Glaser #2087

References

Copson, D. A. (1956), "Microwave Energy in Food Procedures," *IRE Trans., Med. Electron.* 27.

Borg, S-B. (1968), "Thermal Imaging with Real Time Picture Presentation," *Appl. Optics.* 7 (Sept.), 1697.

Janes, M., and Aalders, B. G. M. (1969), Uber die Verwendung einer Infrarot-Kamera zur Lösung spezieller Probleme in der Raumfahrttechnik," *Raumfahrtsforschung*, 1 (Jan.-Feb.), 5.

Applications of Microwave Energy in Preparation of Poultry Convenience Foods*

K. N. May†

ABSTRACT

An economic analysis of three systems for the commercial cooking of chicken is presented based on actual costs of batch steam and theoretical (but believed realistic) costs of conveyorized steam and conveyorized microwave in steam atmosphere systems. Microwave cooking shows certain advantages in operation over batch systems and over steam or water continuous systems of cooking. Advantages are of such magnitude that they would pay out the increased capital investment in about 1.27 years. Other advantages in microwave cooking are discussed.

Introduction

Changing market characteristics in the poultry industry offer the potential application of large quantities of microwave energy for cooking purposes. Per capita consumption of poultry meat has risen dramatically in recent years, climbing from 28.3 lb. in 1955 to an estimated 44.4 lb. in 1968 (USDA statistics). Historically, most poultry meat has been sold as fresh product with only about 5 per cent of the broilers produced as late as 1966 being sold in the form of cooked, canned, or other "further processed" items (Roy 1966).

Recent trends indicate a rapid movement toward the consumption of large quantities of chicken in institutional outlets such as drive-in and conventional restaurants, hospitals, school cafeterias, and in-plant feeding establishments. It has been estimated that 10–15 per cent of the broilers produced in 1968 (some 30 million birds) were consumed in such outlets. Because of labour shortages, convenience in handling, exact portion sizing, and ease of cost accounting, many institutional outlets are now using precooked convenience poultry foods.

Most firms that are currently producing precooked poultry convenience foods and many new ones that are moving into production are interested in continuous cooking and freezing equipment to facilitate product flow with an increase in efficiency of production. Microwave power has properties that make it adaptable to efficient, continuous, large-scale cooking systems with certain possible economic and process advantages over alternative sources of heat energy.

It is the purpose of this paper to pre-

*IMPI Symposium Paper H4, Edmonton, May 23, 1969. Manuscript received for publication May 15, 1969.

†Department of Poultry Science, Mississippi State University, P.O. Box 5188, State College, Miss. 39762.

sent and discuss a step-by-step model of a conventional batch steam system of cooking and compare it with continuous steam and microwave systems for preparation of precooked chicken parts.

Systems

Batch steam systems for cooking have been in commercial use for many years. Usually they consist of simple metal cabinets equipped with steam and controls (Fig. 1). The product to be cooked is cut up, placed on trays, and accumulated on floats which are then rolled into cabinets for cooking. Following cooking, the floats are removed from the cooker and moved to the next operation. At this time, the author does not know of any continuous steam cooker in commercial use.

Continuous water cookers have been used by some plants. In such systems, parts are fed into a long metal container containing cooking water and conveyed through the cooker with a screw conveyor. Various parts are fed into the system at different points depending upon the cooking time required.

