STANDARDIZATION OF THERMAL PROCESSES FOR LOCAL FOODS WITH EMPHASIS ON LOW-ACID FOODS

Dr. Estrella F. Alabastro and Mrs. Virginia B. Magluyan

College of Home Economics

ABSTRACT

The minimum process for selected low acid foods was established based on the thermal death time (TDT) of *P.A. 3679* in the food and the heat penetration characteristics of the food products. The products studied were: (a) vegetable products — green papaya, langka, sitao, mushroom, waterchestnut and baby corn; (b) meat products — lechon, paksiw, dinuguan, longaniza and caldereta; and (c) seafood products — squid adobo. The integrated lethality approach was adopted for process calculations recommended by Stumbo (1973).

The minimum thermal process was tested by a pilot scale production followed by microbiological, physico-chemical and sensory evaluation tests to check the soundness of the product.

Preliminary research on the effect of the minimum process established on the retention of nutrients, particularly thiamine, was also carried out for lechon paksiw and sitao.

INTRODUCTION

Canning is an effective method of preserving foods. It is based on the principle that perishable foods can be pre-

served through proper application of heat process (Heid and Joslyn, 1967). Canning gives the food protection against microbial contamination, undesirable gains and losses of moisture, absorption against light; hence it provides longer shelf life. Cans also lend themselves to high speed mechanized handling, filling, sealing and casing. They can be easily stored for a long period of time and still retain their buying quality.

Besides the advantage provided by canned foods from the standpoint of preserving the product and easy handling, this form of preserved foods has become popular among consumers because of the convenience afforded them. Canned foods can readily be consumed. For certain products like canned meat and fish, only a short preheating step is required prior to serving. The increasing demand for this convenience food products could be attributed to the increase in the number of working mothers who have less time for food preparation.

In the canning process, heat inactivates the enzymes which cause undesirable changes to food and destroys the spoilage microorganisms. These desired effects, however, are accompanied by changes in the physical attributes of the food, particularly, color, texture and flavor, as well as destruction of nutritive properties. In canning therefore, to assure maximum quality retention in terms of organoleptic and nutritive properties and still achieve commercial sterility, the minimum heat treatment should be applied (Lund, 1973; Adam, 1962; Stumbo, 1965).

Preserving the nutritional values of foods has become an important field of research, along the area of food processing. The most heat-sensitive of the nutrients are the vitamins. Among the vitamins common in foods, thiamine is one of the most heat-sensitive. This property of thiamine accounts for its being used as an index of severity of processing and storage conditions (Clifcorn, *et al.*, 1950). Literature survey however, revealed that local studies on this area have not yet been carried out.

This study aims to establish the minimum thermal processes for the four meat products, namely, pork dinuguan,

longaniza, caldereta, and lechon paksiw; a seafood, squid adobo; and six vegetable products, namely, papaya, sitao, langka, waterchestnut, mushroom, and baby corn. A standard minimum process ensures a safe canned food product with a remote probability of survival of *Clostridium botulinum* and more-resistant spore-forming, mesophilic bacteria in low-acid, canned foods (Stumbo, *et al.*, 1975); it prevents over-processing which may cause deleterious effect on the organoleptic and nutritional qualities of the products. To suit the conditions in the Philippines, processing is limited to the use of still retort.

The specific objectives of this research are:

1) to establish the best formulation for selected processed foods;
2) to conduct heat penetration studies;
3) to perform thermal death time studies on the pure culture of chosen reference organism; *P.A. 3679*
4) to determine the minimum time-temperature requirements for each food product based on the results of the TDT and heat penetration studies;
5) to determine the thermal destruction characteristics of thiamine in buffered solution and in purees of selected food products;
6) to determine the effect of established minimum time-temperature processing on the extent of thiamine destruction; and
7) to determine the effect of the length and temperature of storage on thiamine content of selected canned products.

REVIEW OF LITERATURE

Vegetables

Meyer (1960) classified vegetables into five groups: 1) leafy vegetables which are high in water and cellulose and low in calories and protein; 2) flowers, buds and stems which

are relatively high in water and cellulose but low in protein; 3) bulbs, roots and tubers which are high in water, moderate in cellulose and contain an appreciable amount of available carbohydrates; 4) seeds and legumes which are relatively low in water and cellulose, but containing fair amount of protein and a large amount of starch; 5) vegetable fruits which are relatively high in water and cellulose but low in calories and protein.

Some products in this study, namely, green langka, green papaya, waterchestnut, sitao, mushroom and baby corn are vegetables and can be categorized according to the above classifications. Green langka, green papaya and baby corn could be classified as vegetable fruits. Waterchestnut belongs to "bulbs, roots and tubers"; sitao is a legume; and mushroom belongs to "buds and stems."

