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MICROBIOLOGICAL AND SENSORY EVALUATION OF SIX OHMICALLY HEATED STEW TYPE FOODS

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ABSTRACT

Presented are the results of a Natick RD&E Center study of microbiological and sensory evaluation of six commercially produced ohmically heated stew type products before and after three years' storage at 27C. All six products were commercially sterile and had no post processing contamination and, in general, had excellent retention of sensory quality, as determined by sensory measurement of color, appearance, flavor, texture and integrity attributes and overall quality ratings. These studies indicated that ohmic heating technology has the potential to provide shelf-stable foods closely equivalent to those prepared from scratch. It was also evident that reformulation of the entree items presented and development of new items is needed to take full advantage of this technology.

INTRODUCTION

Ohmic heating (direct resistance heating) is a process in which food liquids and solids are heated simultaneously by passing an electric current through them.

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Because uniform heating occurs throughout a food, process times can be shortened resulting in improved flavor and nutrient retention (Palaniappan and Sastry 1991; Sastry and Palaniappan 1992; Parrott 1992). The U.S. Army Soldier Systems Command, Natick Research, Development & Engineering Center (NRDEC) has had a long term interest in the potential of this process to provide rations of excellent quality to meet a three year shelf life requirement at ambient temperature (Yang *et al.* 1994). Previously, successful studies demonstrated the lethality of the process to spores of *Bacillus stearothermophilus* in alginate beads (Brown *et al* . 1984) as well as via measurement of the concentration of two intrinsic chemical markers formed during thermal treatment (i.e., M-1 [2,3-dihydro- 3,5-dihydroxy- 6-methyl- 4(H)-pyran-4-one] formed by the reaction of sugar with protein through the Maillard reaction, and M-2 [4-hydroxy- 5-methyl-3(2H)-furanone] formed by a similar reaction between ribose and protein; (Kim *et al.* 1996), the latter was proven to be an excellent indicator of thermal lethality to the organism (Kim and Taub 1993).

In commercial ohmic heating systems in England, food is heated by pumping between a series of electrodes to which alternating current is applied (Skudder 1993). Typically, dwell time in the ohmic heater is not more than 90 s, after which food is pumped through a series of holding tubes or to a holding tank to equilibrate temperature. The food, now sterile, is subsequently cooled in a tubular heat exchanger and aseptically packaged. Since the process heats food particles from within, a product can be completely cooked without the need for additional external heating. Thus, overheating can be avoided, making it particularly suited for pumpable foods containing particulates, such as stews or similar ready-to-serve meals.

Ohmic heating is a continuous high temperature, short time (HTST) sterilization process. It is conceptually simple but has complex system characteristics including electrochemistry, advanced construction materials, aseptic technology, and most critical, proper heating control technology (de Alwis 1990). In the U.K., microprocessor technology was used to compute the energy required for the process based on the flow rate, temperature rise required, specific heat of the product and a feed-forward control system. This first successful commercial ohmic system was licensed to APV Baker. To obtain approval from the U.S. Food and Drug Administration (FDA), further demonstration of sterility at the center of a food particulate is required, based on a definitive microbiological procedure and a conservative mathematical model (Dignan *et al.* 1989). Using the existing APV Baker system, the objectives of our study were to examine the microbiological safety and sensory quality of six different, British formulated, ohmically heated foods initially and after three years' storage at 27C.

MATERIALS AND METHODS

Ohmically Heated Foods

Since the heating rate of individual ingredients in a food product during ohmic heating is primarily dependent on electrical conductivity, food products (especially the low acid food) containing a mixture of components of different electrical conductivity is normally precooked (in excess of 55C for a minimum of 10 min) which causes the intra-cellular structure of the particulates to lyse and renders partial equilibrium of the ion concentration between the particulates and carrier liquid (Skudder 1993). Six products, Carbonara Sauce, California Beijing Beef, Winter Soup, Mushroom a la Greque, Ratatouille, and Cappelletti in Tomato Sauce (Table 1), were ohmically processed using a commercial-size, APV 45kW unit at Carnaud Metalbox (CMB) Technology, Wantage, England. A line diagram of the 45 kW ohmic heating pilot plant appears in Fig. 1. Formulations contained particulates up to 2.5 cm and solids content greater than 75% (w/w) were designed by CMB (Yang *et al.* 1994) to heat more uniformly during a relatively short ohmic processing period. In most cases, minimally processed or fresh ingredients were used. Vegetables were blanched and meats were precooked to remove the redness and excess fat before processing. For each run, approximately 250 kg of ingredients were mixed, precooked and processed. Finished products were then aseptically filled into 230cc high barrier polypropylene cups and heat sealed with aluminum foil lids. About 500 cups of each product were packed.

