression springiness and compression cohesiveness were measured. Also, collagen solubility was measured and the relationship between instron measurements and collagen solubility was investigated. Significant differences of instron measurents of meat were among three different microwave power levles. Significant differences for the collagen solubility were among different sizes of meat masses (0.1 kg, 0.5 kg, 1 kg, 1 kg), not among different microwave power levels (40,60,100%). Collagen solubility was affected by the time of cooking rather than by the microwave power level.

References

1. Schiffmann, R.F. Performance testing of products in microwave ovens. Microwave World. 8(1): 7 (1987).
2. Ohlsson, T. Fundamentals of microwave cooking. Microwave World. 4(2): 4 (1983).
3. Meloan, C.E. and Pomeranz, Y. "Food Analysis Laboratory Experiments." p. 102. The AVI Publishing Co. Westport, CT. (1973).
4. Ellefson, W.C. Thiamin. In "Methods of Vitamin Assay", 4th ed. Edited by Augustin, J., Klein, B.P., Becker, D. and Venugopal, P.B. John Wiley and Sons. P. 349 (1984).
5. Miller, E. M. and Harrison, D. L. Effect of marination in sodium hexameta phosphate solution on the palatability of loin steaks. Food Technology. 19: 94 (1965).
6. Zayas, J.F. and Naewbanij, J.O. The influence of microwave heating on the textural properties of meat and collagen solubilization. J. Food Processing and Preservation. 10: 203 (1986).
7. Woessener, J.F. The determination of hydroxyproline in tissue and protein samples containing small proportions of this imino acid. Archives of Biochemistry and biophysics. 93: 440 (1961).
8. Schiffmann, R.F. Basic principles of microwaves. In "Microwave ovens and frozen foods make cents" Ed. R.V. Decareau. Transactions of the international microwave power institute. 5: 20. International Microwave Power Institute, Edmonton, Alberta, Canada (1975).
9. Kylen, A.M., McGrath, B.H., Hallmark, E.L. and Van Duyne, F.O. Microwave and conventional cooking of meat. J. American Dietic Association 45: 139 (1964).
10. Korschgen, B.M. and Baldwin, R.E. and Snider, S. Quality factors in beef, pork, and lamb cooked by microwaves. *J. American Dietetic Association* 69: 635 (1976).
11. Starrak, G. New approaches and methods for microwave cooking of meat. Proceedings of the 35th Reciprocal Meat Conference. 35: 86 (1982).
12. Drew, F., Rhee, K.S. and Carpenter, Z.L. Cooking at variable microwave power levels. J. American Dietetic Association 77: 455 (1980).
13. Reem, E.E., Wilcox, E.B., Taylor, F.G. and Bennett, J.A. Tenderness of beef roasts. J. American Dietetic Association 65: 155 (1974).
14. Korschgen, B.M. and Baldwin, R.E. Moist-heat microwave and conventional cooking of round roasts of beef. J. Microwave Power 13(3): 257 (1978).
15. Voris, H. H. and Van duyne, F.O. Low wattage microwave cooking of top round roasts: energy consumption, thiamin content and palatability. J. Food Science. 44: 1447 (1979).
16. Hawrysh, Z.J., Price, M.A. and Berg R.T. The effect of conventional and microwave cooking on the eating quality of beef from bulls of three differing breed-types. J. Inst. Can. Sci. Technol. Aliment. 12: 78 (1979).
17. Moore, L.J., Harrison, D.L. and Dayton, A.D. Differen-

ces among top round steaks cooked by dry or moist heat in a conventional or a microwave oven. J. Food Science. 45: 777 (1980).
18. Thomas, M.H., Brenner, S., Eaton, A. and Craig, V. Effect of electronic cooking on nutritive value of foods. J. American Dietetic Association 25: 39 (1949).
19. Dawson, E.H., Linton, G.S., Harkin, A.M. and Miller, C. Factors influencing the palatability, vitamin content, and yield of cooked beef. Home Economics Research Report No. 9, U.S. Department of Agriculture, Washington, DC. USDA Home Econ. Res. Rep. No. 9, p. 27-33 (1959).
20. Fulton, L. and Davis, C. Roasting and braising beef roasts in microwave ovens. J. American Dietetic Association 83: 560 (1983).
21. Howat, P.M., Gros, J.N., McMillin, K.W., Saxton, A.M. and Hoskins, F. A comparison of beef blade roasts cooked by microwave, microwave-convection and convetional oven. *J. Microwave Power.* 22: 95 (1987).