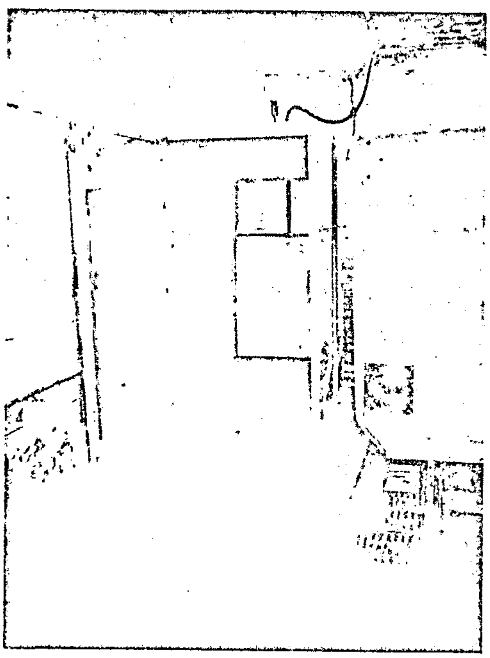

FIG. 1. A metal steam cabinet used for cooking chicken. Left, cabinet with door open; right, with door closed. Note steam line and control on top of cabinet. Courtesy of J. D. Jewell, Inc.

A model of a continuous microwave cooking system (in steam atmosphere) designed for an input of 2500 lb of product per hour is shown in Figure 2. The system would convey parts directly from the cut-up line into two microwave cookers. Breasts and thighs (the heavier parts) would go through a cooker supplied with two 30-kw power packs while wings and drumsticks would be cooked in a parallel cooker powered with one 30-kw power pack. Following cooking, the product would be cooled in an on-line chiller, battered and breaded, and frozen in a continuous freezer either with or without a prior oil frying step. A continuous steam system would involve much the same system except that steam would supply the total BTU input.

Economic Analysis

Actual cost data from operating plants using batch steam systems of cooking were used to project a cost analysis of a cooking system with a capacity of 2500 lb of raw product input per hour. These data were compared to figures calculated for hypothetical continuous steam and continuous microwave (in steam atmosphere) systems.

Direct costs of the three systems, including costs through the freezing step, are shown in Table I. Conveyorizing the system (steam or microwave) reduces the labor by about 10 people, effecting a savings of $30 per hour in direct labor and overhead burden. Utility costs are about $1.20 per hour less in the microwave system than in either steam system, but an allowance of $1.80 per hour must be calculated for tube replacement cost. Thus, direct costs of conveyorized steam and microwave systems are approximately equal in direct hourly operational costs and both result in savings of about $30 per hour over batch steam. Direct costs for a two-shift operation are shown to be approximately $480 and $478 per day