TABLE 1.
MAJOR INGREDIENTS OF THE SIX OHMICALLY HEATED PRODUCTS

Carbonara Sauce	Winter Soup	Mushroom a la Greque	California Beijing Beef	Cappelletti in Tomato Sauce	Ratatouille
Milk, whole	Potato	Mushroom	Beef	Cappelletti	Tomato
Ham, smoked	Leek	Tomato	Carrot	Onion	Courgettes
Sweet corn	Pea	Onion	Green pea	Courgettes	Onion
Double cream	Green bean		Onion	Tomato	Pepper
	Carrot		Pepper		
	Ham, smoked		Baby corn		
	Onion		Soy sauce		
	Butter		Dry Sherry		

Processing Temperature and F_O-values

Before the production all products were test-run for numerous times by CMB to ensure consistent processing conditions and to establish required F_o-values (i.e., amount of time required to destroy all the microorganisms at 121.1C). F_o value, an integrated lethality to quantify the thermal processing of foods, is described as (Holdsworth 1985):

$$F_o = \int_0^t 10^{(T-Tr)/z} dt$$

where T is temperature, Tr is reference temperature (i.e., 121.1C), t is holding time, and Z the slope of the line of Log D vs T. The decimal reduction time, D, is the time for a reduction of microbes by a log 10 factor.

Because particulate heat faster than the liquid phase of a food in an ohmic system (Kim *et al.* 1996), a conservative processing temperature was measured in the liquid phase of the product at the outlet of the holding tube (Fig. 1).

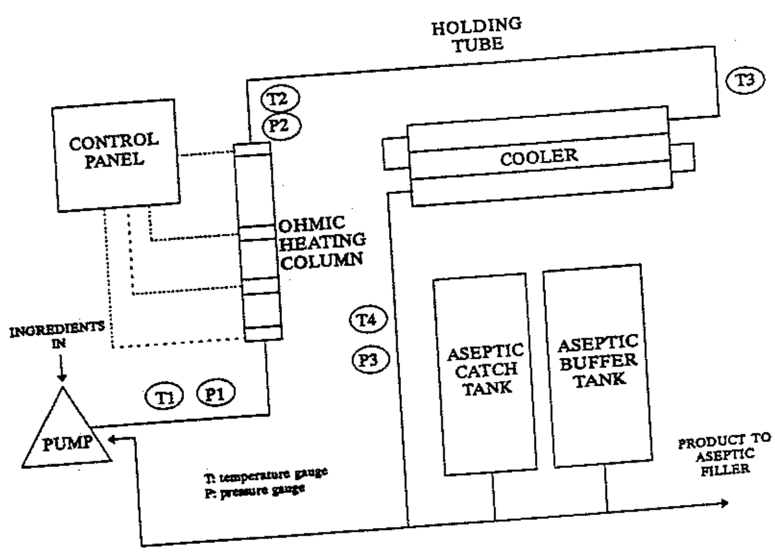

FIG. 1. A LINE DIAGRAM OF THE 45 kW OHMIC HEATING PILOT PLANT

Microbiological Examination

A total of 40 samples of each product were randomly collected during the beginning (20), the middle (10), and the end (10) of the aseptic filling. Samples were stored at 30, 37, and 55C and observed for 14 days prior to microbiological examination. Changes in external package appearance (swells, etc.) were assessed. All samples were then examined per the laboratory standard method (Gaze 1988) for aseptically filled low-acid foods. Aliquots of product, removed aseptically from each pack, were inoculated into the following recovery media (a) incubation 37/55C: tryptone dextrose broth (TDB; aerobes) and peas, peptone, yeast extract, starch medium (PPYS; anaerobes). (b) incubation 30C: single 90 mm streak plate of Oxoid Nutrient Agar™ (aerobes) and peas, peptone, yeast extract. starch medium (PPYS; anaerobes). All cultures were incubated for 7 days and plate counts were given as colony forming units (CFU's) per gm of sample. In addition each product was examined by direct microscopy, and pH was measured. Stored samples were incubated at 38C for 10 days and observed daily for swells before clearance for sensory evaluation.