De Jesus (1969) gave a brief description of these vegetables:

> "Langka is a green, oblong, fleshy, 25 to 60 cm long, edible fruit covered with pyramidal projections. It is rich in carbohydrates but deficient in calcium and iron. The seed is very rich in starch. The pulp of the green langka is usually cooked with fish and coconut milk while the ripe fruit is eaten fresh or made into sweets.
>
> "Papaya is a large, oblong or melon-shaped fruit which is greenish yellow at the ripe stage. At the unripe stage, the flesh is thick, white and firm. Within the flesh is a large cavity containing numerous small, round seeds or no seeds at all.
>
> Papaya contains a milky juice known as papain which is good for tenderizing meat. Green papaya is served as vegetables when boiled or it is used for pickles, salads or sweet preserves.
>
> "Sitao is one of the most widely grown legumes in the Philippines. It has two well-known varieties: the greenish white and the reddish purple. The pods are very long, 20 to 40 cm and less than a cm wide, with many seeds.

"Waterchestnut is a corn belonging to the Sedge Family (*cyperacea*). It is dark brown and onion-shaped measuring from 2.5 to 4 cm and grows underwater in low muddy areas. When cut transversely, the flesh appears whitish with a narrow line (endoderm) about 1 mm from the surface. It has a sweetish taste and an unusually firm crisp texture."

Corn belongs to the grass family. There are numerous varieties of corn locally grown and there are various preserved food products from it, the most commonly available of which is canned cream style corn. A new variety from Taiwan which yields baby corn has recently been introduced in the Philippines. The size of the fruit is much smaller than the ordinary varieties and when cooked it is eaten whole. It is best harvested when the size of the fruit is approximately 75 mm in length and 10 mm in diameter. At this stage, the corn is characterized as most succulent, tender and sweet. Baby corn has been canned in brine with added sugar and salt, and also made into a pickled product. It is a common ingredient of soups and Chinese dishes.

Mushroom belongs to a large group of lower plants known as fungi, which are spore bearing or non-flowering. Fungi depend on organic matters for nutrition and are consequently devoid of chlorophyll. There are several species of mushrooms which can be cultivated in the Philippines and most of these can grow only in the Mountain Province.
The species that can be cultivated all year round in the prevailing Philippine climate is the tropical mushroom *Volvariella*, known locally as "kabuting saging" or "kabuting dayami." The spawn which refers to the vegetative or growing stage, when planted in rice straw or water lily beds as organic substrates, yields the first harvest after ten to fourteen days (Alicbusan and Ela, 1962). Mushrooms to be canned should still be at the "button" or fruiting stage, wherein small knots or buttons appear on the strands. Later they elongate while the ends become larger. At this stage, the main parts of the mushroom, which are the stem and cap

begin to be more distinct (Christensen, 1943; Mendoza, 1938).

Meats

Meats in general. The Food and Drug Administration defines meat "as the properly dressed flesh derived from cattle, swine, sheep or goat sufficiently mature and in good health at the time of slaughter, but is restricted to that part of the striated muscle which is skeletal or that which is found in the tongue, diaphragm, heart or esophagus, and does not include the lips, snout or ears with or without the accompanying or overlaying fat, and the portions of bone sinew, nerve and blood vessels which normally accompany the flesh and which may not have been separated from it in the process of dressing it for sale."

Carcass structure. The gross carcass structure is made up of four different constituents, namely: 1) the edible lean or muscular tissue; 2) the fat, imbedded in between or over the muscles; 3) the connective tissue or gristle which holds the body together; and 4) the bone or framework of the structure (Bull. 1951).

The carcass is divided into different cuts. Each cut exhibits different characteristics such as length of fibers and amount of fat content which are inherent on the part of the animal from which the cut was obtained. Different cuts have different suitability for cookery. Generally, cuts which are relatively tough are cooked by moist heat (as in braising), while cuts which are relatively tender are cooked by dry heat (as in roasting or frying).

Meat products. The best pork sausage is made of picnics, shoulders (sometimes hams and loins) and trimmings. It should contain 75% lean and 25% fat. Lower grades contain pork trimmings, a high percentage of fat, meat other than pork, and "extenders" or "fillers" such as corn or potato flour. Sausage with an excessive amount of fat is nearly white in

color, fries away and leaves almost nothing when cooked (Bull, 1951).

Any portion of roasted pig or lechon can be made into paksiw. However, if fat is present in large amount, the product becomes undesirable. After the pig has been roasted, it is assumed that it has already been cooked; hence, the tenderness of the meat must have also been affected.

Meat cuts usually made into dinuguan are head, picnic, shoulders, loins and variety meats (internal organs). A desirable dinuguan must contain 75% lean and 25% fat. Chunks of fat with skin may also be used provided that lard is rendered first and the residual "chicharon" composed of fat and skin constitutes not more than 25% of the total weight of the meat.