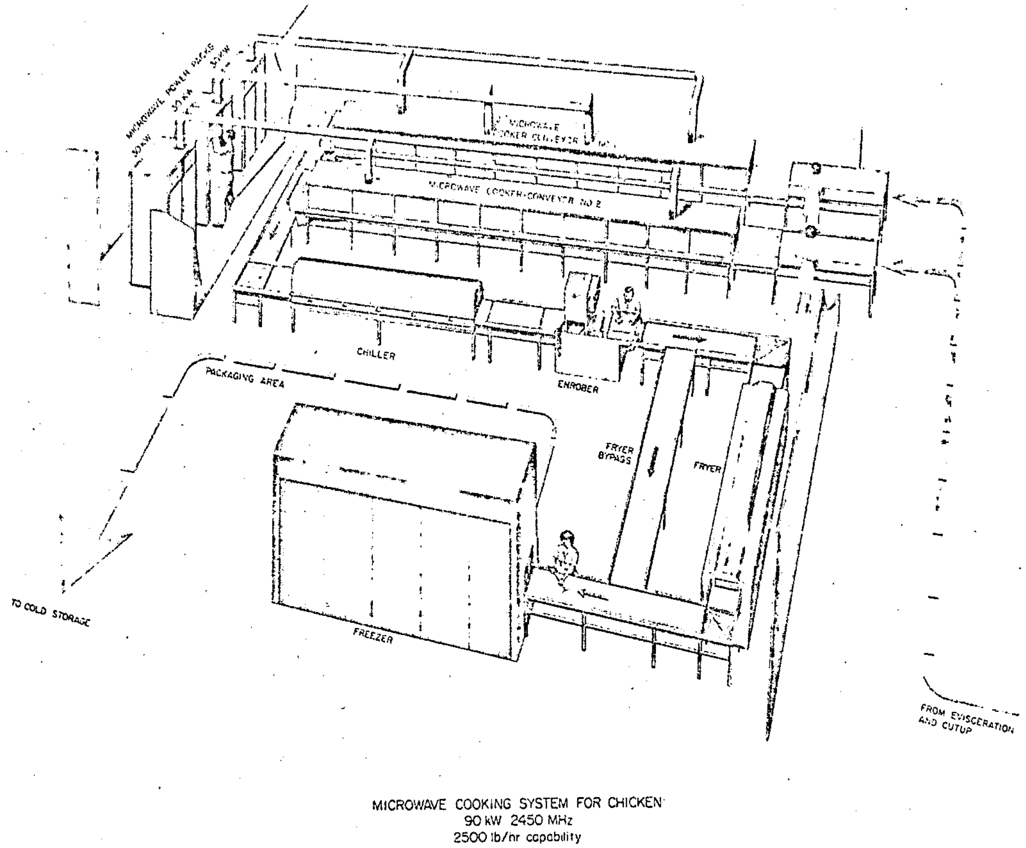

FIG. 2. Schematic model of microwave (in steam atmosphere) system for cooking of chicken. Courtesy of Varian Associates.

for conveyorized steam and microwave, respectively.

In Table II, direct costs have been calculated per pound of product produced and projected for a one-year period based on a two-shift operation. Savings of \$120,000 per year are shown by conveyorizing the cooking operation over the batch system. An additional savings of \$180,000 per year is shown for the microwave system based on a 3 per cent yield improvement over steam cooking. The 3 per cent yield enhancement is estimated from data of Smith *et al.* (1966) and Olsen (1969). Unfortunately, actual plant data on yields from in-plant use of microwave are not available, but the operating advantage per year over a batch steam system would be \$120,000 (1.2¢/lb) for conveyorizing steam and \$300,000 (3.0¢/lb) for microwave (assuming the yield enhancement).

The capital investment required for cooking, conveying, and chilling by the three systems is shown in Table III. Items such as breading machines, cut-up lines, fryer and packaging lines, common to all three systems, are not shown. The initial capital outlay for the continuous systems is considerably higher than that required for the batch steam system. The microwave advantage in operating costs results in an increase of \$100,500 net cash flow (after taxes) over continuous steam (\$171,800 over batch steam) which in turn shows a \$71,300 advantage over the batch steam system. Based on these figures, the microwave system would pay out in 1.27 years and would give a 64 per cent return on investment.

TABLE I

ECONOMIC ANALYSIS OF DIRECT OPERATING COSTS IN THREE CHICKEN COOKING SYSTEMS (2500 LB/HR)

Cost item	Steam batch	Steam conveyor	Microwave conveyor*
Labor (at $2.00/hr)	$74.00 (37 hr)	$54.00 (27 hr)	$54.00 (27 hr)
Manufacturing overhead	37.00	27.00	27.00
Total labor and overhead/hr	$111.00	$81.00	$81.00
Electricity ($0.01/kWh)			
Cooking	—	—	$1.80
Freezing	$6.00	$6.00	6.00
Miscellaneous	1.00	1.00	1.00
Steam	4.00	4.00	2.00
Water	3.00	3.00	2.00
Total utility cost/hr	$14.00	$14.00	$12.80
Maintenance	3.00	3.00	2.50
Tube replacement cost	—	—	1.80
Total direct costs/hr	$128.00	$98.00	$98.10
Total direct costs/shift	$1,024.00	$784.00	$784.80
Total direct costs/2 shifts	$2,048.00	$1,568.00	$1,569.60

*Microwave system uses a steam atmosphere at about 190–200°F.

