Microwave Cooking and Meat Microbiology

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Introduction

Microwave cooking is now a common practice in homes, and institutional feeding programs as well as in government and private organizations. A symposium on the practical application of microwave energy held at Kansas State University in September, 1979, dealt with the principles of microwave radiation, biological hazards of microwave irradiation, design and use of domestic microwave ovens, effects of microwave on food quality attributes, microwave and bread making and nutritive values, effects of microwave on microorganisms in foods, moisture measurements by microwave and sanitizing textiles by microwaves. The proceeding of this symposium was published in the 1980 August issue (Vol 43) of the *Journal of Food Protection* (P.O. Box 701, Ames, Iowa). Recently Cross and Fung (1982a and 1982b) reviewed the effects of microwave cooking on nutrient values in foods and concluded that no significant nutrient differences exist between food prepared by conventional and microwave methods. Any differences reported in the literature are minimal.

Since the time to process food by microwaves is much shorter than that with conventional methods, questions have been raised as to the microbial safety of foods cooked with microwaves. Fung and Cunningham (1980) reviewed the existing literature on the effect of microwaves on microorganisms in foods and concluded that a) microwave heating of food is more "food dependent" than conventional heating, b) the manufacturer-recommended microwave treatment time for some foods may not destroy high levels of bacteria, c) use of microwaves in combination with other conventional heating methods results in more uniform heating in foods and destruction of bacteria, d) heat generated by microwaves kills naturally-occurring microorganisms as long as the size and type of food are carefully correlated with exposure time, e) microwaves exert different killing effects on individual bacterial species and f) the question of thermal versus nonthermal effects of microwaves on microorganisms has not been settled. They believe microwave heating is an important method for processing of foods at home, in institutions and in commercial operations. Microwave heating is acceptable from the standpoint of food spoilage and food safety as long as the users understand its limitations and possibilities and are aware of the major points described above.

This paper is a review on the effect of microwave irradiation on the destruction of microorganisms in meat and meat products. The main points covered include influence of exposure time and temperature, moisture, bacterial species, and survival of microorganisms in meat and meat products. Some preliminary data on effect of low doses of microwave on shelf-life of hot-boned and conventionally processed meat were also presented.

Influence of Time and Temperature

One of the most distinctive characteristics of microwave cooking is speed: foods are cooked in seconds and minutes versus minutes and hours compared with conventional cooking. For example in heating the same volume of tomato soup from a starting temperature of 75°F, it took 20 sec to reach 100°F and 100 sec to reach 150°F in microwave oven whereas it took 3 min to reach 100°F and 6 min to reach 150°F for the conventional method. In the same study it took 100 sec to reduce 3 Log units of *Escherichia coli* in tomato soup (from Log 6/ml to Log 3/ml) by microwave and 10 minutes to achieve the same level of destruction by conventional method.

An excellent review on microwave versus conventional cooking methods in relation to effects on food quality attributes was made by Harrison (1980). In the article the author discussed the major factors affecting microwave heating of food: Initial temperature, density and homogeneity, shape, quantity of food, post-oven temperature rises, utensils and distribution of energy in the oven. Particularly stressed was the effect of microwave energy on quality attributes of cooked meat and the author concluded that "early research indicated that generally meat cooked by microwaves was rated lower in eating quality than meat cooked by conventional methods. Recent studies with meat that were designed for a volume heating process indicate that microwave cookery of meat has potential in the home and as a research tool."

Much of the research data on time-temperature relation and microbial destruction in microwave cooking were conducted without direct temperature measuring devices. This was because microwaves affect conventional temperature measuring devices making direct temperature measurement in the microwave oven impossible. Recent introduction of microwave-proof temperature measurement devices opens a new area of research for food microbiologists. To date, no comprehensive study on microbial destruction by microwaves

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using microwave-proof temperature measurement devices to monitor time-temperature relation has been reported.

Moisture

Water in biological materials, such as meat, is primarily responsible for heat generation in a microwave field. In a 2450 MH_z microwave oven, water molecules tend to oscillate 2450 million times per sec in the presence of microwave, thereby generating heat through friction. Thus, the amount of water in a sample has direct influence on the ability of microwaves to heat the sample. A sample with high moisture content will heat much faster than a dry sample. This fact also influences destruction of microorganisms in foods. Microorganisms will be destroyed by microwaves in a moist state but will not be destroyed in a dry state. A number of studies on effects of microwaves on microorganisms in the presence and absence of water have been made: Grecz et al. (1964) on *Clostridium sporogenes;* Delaney et al. (1968) on *Aspergillus niger* and *Bacillus stearothermophilus;* Dreyfuss (1978) on *Escherichia coli*, *Staphylococcus aureus*, *Salmonella enteriditis* and *Bacillus cereus*; Page and Martin (1978) on *E. coli*, *S. aureus* and *B. subtilis*; Roberts (1972) on yeast cells, and Vela et al. (1976) and Vela and Wu (1979) on soil microorganisms. The conclusion was that, in the presence of water, microwaves effectively destroy microorganisms whereas, in the absence of water, very little or no destruction of microorganisms occurs.