For caldereta, beef cuts commonly used are round, flank, chuck and sirloin tip. These parts of the beef carcass are tender cuts which are most suited for caldereta. The beef cuts to be used should be free of bony parts.

Meat changes due to cooking. All cooking processes reduce the number of bacteria, yeasts and molds, and if the meat is cooked to well-done stage it may even be rendered sterile. Pork is often infected with a parasite *Trinchinella spiralis* which is dangerous to man but is readily killed at a temperature of 132°C (Mayer, 1960). For beef, a common infection is caused by *Taenia saginata* which could be destroyed by proper cooking.

Besides decreasing the microbial load and killing parasitic and disease-causing organisms, cooking is also accompanied by the following changes:

1. Cooking causes protein denaturation. This is evidenced by the physical condition of the meat. The jelly-like structure stiffens and often toughens. There is a decrease in volume and an increase in density as cooking proceeds.

2. Large collagen molecules are hydrolyzed to form relatively small gelatin molecules. This is actually what happens when a piece of meat is cooked for a long time. The connective tissue disappears and the gravy gels upon cooling.

3. Meat color changes from red to purplish red to brown or gray on cooking. This occurs because the oxyhemoglobin (red), hemoglobin and myoglobin (purplish) red are denatured.

4. Meat loses weight due to drippings. The drip is composed of water carrying a number of soluble compounds as well as some coagulable proteins and fat.

5. Meat develops flavor and aroma. The aroma is composed of low molecular weight, volatile compounds such as amines, ammonia, hydrogen sulfide and organic acids. These compounds probably arise from the cracking of amino acids during heating.

6. Fat cells rupture and fat disperses through the meat on cooking.

7. Overcooking meat causes an excessive loss of drip and toughening of the meat fibers. The meat becomes stringy as the amount of connective tissue falls and fat drips out. Not only are the tenderness and the juiciness of the meat diminished but also the flavor and the nutritive value.

Squid

The squid, *Loligo peali*, is classified as a mollusk. The ratio of edible parts to the whole in squid is as much as 30%, made up of 50% trunk and 30% arms. The liver constitutes 10% of the whole.

Squid provides as many calories as the white meat of fish (Tanikawa and Suno, 1952 as cited by Takahashi, 1965). Its amino acid content is comparable to that of meat; hence, it is an excellent source of protein.

In certain Asian countries, squid has become a popular food item. In Japan, particularly, it is made into various types of food such as smoked, salted and fermented products. As a delicacy, "misu," sugar, salt and soy sauce are commonly added. In the Philippines, squid is available as fresh, raw, dried and canned. It may be canned whole or cut-up in oil, or as "adobo," a popular native preparation. In addition, squid is also made into tempura or rebosado, locally known as "calamares."

Squid muscle changes upon cooking. When squid is cooked, a considerable reduction in size occurs. This occurrence is explained by Takahashi (1965) as follows: When the trunk meat is heated in water without stripping the skin off at either side, contraction occurs — lengthwise, 60% of the initial length and breadthwise, 75%. The longitudinal hydrothermal shrinkage is due to the collagen in the skin while the lateral shrinkage is caused by the muscle fibers in the meat. A finding by Tanaka (1958) as cited by Takahashi (1965) showed that when squid meat is cooked, the muscle fibers bend, resulting in reduced diameter of the component fibers.

The extent of contraction is affected by the freshness of the squid. In this connection, studies by Takahashi (1968) revealed that every fresh meat, when cooked at a temperature of about 100°C, exhibits some degree of transverse contraction. Staler meat, cold stored for one or two days after death, shows hydrothermal shrinkage of about 75%.Contraction of fresh squid was found to occur when the cooking temperature reaches 65° to 70°C while stale squid starts to shrink at a lower temperature.

Squid meat begins to lose weight when the cooking temperature reaches 50° to 60°C. At 100°C, the meat is further reduced to about half of its original weight and the water brought down to about 15%.

Thermal Processing. There are several methods to determine the amount of heat necessary to sterilize a canned product. One of these is the trial and error method which involves experimenting with a series of batches of food subjected to different time-temperature combinations. The samples are incubated for a period of time to determine the spoilage levels. This approach, however, being subject to errors, is impractical, and therefore unreliable. Another method is the inoculated pack test wherein the samples are inoculated with a known quantity of a spoilage organism and then processed at different time-temperature combinations. This method requires a rather large amount of raw material and the results are difficult to interpret. A third method, the most reliable of the three, information, has two sets of empri-

cally-established properties the heat penetration characteristics of the product and the thermal death time curve of the spoilage organism to be destroyed (Herndon, *et al.*, 1968). of time to determine the spoilage levels. This approach, however, being subject to errors, is impractical, and therefore unliable. Another method is the inoculated pack test wherein the samples are inoculated with a known quantity of a spoilage organism and then processed at different time-temperature combinations. This method requires a rather large amount of raw material and the results are difficult to interpret. A third method, the most reliable of the three, information, has two sets of empirically-established properties the heat penetration characteristics of the product and the thermal death time curve of the spoilage organism to be destroyed (Herndon, *et al.*, 1968).