TABLE II

ECONOMIC ANALYSIS OF CONVEYORIZED STEAM AND MICROWAVE COOKING ADVANTAGES OVER BATCH STEAM FOR COOKING CHICKEN (2500 LB/HR)

Cost item	Steam batch	Steam conveyor	Microwave conveyor
Total direct costs/day*	$ 2,048	$ 1,568	$ 1,570
Product input (lb/day)	40,000	40,000	40,000
Direct cost/lb	$0.0512	$ 0.0392	$ 0.0392
Direct cost savings/lb		$ 0.0120	$ 0.0120
Direct cost savings (10 million)		$120,000	$120,000
Yield improvement/yr (3% at $0.60/lb)		—	$180,000
Operating advantage/yr		$120,000	$300,000
Savings/lb		1.2¢	3.0¢

*From Table I.

It should be pointed out that a microwave system (with steam atmosphere) of the approximate capacity of the one illustrated has been in commercial use on a two-shift basis for approximately three years, but no operational cost figures were available from it. No conveyorized steam operation of this capacity is known to exist at this time.

Advantages of Microwave

One of the advantages of microwave for cooking of chicken over steam or hot water is the deep penetration. One of the most consistent quality problems with precooked frozen chicken is bone darkening due to pigment forced from the bone marrow to the surface during freezing. Thorough cooking reduces this problem

TABLE III

CAPITAL INVESTMENT AND RETURN TO INVESTMENT OF THREE COOKING SYSTEMS*

	Steam batch	Steam conveyor	Microwave conveyor
Tanks, racks, and trays	$ 8,500	—	—
Cookers	24,000	$125,000	$230,000
Transfer conveyors	—	10,000	10,000
Chiller	8,000	18,500	18,500
	$40,500	$113,000	$218,000
Added investment over batch system		$113,000	$218,000
Operating advantage/yr (BT)		$120,000†	$300,000†
Operating advantage/yr (AT)		60,000	150,000
Depreciation, 5-year straight line (AT)		11,300	21,800
Net cash flow (AT)		71,300	171,800
Payout (yr)		1.56	1.27
Return on investment		51%	64%

*Figures for batch steam are composite values based on actual production costs from industrial systems. Those for conveyorized microwave in a steam atmosphere are based on pilot plant data and projected costs. Conveyorized steam figures are believed to be realistic projections.

Items of equipment common to all three systems are not shown. Such items would include cut-up lines, breading machines, fryers, and packaging equipment.

†Does not include a floor space advantage of approximately 4000–5000 sq. ft. over batch steam.

significantly. Most operations overcook chicken slightly in order to avoid the darkened bone, resulting in a reduction in yield. Because of deep penetration, microwave has been shown to reduce bone darkening significantly even in undercooked product (Essary 1959).

Another advantage of microwave is its adaptability for the production of various types of product using the same equipment. Thus, coating can be done prior to cooking (impractical in water cooking) or after cooking depending upon the type of product desired. The ease of change in power setting and the instant response in BTU output is another advantage if different sizes of product are to be run during the same shift.

The quality of microwave-cooked product, from an organoleptic standpoint, is as good as the best produced by water or steam systems in the writer's opinion and may offer an advantage in juiciness and apparent tenderness. Smith *et al.* (1966) claimed superior organoleptic properties for chicken cooked by microwave power.

Time reduction in the cooking operation is an advantage of microwave for cooking chicken parts. By varying the power input per pound of product, the cooking time can be reduced significantly over that required for water (approximately 20–30 minutes) and steam (approximately 25–50 minutes). The lower limit of cooking time by microwave power appears to be approximately 5 minutes. Although the internal temperature of the product can be elevated to one normally considered to be in the well-cooked range (185–195°F) in less than 5 minutes, the product requires a little more cooking in order to appear fully cooked and to develop a cooked flavor. Stone and May (1969) note that fowl cooked quickly under high steam pressure does not appear organoleptically "done" even though the product temperature may be 190°F internally.

Other Possible Applications of Microwave

Fowl carcasses intended for the production of canned meat are frequently cooked to facilitate deboning. Microwave power might offer an advantage in rapid continuous cooking for such a product, but data are not currently available.