Bacterial Species

Meat and meat products harbor large and diversified population of bacteria and other microbes. To date no study has been made on the effect of microwaves on destruction of major species isolated from meat. Fung and Cunningham (1980) reported that there is a difference in survival ability of bacterial species after microwave treatments. After subjecting test cultures to 2 minutes of microwave exposure they reported the % survival of bacteria as follows: *Streptococcus faecalis* (7.9), *Escherichia coli* (0.93), *Salmonella typhimurium* (0.87), *Staphylococcus aureus* (0.46), *Pseudomonas fluorescens* (0.41), *Alcaligenes viscolactis* (0.070), *Salmonella pullorum* (0.046), *Micrococcus rhodochrous* (0.036), *Shigella flexneri* (0.029), and *Proteus vulgaris* (0.018). *Streptococcus faecalis* is notably resistant to microwave treatment. As this organism is commonly found in vacuum packaged meat, more research should be directed to elucidate the mechanism of resistance to microwave irradiation.

Effect of Microwave on Meat Microbiology

Fung and Cunningham (1980) made a detailed review of effects of microwaves on microorganisms in foods. A literature review was made concerning destruction of microorganisms by microwaves in meat and meat products, poultry and egg products, dairy products, cereal products, fruit products, vegetables, and miscellaneous foods. Table 1 is an up-date of the information concerning effects of microwaves on specific groups of microorganisms in various types of meat products. The data were arranged chronologically according to date of publication. Most researchers studied effect of microwaves on aerobic counts in meat. A number of reports were made on *Escherichia coli* and *Streptococcus faecalis*. The general conclusion indicated that when meat products were properly exposed to microwave treatments, microorganisms will be reduced to a safe level. Important considerations include the initial temperature of the product, final internal temperatures and effects of combinations of microwave and conventional cooking on destruction of microorganisms in foods.

Fung and Cunningham (1980) reported complete destruction of *Escherichia coli* in hot dogs, hamburger and fish fillets by microwave alone or in combination with conventional cooking. Conventional broiling, broiling plus microwave and microwave alone cooking of fish fillets reduced bacterial count to non-detectable level. For hot dogs, conventional boiling and microwave treatment plus wrapping reduced bacterial counts to nondetectable levels. However, conventional frying and microwave treatment alone did not destroy all organisms. For hamburger, conventional frying and microwave plus broiling destroyed all bacteria while microwave treatment alone did not. It was interesting to note that there was more destruction of cells in the center of the hamburger compared to the surface and edge of the hamburger. This is because the center of food becomes hotter than the surface in a microwave field. Air around the surface acts as a "heat sink" during microwave irradiation.

Effect of Low Doses of Microwave on Meat Microbiology

We made a pilot study on effects of low doses of microwave on hot-boned and conventionally processed vacuum packaged beef before and after cold storage, and display to ascertain the possible benefit of microwave treatment to prolong shelf life of these products. The purpose was to irradiate meat cuts to reduce microorganisms but without overheating or visibly denaturing the surface of fresh beef samples.

Meat cuts were processed according to procedures described by Fung et al. (1980 and 1981). After vacuum packaging, meat cuts were irradiated in microwave oven for 0, 5, 10, 13, and 20 sec. Microbial counts were taken and meat cuts were re-vacuum packaged and stored at 2°C for 14 days. After storage, microbial counts were made and odor of the beef was scored on a 3 point scale (1 = acceptable, 2 = barely acceptable, and 3 = unacceptable). The meat was then repackaged with polyvinylchloride film and displaced under light for 3 or 5 days. Final microbial counts and odor scores were then obtained.

Table 2 shows the results of a preliminary study. For both hot-boned and conventionally processed beef, the irradiated samples had lower bacterial counts and more favorable odor scores at all evaluation times. The conventionally processed beef also had lower counts and better scores than the hot-boned cuts. The preliminary study of hot-boned beef did not put into consideration the effect of chilling rates; thus the relatively poorer quality of hot-boned beef compared with the conventionally processed beef. In later studies, when the chilling rates were properly applied there were no great differences between the two types of meat. Table 3 shows the odor scores of three experiments after meat cuts were exposed to low doses of irradiation. The general trend indicated that irradiated meat had better odor score compared to non-