It would be noted that all the eleven products in this study six vegetables, four meat products and one seafood belong to the low-acid foods with a pH value above 4.6. At this pH range, the spore-bearing bacteria are of greatest concern from the standpoint of sterilization (Stumbo, 1965; Heid and Joslyn, 1967). Among the spore-formers, *Clostridium botulinum* is the most important because of its public health significance. Under favorable conditions, this organism produces an extremely potent exotoxin that causes 65% fatality to man. Botulism is a highly lethal food poisoning and hence, it is one of the most dreaded food intoxications. In the formulation of food processing techniques, the danger of botulism has been a deciding factor (Rieman, 1969).

Heat resistance of microorganisms. Generally, yeasts, molds, and vegetative stage bacteria die at temperatures from 20° to 30°F above that optimum for their growth. However, certain heat resistant strains can tolerate prolonged exposure to boiling temperature. The spores of bacteria are much more heat resistant than vegetative cells. For example, *Clostridium botulinum,* which could thrive in low-acid foods can endure exposure to 212°F (100°C) for sp. hours.

Heat resistance of this organism, however, is greatly reduced at higher temperature; hence, processing of low-acid foods is done at temperature above 212°F (100°C) specifically at temperatures from 240° to 260°F (115. 5° to 126.7°C), by using steam-heated retorts at steam pressures of 10 to 20 psig (Charm, 1971; Borgstrom, 1967).

The increase in rate of inactivation of spores with rise in temperature is due to increase in the number of collisions per unit time between water molecules and sensitive molecules as well as increase in water molecules with energy adequate for inactivation.

There are various factors which affect heat resistance of spore. Schmidt (1957) as cited by Stumbo (1973) considers three main factors, namely: 1) inherent resistance of spores which varies not only with species; 2) environmental influences active during the growth and formation of spores; and 3) environmental influences active during the time of heating of spores. The environmental factors which affect the growth of spores are: age, growth temperature, nature of medium in which the spores are produced and nature of the suspending medium.

Thermal death time (TDT). The main objective of thermal processing is to free the food of all visible organisms that may cause spoilage and, hence, render the food inedible.

Death of bacteria occurs over a period of time and the shortest time required to kill a particular microorganism is referred to as thermal death time (TDT). TDT is then a measure of the resistance of the microorganism to heat (Sacharow, 1970; Herndon, 1971).

For low-acid foods, the organism of great concern is the toxin-producing *Clostridium botulinum.* Processing of such food should be adequate enough to destroy the said organism. In most TDT tests, however, owing to the potential dangers in working with *Clostridium botulinum, Putrefactive Anaerobe 3679* (*P.A. 3679*) is used instead. This mesophile is a non-toxic, easy to cultivate, spore-forming and gas-producing putrefactive anaerobe. Such characteristics are somewhat similar to those of *Cl. botulinum,* thus making *P.A.*

3679 a useful test organism for checking the adequacy of thermal processing.

With regards to comparison of approximate range of resistance in terms of D and z values, types A and B groups of *Cl. botulinum* are characterized by Dr values of 0.10 to 0.20 while the more resistant *P.A. 3679* is characterized by Dr values of 0.10 to 1.50 The z value of the two organism however, both range from 14 to 18 (Stumbo, 1973).

The z value employed in process calculation is a measure of the change in the resistance of the microorganisms with a change in temperature. This value is obtained by plotting the logarithm of D or some multiple of D (where D is the decimal reduction time or the time at a given temperature which will bring about a 90% destruction) against the corresponding temperature. Such a plot represents a TDT graph as shown in Fig. 1 (Stumbo, 1965). The D value at 250°F is represented by the symbol Dr.