Microwave might be used in the precooking of fresh breaded chicken which is to be fried in short-order restaurants to reduce cooking time. Another application might be to in-store microwave–infrared units for use of retail customers for fast cooking of chicken after the selection of the raw product. Microwave ovens are currently in wide use for fast thawing and heating of prebrowned poultry products.

References

Essary, E. O. (1959), "Influence of Microwave Heat on Bone Discoloration," *Poultry Sci. 38*, 527–9.

Olsen, C. M. (1969), Personal Communication.

Roy, E. P. (1966), "Effective Competition and Changing Patterns in Marketing Broiler Chickens," *Jr. Farm Econom. 48*, 188–201.

Smith, D. P. Decareau, R. V., and Gerling, J. (1966), "Microwave Cooking for Further Processing," *Poultry Meat, 3* (4), 65–6.

Stone, E. W., Jr. and May, K. N. (1969), "The Effect of Time and Temperature of Cooking on Quality of Freeze-Dehydrated Chicken," *Poultry Sci.* (in press).

Some Thoughts on the Problems of Microwave Heating and Food Processing*

Walter M. Urbain†

ABSTRACT

A discussion of the development of applications of microwave processing in the food industry in terms of current limitations is presented.

The application of microwave energy to food processing operations so far has not been a major success. Yet one can see that there is both a need for such a heating method and an opportunity to overcome basic heating problems associated with food processing. Despite the obvious need and opportunity, why the lack of great success? It is my opinion that part of the story lies in a failure of those who can provide the needed technology of microwave power and of those of the food processing industry who understand the requirements and problems of foods to get together and to accomplish what is required.

Consider what equipment is available for generating microwave power for food processing operations. At present only two frequencies can be used, and in a sense these are "hand-me-downs" from other uses.‡ Would the engineer consider two steam pressures all that he needed for processes using steam? Of course this part of the microwave story is only a repetition of the old story of the hen and the egg. Which comes first, the power unit or the process? Without an assurance of a market, new equipment cannot be developed. Without equipment available, the process cannot be developed.

*Keynote address, Session H, 1969 IMPI Symposium, Edmonton, May 23, 1969.

†Department of Food Science, Michigan State University, East Lansing, Mich. 48823.

‡See Editor's note at the end of the paper.

If one accepts the idea that frequencies other than 915 and 2450 MHz might have value in food processing, which ones would we want? Here is the other side of the "failure" story. Who knows what frequencies are best for a particular food or food product? We know so little about the characteristics of the foods in terms of what is important for microwave heating that we are reduced to essentially empirical approaches in developing applications. Clearly this is an area for contribution by the food processors and food technologists. Perhaps with such knowledge we could select the most appropriate frequency *for the specific food under the specific process conditions.* It would seem reasonable that we could hope for better results with more than two choices of frequency.

Another part of the "failure" story, in my opinion, is in the working out of applications. Here is a joint responsibility of the microwave power engineer and the food process engineer. The relatively high cost of microwave energy requires gains in other aspects of the food process to offset this cost, gains such as improved labor efficiency, product yield, or product quality. Identification of such values and the means to secure them would seem to fall in the province of the food engineer, and it would seem reasonable to look to him for interest and action in this area.

Yet the proper use of microwave energy in an application must be the work of the microwave power engineer. He and the food engineer, each with his speciality, must work together. They must understand each other's needs and together they must see that what is needed in total is, in fact, provided.

This is an important area. Harmful compromise on essentials, failure to engineer the total process, failure to make needed process adjustments above and below the point of application of microwave energy, failure to train operators in using and maintaining the equipment, failure to set limits as to what is to be expected of the process, all these and other deficiencies can lead to failure of the total process.

Requirements such as those just named do not necessarily apply only to the use of microwave energy for food processing. Similar considerations apply to other kinds of process innovations. They are general requirements, and if not met in microwave and other applications, they will always cause difficulty.