Sensory Evaluation

The six products were formulated by CMB, primarily to demonstrate ohmic heating technology without reference to U.S. consumer preferences. No similar U.S. products, in particular thermally processed military rations, were found for comparison. Thus, it was considered appropriate to describe sensory characteristics without reference to acceptability. Sensory tests were conducted at the NRDEC. Preliminary examination of the products was first made by food technologists and sensory scientists to identify salient sensory attributes and create a rating form. An example of the rating forms developed is given in Fig. 2. Nine-point word anchored rating scales were used, as indicated.

The following attributes were common to all products: color, appearance (visual consistency of sauces), overall flavor intensity, and texture and integrity of particulates (meat dice, vegetable and pasta ingredients). Texture scales were included because texture retention was considered a key potential advantage of ohmic processed foods. The quality scale (overall quality) is frequently used to assess military ration quality, and the similarity scale was intended to be a rough estimate of how close the item was to restaurant (cook from scratch) quality.

Sensory panels were conducted in the Food Acceptance Laboratory at NRDEC, a facility equipped with individual booths and ports connected to the food preparation area. Panelists were selected from food technologists with demonstrated sensory acuity and experience in assessing a wide variety of military rations. Each session included 12 to 17 panelists. They were advised that (1) samples were produced by a novel processing technology, (2) purpose of the test was to determine degree to which the process preserved product characteristics and (3) flavors were

NAME____________________

PRODUCT: **Cream of Vegetable Soup**

Soup Base

Color

1 2 3 4 5 6 7 8 9

Light — Dark

Appearance

1 2 3 4 5 6 7 8 9

Very Thin — Very Thick

Overall Flavor Intensity

1 2 3 4 5 6 7 8 9

Weak — Strong

Vegetable Ingredients

Texture

1 2 3 4 5 6 7 8 9

Very Soft — Very Firm

Integrity of Pieces

1 2 3 4 5 6 7 8 9

Most Broken — Some Broken/ Some Whole — Most Whole

Ham Dice

Texture

1 2 3 4 5 6 7 8 9

Very Soft — Very Firm

Integrity of Pieces

1 2 3 4 5 6 7 8 9

Most Crushed — Some Crushed/ Some Whole — Most Whole

Product as a Whole

Overall Quality

1 2 3 4 5 6 7 8 9

Extremely Poor — Poor — Fair (Borderline) — Good — Excellent

Similarity to restaurant prepared product

1 2 3 4 5 6 7 8 9

Not at all Similar — Extremely Similar

Comments:____________________

FIG. 2. EXAMPLE OF RATING FORM USED IN SENSORY TESTS

typically British and therefore might not be familiar to them. An ingredient list for each item was also provided. Samples were reheated in their original heat sealed polymeric cups in boiling water to approximately 65C. Single samples of each item were presented one at a time in random order. Testing was divided into two sessions of three samples each. The initial test was conducted shortly after receipt of samples in the US, and the second test after three years' storage at 27C. After completion of testing, an analysis of variance (ANOVA) was computed for attribute ratings before and after storage, $P \leq 0.05$ was the criterion for significance.

RESULTS AND DISCUSSION

Processing Parameters

Processing parameters are given in Table 2. All holding times (assuming laminar flow), temperatures and corresponding F_o values were minimal values. For extra assurance of safety, the FDA only regards the contribution of thermal lethality from the holding tube (Dignan *et al.* 1989) and requires a minimum sterilizing value of F_o= 3 [(i.e., lethality equivalent to 3 min heating at 121C; (Pflug 1987)]. In HTST processes, such as ohmic heating, the target temperature often exceeds 131C and therefore only a minimum of 0.3 min in the holding tube is required. In Table 2, F_o values indicated a substantial safety margin, although they are much less than those for conventional retort-processed low acid particulate foods [(i.e., some exceed F_o= 100 min; (Skudder 1993)]. With refinement of the formulations and a more precise heating control system, F_o values of these ohmically heated foods could be further reduced to improve product quality without sacrificing sterility.