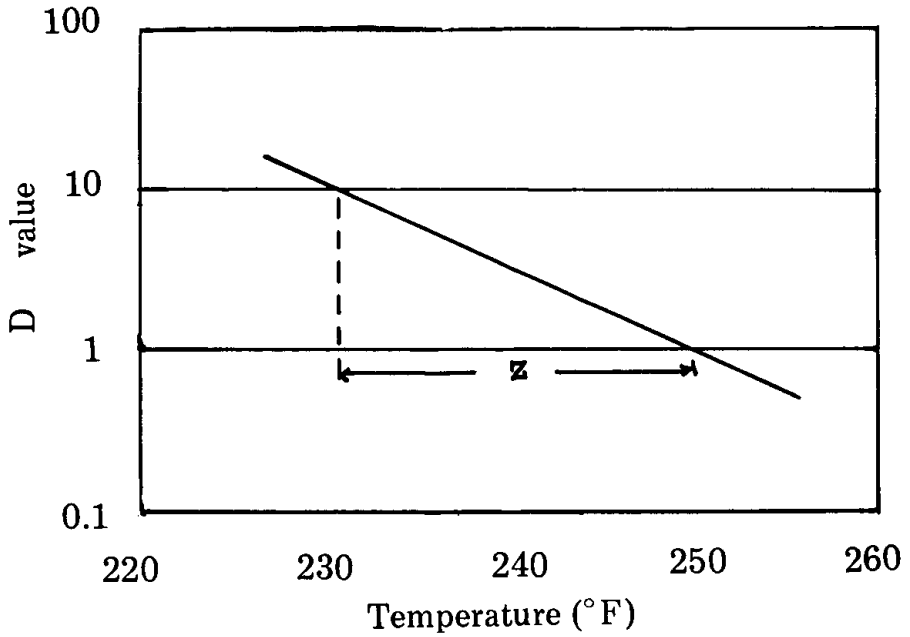

Fig. 1. Thermal death time curve passing through 1 minute at 250°F (Stumbo, 1965).

The Z and F values determined for a given spoilage organism in a particular product are used in calculating the minimum process that will prevent spoilage by the given organism. The sterilizing value or "lethality" of a given process is defined to be the length in minutes of an equivalent process at 250°F where the container contents, immediately upon the beginning of the process, attain the retort temperature (250°F). The contents are held at such temperature throughout the process and at the end of the process, immediate drop to a sub-lethal temperature occurs. The minimum process for the prevention of spoilage by the given organism should have a lethality equal to the F value of the organism (Ball and Olson, 1957).

F is generally some multiple of Dr. For *Cl. botulinum*, F is usually taken to be 12 times the value of Dr. This represents a reduction in microbial load from 10^{12} to 10^{0}. For *P.A. 3679*, F value is 5 times the Dr value, representing 99.999% destruction. This is equivalent to a reduction in microbial population from 10^{5} to 10^{0}. A process based on 99.999% destruction of *P.A. 3679* will satisfy the minimum processing requirements to prevent spoilage of *Cl. botulinum* (Stumbo, 1973).

Heat penetration. The objective of determining the rate of heat penetration is to obtain data needed for process calculations. Measuring the rate of heat penetration entails the use of a potentio-meter and copper-constantan thermocouples. The principle behind this test is that when dissimilar metal wires such as copper and constantan are joined at both ends to form a closed circuit, and one junction is at a higher temperature than the other, a current is set-up, the magnitude of which depends on the temperature difference between the two junctions (Baumgartner and Hersom, 1956).

According to Heid and Joslyn (1967), the rate of heating food products in containers is a function of the geometry of the container, physical properties of the food products, heat transfer characteristics of the heating medium and heat transfer characteristics of the container.

Heat transfer mechanism. There are three recognized modes of heat transfer to food products in containers: con-

duction, convection and broken heating. The last-mentioned is characterized by a shift from convection to conduction and vice versa. The products in this study exhibit either conduction or convection heating.

In conduction heating, the product remains stationary and the heat from the surrounding medium is transferred to the outermost layer of the food, then inwards to the center of the food without disturbing the food itself (Le Phu, 1974). The slowest heating and cooling point is at the geometric center.

In convection heating, the heat transfer in the food mass is aided by product movement within the container. Because of constant movement of the material, temperature of the food mass is nearly uniform throughout the process. Heat transfer occurs at a faster rate than in conduction heating. The slowest heating and cooling point for convection heating products is below the geometric center of the container. For No. 2 (307 x 409) cans, for instance, this point is about 3/4 inch from the bottom of the can.

Heat penetration graph. The heating curve is obtained by plotting temperature versus time on an inverted semi-logarithmic paper. The cooling curve is similarly obtained except that an upright semi-logarithmic paper is used. The majority of the heating and cooling curves will exhibit a straight line portion described by two parameters: f, the number of minutes required for the straight line portion of the heating or cooling curve to traverse one log cycle; and the j value which represents the time lag before the heating or cooling curve assumes a straight line. The f value for a product varies with can size. If the f value for a good product in one size of container is known, the f value of the same product in other sizes of containers processed under similar conditions can be calculated. This is done by simply multiplying the given f value by the appropriate conversion factor. However, when the conversion factor cannot be obtained, the new f value for a conduction heating product may be calculated from the following formula:

$$\frac{f_{h1}}{f_{h_2}} = \frac{(0.933)d_1{}^2}{d_1/1_1)^2 + 2.34} \quad \frac{(d_2/1_2)^2 + 2.34}{(0.933)d_2{}^2}$$

where

d = inside diameter of can (outside the diameter minus 1/8 in.)
1 = inside length of can (outside length minus 1/4 in.)
f_{h2} = known f

For convection heating products, can factors may be calculated according to the formula:

$$\text{Can factor} = \frac{rl}{r + l}$$

where

r = inside radius of can (outside radius minus 1/16 in.)
1= inside length of can (outside length minus 1/4 in.)