Table 1

Meat products subjected to microwave cooking and microbial analysis

Meat Products	Aerobic counts	Anaerobic counts	*Bacillus subtilis*	*Clostridium perfringens*	*Lactobacillus* sp.	*Staphylococcus aureus*	*Streptococcus faecalis*	*Escherichia coli*	*Leuconostoc mesenteroides*	*Pseudomonas*	*Salmonella sanftenberg*	*Salmonella typhosa*	Yeast	Authors
Meat balls	X													Causey and Fenton (1951)
Ham patties	X													Causey and Fenton (1951)
Ground beef patties	X											X		Dessel et al (1960)
Ham pie	X							X						Strong and Boeck (1961)
Raw horse meat	X	X	X	X		X					X			White and Hobbs (1963)
Sausage	X		X								X			White and Hobbs (1963)
Stew			X					X						White and Hobbs (1963)
Hamburger	X													White and Hobbs (1963)
Wieners	X				X		X	X					X	Watanabe and Tapen (1969)
Ham	X													Bengtsson et al (1970)
Meat balls	X						X	X						Madson et al (1971)
Ham pie	X						X	X						Madson et al (1971)
Roast beef	X						X	X						Madson et al (1971)
Ham	X													Ayaub et al (1974)
Pork			X						X	X				Ockerman et al (1976 and 1977)
Ground beef	X													Crespo and Ockerman (1977)
Meat tissue					X		X			X				Crespo et al (1977)
Beef soy loaf	X					X								Bunch et al (1977)
Beef loaf	X					X								Dahl et al (1980a and 1980b)
Hamburger	X													Fung and Cunningham (1980)
Hot dogs	X													Fung and Cunningham (1980)

irradiated meat and that hot-boned and conventionally processed beef had relatively close scores. These data were taken when hot-boned beef was chilled properly, according to the criteria of Fung et al. (1981). Bacterial counts (data not shown) also indicated a decline in counts after microwave irradiation.

The conclusion of this pilot study is that low doses (up to 13 sec) of microwave treatment seem to produce hot-boned and conventionally processed beef that may have longer shelf life than the non-irradiated controls. More data are needed before a firm claim can be made.

In conclusion, this paper is addressed to some of the more important issues concerning microwave cooking and microbiology of meats. There is a definite lag of research in relationship to the rapid advancement in microwave oven technology. We challenge meat microbiologists to spend more effort in research on microwave cooking and meat microbiology.

Table 2

Effect of low doses of microwaves on microbial counts and odor score of hot-boned and conventionally processed beef

Seconds of microwave irradiation	*Hot-boned beef Log CFU[a]/cm² Tape count*				*Conventional processed beef Log CFU[a]/cm² Tape count[b]*			
	pre-storage	post-storage[c]	3-day[d] display	score[e]	pre-storage	post-storage[c]	3-day display	score[e]
No irradiation	0.20	2.10	2.18	2.7	0.18	1.22	1.54	1
5 sec	0.60	1.72	1.90	1.3	0.16	0.89	1.13	1
10 sec	0.08	1.45	1.77	1.0	0.55	0.61	0.89	1
13 sec	−1.99	0.87	1.23	1.7	0.58	0.86	1.11	1
20 sec	product surface-cooked appearance				product surface-cooked appearance			

[a]Average of 3 meat samples per sampling time and treatment.
[b]Tape count = viable cell counts by the tape method of Fung et al. (1980).
[c]Post-storage = 14 day vacuum storage at 2°C.
[d]3-day display — meat cuts repacked in polyvinylchloride film and displayed under display lighting at 4°C for 3 days.
[e]Odor score = 1:acceptable, 2:barely acceptable, 3:unacceptable.

Table 3

Odor scores of three sets of data on low dose microwave treated hot-boned and conventionally processed beef after storage and display.

	Score[a] after 14 day storage[b]		*Score after 3 day display[c]*		*Score after 5 day display*	
	Hot-boned	*Conventional*	*Hot-boned*	*Conventional*	*Hot-boned*	*Conventional*
1st Experiment						
No Irradiation			1.67	1.0		
10 sec			1.84	1.0		
13 sec			1.50	1.0		
n = 3						
2nd Experiment						
No Irradiation	1.0		1.6			
10 sec	1.4		1.4			
13 sec	1.1		1.0			
n = 5						
3rd Experiment						
No Irradiation	1.25	1.50			2.32	2.13
10 sec	1.50	1.25			1.50	1.75
13 sec	1.13	1.25			1.75	1.50
n = 4						

[a]Odor score = 1:acceptable, 2:barely acceptable, 3:unacceptable.
[b]Post-storage = 14 day vacuum storage at 2°C.
[c]Display = meat cuts repackaged in polyvinylchloride film and displayed under light at 4°C for 3 or 5 days.

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