Microbiological Examination

There was no obvious change in external package condition during the observation period. Among the six products, all but Ratatouille were low-acid foods ($pH \geq 4.5$) and therefore required sterilization (Table 3). All five low-acid products had negative plate counts and normal results under direct microscopy (i.e., no or low levels of microorganisms visible). These results verifed the commercial sterility of these products as indicated in Table 2. Ratatouille, which received pasteurization treatment, due to low pH, showed low levels of aerobic spore formers in a direct smear test. However, these are unlikely to cause spoilage at pH of 4.1-4.2. All samples before and after three-year storage showed no container leakage or swelling during the 10 day incubation at 38C.

Sensory Evalualtion

Results are given in Table 4 and are discussed by attribute.

(1) Color of sauce. After three years storage at 27C, the panel indicated that significant ($p \leq 0.05$) darkening of sauce color occurred for all items except Beijing Beef. Of the six items, Carbonara Sauce was perceived the lightest initially and Beijing Beef the darkest.

TABLE 2.
PROCESSING CONDITIONS FOR THE SIX OMICALLY HEATED PRODUCTS

	Holding time (sec)	Temperature[1](C)	F_o[2] (min)
Carbonara Sauce	70	132	14
Winter Soup	70	133	18
Mushroom a la Greque	34	137	22
California Beijing Beef	109	130	14
Cappelletti	30	133	15
Ratatouille	45	90	Pasteurization

[1] Measured at end of holding tube
[2] Calculations based on Z value of 10C

TABLE 3.
MICROBIOLOGICAL RESULTS OF SIX OHMICALLY HEATED PRODUCTS

	pH	Aerobic Plate Count	Anaerobic Plate Count	Direct Microscopical
Carbonara Sauce	5.8	<10	<10	Normal[1]
Winter Soup	5.4	<10	<10	Normal
Mushroom a la Greque	4.7	<10	<10	Normal
California Beijing Beef	5.4	<10	<10	Normal
Cappelletti	4.6	<10	<10	Normal
Ratatouille	4.2	<10	<10	Normal

[1]Normal denotes no or low levels of microorganisms visible

(2) Appearance of sauce. Overall, there was no visible evidence of change in sauce consistency over three years. Among the six items, the Beijing Beef and Cappelletti items were perceived as intermediate between thin and thick while the other items were thicker to various degrees.

(3) Overall flavor intensity. All products approached "moderately strong" (7 score on the scale) in this general characteristic, and except for one item, no significant changes were observed after storage. The Ratatouille item increased significantly over time.

(4) Texture, first scale - vegetable or pasta ingredients; integrity of pieces, first scale. Mean texture ratings ranged from a level intermediate between the scale anchors (vegetables in Beijing Beef) to very firm (corn in the Carbonara Sauce item). With the exception of vegetable ingredients in Beijing Beef, integrity was very high, evidence of a claimed advantage of ohmic heating. In general very slight decrements in these attributes occurred after three years' storage but none were significant.

(5) Texture, second scale - meat dice, other vegetable ingredients; integrity of pieces, second scale. Ham dice in the Winter Soup and beef dice in the Beijing Beef became somewhat firmer (tougher) over 36 months' storage but the difference was not significant. Although ham fibers apparently toughened over time, the integrity of the pieces broke down to a significant degree as indicated in Table 4. A similar phenomenon was not observed with beef cubes. Lastly, green pepper dice in the Ratatouille became significantly softer with storage, zucchini pieces in the Capelletti item also softened but not significantly.

(6) Overall Quality. After three years storage, significant decreases were noted in Carbonara Sauce, Winter Soup and Beijing Beef items. For the first two items, the darkening of color was likely the predominant factor influencing panelist ratings; for the third item, it was likely a factor not rated as such, flavor quality. After three years, a very strong off spice component was noted that hadn't been present initially.