The f value of the unknown can be calculated by the following formula:

$$\text{f of the unknown} = \frac{\text{(can factor of unknown) x (f of known)}}{\text{(can factor of known)}}$$

The j value is usually invariable with can size (Joslyn, 1967).

Process calculations. To calculate the minimum required process for any product or the lethality of an existing process, one should have on hand heat penetration data and the thermal resistance characteristics, the F or Dr value and the z value, of the reference organism. There are two ways of cal-

culating the required process time or the lethality of an existing process. One can adopt as a basis the lethal heat received by the slowest heating point in the container. If the lethality based on this critical point is sufficient, then it is presumed that all other points would have more than the amount of heat required to reduce the microbial load per unit volume from some initial value to a desired low value. Critics of this point of view contend that the point or region of greatest probability of survival is not the point that receives the smallest amount of sterilizing heat action. Stumbo (1973) has developed a procedure for process calculations which is based on the number of surviving microorganisms in a container as the criterion of sufficiency of heat treatment. This method of process calculation is called the integrated lethality approach.

EXPERIMENTAL PROCEDURE

Standardization of Meat and Seafood Product Formulations

For each canned meat and seafood product, at least three formulations were made and presented to an average of ten panelists for sensory evaluation. Based on the statistical analysis of the sensory evaluation results using the Analysis of Variance method, the following formulations and procedures were adopted:

A. *Longanisa*

lean meat (pork)	37.500 kg
pork fat	12.500
prague powder	.025
salt (NaCl)	1.400
brown sugar	5.700
soy sauce	1.550
ground black pepper	.260
garlic (macerated)	.400
MSG	.050

1. Grind lean meat using the blade with the biggest diameter (approximately 1/4 inch).
2. Cut the pork fat into 1/4 inch cubes.
3. Combine fat and lean and mix with all the other

ingredients.

4. Stuff the meat mixture into the hog's casing using the extruder.
5. Twist the stuffed casings into 4-inch long longanizas.
6. Dry for 3 hours at 60°C.
7. Cut the links and make 5 to 7 perforations in each longaniza using well-sharpened, clean piercing needles.
8. Arrange longaniza vertically in cans.
9. Fill cans with boiling water leaving 1/4 inch head-space from the top of the can.
10. Exhaust to 180°F.
11. Seal.
12. Process.

B. *Lechon Paksiw*

lechon	50.000 kg.
liver	3.500
white vinegar (Mariz)	10.700
water	11.400
bread crumbs	1.200
sugar	10.200
salt (NaCl)	.975
kasubha (saffron)	.100
ground black pepper	.100
garlic (macerated)	1.185
onions	12.745
MSG	.150

1. Roast pork liver and grind using the smallest diameter blade.
2. Grind onions and garlic.
3. Combine ground liver, onions and garlic and pass through the colloid mill two times.
4. Boil vinegar without stirring for ten minutes.
5. Combine lechon (cut into 1½-inch squares) and all of other ingredients except kasubha and bread crumbs and let boil for 20 minutes.
6. Add bread crumbs and kasubha and boil again for another 10 minutes.
7. Separate meat from the sauce.

8. Fill meat into cans.
9. Add the sauce leaving 1/4 inch head space from the top of the can.
10. Exhaust to 180°F.
11. Seal
12. Process

C. *Dinuguan*

lean meat	37.500 kg.
pork fat (browned)	12.500
salt (NaCl)	.900
sugar	.400
ground black pepper	.200
pounded garlic	.400
oregano	.050
green pepper	.350
white vinegar	8.000
blood	14.000
broth	23.200
MSG	.250

1. Boil vinegar for ten minutes without stirring.
2. Combine blood with boiled vinegar and pass through the colloid mill twice.
3. Wash, then parboil the meat, and save the broth. Separate the lean from the fat and cut into 1 inch cubes.
4. Render the lard from the fat until the pieces are browned.
5. Remove the fat and the lard from the kettle and leave only just enough lard to sauté the garlic.
6. Sauté the garlic.
7. Combine spices, lean meat and browned fat and other ingredients into the sautéed garlic and boil for 10 minutes.
8. Add strained blood and vinegar little by little with continuous stirring and boil again for another 10 minutes.
9. Add the remaining broth and boil again for 10 min.
10. Fill into cans.
11. Exhaust to 180°F.