To bring about this joint effort of the microwave and food engineers is not easy. To a considerable degree the two fields are technically far apart, and communication between the specialists in each area is not easy. One would hope that with determination on the part of both groups the needed joint action can be secured. In my judgment this is essential for the broad application of microwave energy to food processing. One would surmise from some situations that this need is critical at the present time.

Just what kinds of needs and opportunities for microwave energy exist in food processing? If this question could be answered in detail with specific uses defined, one would hardly have a developing field and, very likely, we would not be looking toward an expanding future. Despite our inability to give a specific answer, we can suggest general areas for applying microwave energy.

Since liquid foods are capable of being heated effectively and quickly by conventional methods, there is little reason for the use of the more expensive microwave heat with such foods.* Solid foods, however, because of problems of heat transfer by conduction heating, can benefit from the rapidity of microwave heating, and in my opinion, it is with foods that are solids that the potentials for this method of heating lie.

Batch processing has been the traditional method of food manufacture. Since food processing has ancient origins, this is not surprising. But in today's world

*The Editor invites correspondence on this point, as on any other points raised by authors in JMP.

with the need to be more efficient in the use of labor plus the capabilities that have resulted from modern technology, the trend is toward continuous processing. Especially with solid foods the slowness of a heating step becomes a serious difficulty in converting a batch system to a continuous one. Shortening the time for such a step could very well be the justification for microwave heating. There is the further advantage that the finer control of the heat input with microwave energy can improve the process.

To some extent the points just given are illustrated by the two applications that have been described in recent literature, namely the finish-drying of potato chips and the precooking of chicken meat.

But there are many more possibilities. The canned foods process is a whole area untouched at present because the metal container commonly used precludes heating with microwave energy. Replacement of metal with plastic could open up this area, as could changes in canning techniques.

In the meat industry there are a great many solid products which are heat processed. The limitations imposed by the heating rates possible with present methods keep the industry largely on a batch-process basis. Dimensions of these products suggest that the frequencies of 915 and 2450 MHz are not ideal.‡

Some segments of the food processing industry are faced with problems of contamination with living organisms such as bacteria, molds, yeast, and insects. At present public health officials are concerned about foods containing Salmonella bacteria. Many foods contaminated with living organisms are dry solids. Microwave heating after final packaging could cause thermal destruction of such organisms and effectively solve these problems.

The literature of microwave heating lists a number of possible applications. They include blanching (of vegetables), thawing of frozen foods, cooking or precooking, baking, drying, insect disinfestation, and so on. An analysis of these possibilities demonstrates the validity of the generalizations advanced in earlier statements of this discussion. Some of these "possibilities" are now hung up on technical problems, others because of economic inadequacies. No food application to date has been an unqualified success. To me it seems likely that we need to face up to the requirements for success, such as have been mentioned earlier. We need as much as anything the ingenuity of knowledgeable persons to ferret out the peculiar circumstances that mean success in a given use of microwave energy in a food process.

I hope that others who share with me a confidence that microwave heating has an important role in food processing and who might also share at least some of the views I have expressed will want to solve the problems being encountered and to reach for success. In short we need a broader range of frequencies, we need to know more about the properties of foods in terms of the microwave process, we need better engineering of the process through a greater cooperation between the microwave power engineer and the food engineer, and lastly but hardly of lesser importance we need clever persons to recognize situations where microwave heating offers something of special value.

‡See Editor's note at the end of the paper.

Editor's note. The penetration depth at 915 MHz is considered by some people to be too small for raising, for example, large pieces of meat (10 and 20 lb sections) to 160°F prior to shipping (foot and mouth disease control, etc.). It is important to note that frequencies around 500 MHz may be ideal; equipment is available, the generation cost is very low compared to the present 915 MHz cost, and could be used legally (i.e. without interference to communications systems) in metal-lined rooms. Cavity dimensions, for uniform heating, are estimated at target values of 8 ft. Does any reader have information on work done at this frequency?