(7) Similarity to restaurant prepared product. Initially, all items were considered by the panel to be similar to some degree to a restaurant prepared item, with the possible exception of Beijing Beef. A significant decrement in ratings occurred when a salient attribute (color or texture) and/or overall quality decreased with storage.

In summary, stew type entrees prepared by the ohmic heating with aseptic packaging would provide potential for quality and acceptance improvement in shelf stable rations. These foods can be served in various type and shape of container that would provide convenience for soldiers in the field feeding system.

CONCLUSIONS

The six ohmically processed stew type products were demonstrated to be commercially sterile and free from post processing contamination. Of these, three had very good quality retention after three years at 27C. Ohmic heating technology, upon future regulatory approval, will provide potential as one of the future technology insertions of the military ration program for improving shelf stability and quality enhancement of both individual and group field feeding entrees.

TABLE 4.
SENSORY RATINGS OF SIX OHMICALLY HEATED PRODUCTS BEFORE AND AFTER STORAGE AT 27C [1,2]

	Carbonara Sauce		Winter Soup		Mushroom a la Greque		California Beijing Beef		Cappelletti In Tomato Sauce		Ratatouille	
	0Y	3Y	0Y	3Y	0Y	3Y	0Y	3Y	0Y	3Y	0Y	3Y
Attribute	Sauce		Soup		Sauce		Sauce		Sauce		Sauce	
Color	[3.2±1.0	4.6±1.1]	[4.9±0.9	6.1±0.9]	[6.2±1.1	7.1±1.0]	7.1±1.2	7.2±1.0	[6.3±1.0	7.0±0.7]	[6.1±0.9	6.9±0.8]
Appearance	6.9±0.9	6.7±1.1	6.3±1.0	6.8±1.1	6.7±1.0	6.5±0.9	5.5±1.3	5.9±1.4	7.0±0.7	7.4±1.2	4.6±1.3	4.8±1.4
Overall Flavor Intensity	6.9±1.1	7.3±1.1	6.6±1.2	6.4±2.1	6.5±1.4	7.1±0.7	7.0±1.2	6.8±1.3	6.4±1.5	6.8±1.0	[6.4±1.2	7.1±0.7]
	Corn		Vegetables		Mushroom		Vegetables		Cappelletti		Zucchini	
Texture	6.2±1.4	5.3±1.7	6.3±0.8	5.6±1.5	7.5±1.0	7.0±1.5	4.8±1.5	4.8±1.9	4.6±1.2	4.3±1.3	6.6±1.3	6.0±1.3
Integrity	8.4±0.8	7.8±1.1	8.4±0.7	7.9±1.1	8.7±0.6	8.5±0.7	6.6±1.4	6.4±1.4	7.7±1.5	8.3±0.8	7.7±1.4	7.5±1.2
	Ham		Ham				Beef		Zucchini		Pepper	
Texture	5.8±1.4	5.3±1.7	6.3±1.2	7.0±1.3	(Blank)		4.7±1.5	5.8±1.8	4.2±1.5	3.2±1.3	[6.8±1.2	5.1±1.4]
Integrity	8.3±0.7	7.4±1.7	[8.4±0.6	6.4±2.7]	(Blank)		7.7±1.2	7.6±1.2	5.6±1.8	6.0±2.0	8.0±1.1	7.4±1.2
Overall Quality	[7.3±1.1	6.0±1.3]	[7.5±1.0	6.0±1.5]	7.5±0.7	7.3±0.8	[6.7±1.2	5.4±1.7]	7.3±1.1	7.2±1.2	7.6±0.8	7.2±1.1
Similarity	6.4±1.9	5.2±2.3	[6.7±2.2	4.6±1.8]	6.6±2.1	6.3±1.5	[5.7±2.2	4.0±1.4]	7.1±1.5	6.1±1.7	[7.3±1.6	6.2±1.5]

[1] Sensory results presented as mean ± standard deviation; paired data in brackets are significantly different ($p \leq 0.05$)
[2] 0Y: initial evaluation; 22 panelists. 3Y: 3-year storage; 12-17 panelists

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