12. Seal.
13. Process.

D. *Caldereta*

beef (round, chuck or flank)	50.000 kg.
water	1.820
tomato sauce (Del Monte)	6.440
vinegar (Datu Puti)	1.140
ginger extract	4.180
hot sauce (Red Devil)	.190
garlic (macerated)	.665
onion	1.900
salt (NaCl)	.730
black pepper	.034
liver spread	1.140
pepper strips	3.000
potatoes	10.000
cooking oil	.630

1. Prepare ginger extract by blending 50 g. of ginger with 230 g. of water for every kilo of beef in a waring blender. Filter the extract through cheesecloth.
2. Sauté garlic and onion in oil.
3. Add beef sliced into 1½ inch cubes, salt and black pepper and cook for 15 to 20 minutes.
4. Combine water, ginger extract, tomato sauce, hot sauce and vinegar and add to sautéed meat.
5. Allow to boil for 30 minutes or until meat is slightly tender.
6. Add liver spread and bread crumbs and mix throughly. Allow to boil again for 15 minutes until sauce is just slightly thick in consistency and meat is tender.
7. Separate the meat from the sauce.
8. Fill meat into cans. Add pepper strips and raw potatoes cut into 1 inch cubes.
9. Add sauce leaving a 1/4 inch headspace.
10. Seal.
11. Process.

E. *Squid Adobo*

squid	70.000 kg.

vinegar (Del Monte)	4.065
water	4.065
salt	.625
garlic	.850
black pepper	.035
MSG	.067
Cooking oil	2.370

1. Wash and clean the squid without removing the ink bag.
2. Drain for 10 minutes.
3. Sauté garlic in oil.
4. Add squid and cook for about 5 minutes.
5. Add vinegar, water, salt, black pepper and MSG. Allow to boil for another 5 minutes.
6. Separate squid from the sauce.
7. Fill squid into cans.
8. Add the sauce leaving a 1/4 inch headspace from the top of the can.
9. Exhaust to 180°F.
10. Seal.
11. Process.

Preparation of Vegetables for Canning

A. *Papaya*

1. Soak whole, green papaya in chlorinated water.
2. Wash.
3. Peel.
4. Half, remove seeds, and cut into 2" x 1."
5. Soak in water containing 1% $CaCl_2$ (71°-79°C) for 15 minutes.
6. Fill into cans.
7. Fill with boiling 1% brine up to 1/4 inch from the top of the can.
8. Exhaust to 180°F.
9. Seal.
10. Process.

B. *Sitao*

1. Cut sitao into 4-inch long strings.
2. Sort, and choose straight, and uniform diameter strings.
3. Soak in chlorinated water.
4. Wash.
5. Fill into cans.
6. Add 1% boiling brine.
7. Exhaust to 180°F.
8. Seal.
9. Process.

C. *Langka*

1. Soak whole, green langka in chlorinated water.
2. Wash.
3. Peel. (This must be done as fast as possible followed by immediate soaking of the exposed parts in 0.1% citric acid.)
4. Slice in rectangular pieces, 1" x 1-½".
5. Fill into cans.
6. Add 1% brine at room temperature with .1% citric acid.
7. Half-seal.
8. Exhaust to 180°F.
9. Full-seal.
10. Process.

D. *Waterchestnuts*

1. Separate mature nuts by flotation. Mature nuts contain 4 to 7% starch and will not float.
2. Wash.
3. Blanch for 5 minutes.
4. Hand peel.
5. Fill into cans.
6. Add boiling 1% brine.
7. Exhaust to 180°F.
8. Seal.
9. Process.

E. *Baby Corn*

1. Dehusk the corn.
2. Grade and sort. Use corn with diameter of about 10 mm and approximate length of 75 mm.
3. Wash and clean corn.
4. Blanch for 5 minutes.
5. Fill into cans. Arrange corn vertically.
6. Add hot packing medium — 2% salt, 5% sugar.
7. Exhaust to 180°F.
8. Seal.
9. Process.

F. *Mushroom*

1. Sort fresh mushrooms, 3/4 inch in diameter, free from cracks, bruises and discolored portions.
2. Scrape off adhering soil and dust.
3. Soak in chlorinated water.
4. Wash.
5. Blanch in boiling water for 3 to 5 minutes.
6. Fill into cans.
7. Add hot 2% brine with 100 mg% ascorbic acid.
8. Exhaust to 180°F.
9. Seal.
10. Process.

Thermal Resistance of P.A. 3679

Preparation of Spore Suspension. For the production of spores of *P.A. 3679* liver broth was used. (The procedure for preparing this medium is presented in Appendix A.) The flasks of liver broth medium was inoculated with 1 ml of the stock culture of the test organism. A layer of sterile thioglycolate agar (2.8% agar and .2% thioglycolate) was used for sealing. These inoculated flasks were incubated at 89.6°F (32°C) for three weeks.

At the end of the incubation period, the resulting culture was filtered through sterile cheesecloth to remove

meat particles. The contents were then transferred to sterile screw-capped test tubes containing a few glass beads, then centrifuged for ten minutes to throw down the spores. Almost all the liquid was decanted and the spores were resuspended in the remainder by agitating the glass beads. This residual spore crop was suspended again in a sterile neutral phosphate buffer, recentrifuged to wash, the supernatant decanted off and the residual spores were again resuspended in phosphate buffer. The washing operation was done at least five times. The spore suspension was filtered through a double layer cheesecloth with glass wool to remove spore clumps. This spore suspension was heated for five minutes in boiling water to kill the vegetative cells and stored at 37.4° to 39.2°F (3° to 4°C) until used for thermal resistance studies.

Determining the "initial" number of spores. The "initial" number of spores refers to the spore count after the application of sufficient heat to activate most spores for germination. Based on several preliminary runs, the original spore suspension was diluted with neutral phosphate buffer to obtain a concentration of less than one spore per ml (Stumbo, 1973). With a sterile pipette, 1-ml. amount of this diluted suspension were distributed to 50 sterile test tubes. These were then heated at 220°F for 28 seconds in an oil bath to activate the spores, after which these were immediately plunged in a bath of cold water. The tubes were next subcultured in liver broth and then stratified with sterile thioglycolate agar. These were incubated at 89.6°F (32°C) for 21 days. Tubes which showed growth were counted. To compute for the most probable number of spores per ml of dilution, the Halverson and Ziegler's equation was used (see Appendix B).

Determination of heat resistance of P.A. 3679. Having obtained the MPN of spores in the original suspension, several dilutions were prepared using sterile phosphate buffer composed of M/15 KH_2PO_4 and M/15 Na_2HPO_4 with pH value of 7, as diluent. Usually, 10^4 to 10^5 spores per ml are used in TDT tests. One ml of the suspension was emptied into each of the screw-capped TDT tube (13 x 50 mm) contain-

ing 2 ml of either sterile phosphate buffer or sterile food medium. The tubes were then covered tightly and sets of six tubes for each time-temperature combination were placed in the wire baskets for the heat treatment. The baskets were immersed up to the neck of the test tube in a constant temperature oil bath equipped with a power stirrer.

The heating times were selected at regular intervals after a number of preliminary runs. The method recommended in NCA (1968) was followed wherein the shortest and longest times at 250°F (121.1°C) were plotted on a semilog paper with temperature on the lines were drawn through these points to obtain the estimated times at other temperatures.

The shortest and longest heating times at 250°F (121.1°C) were arbitrarily selected based on the trial and error method. If all the tubes showed growth at a particular time chosen, longer heating times were tried. In case all tubes were negative for growth, shorter heating times were selected. This method was repeated until the selected time intervals at 250°F showed both positive and negative tubes. Ideally, the shortest time selected should show all the tubes positive while the longest time should bring about negative results. The times between this interval should result in both positive and negative tubes.

Based on preliminary runs, the heating times selected for most products studied were the following:

220°F (104.4°C) — 155, 195, 235, 275, 305 minutes
230°F (110°C) — 50, 60, 70, 80, 90 minutes
240°F (115.5°C) — 16, 19, 22, 25, 27 minutes
250°F (121.1°C) — 6, 7, 8, 9, 10 minutes

After immersing in the oil bath at different heating times, the tubes were immediately plunged into a bath of cold water. The phosphate buffer suspensions were subcultured in the exhausted liver broth, sealed with thioglycolate agar and incubated at 89.6°F (32°C) for about 3 weeks. The food media were sealed also with thioglycolate agar but without subculturing and incubated also at 89.6°F (32°C) for three weeks. Growth was evidenced by gas production and development of characteristic putrid odor.

Tubes which were positive for growth were counted.

To compute for "b" which refers to the most probable number of spores surviving each time-temperature combination, the Halverson and Ziegler's equation was used. Knowing "b", and "a", the initial number of spores present in all samples, the D value was computed. (Computation for these values are presented in Appendix C.) The computed D values were plotted against their corresponding temperature in a semi-logarithmic paper. The best straight line through the experimental points were drawn to obtain z.

Determination of heating lag time. To account for the delay in reaching the desired temperature, heating lag in the screw-capped TDT tubes were measured using a copper-constantan thermocouple inserted in the caps. The length of the thermocouple wires was adjusted such that it reached the slowest heating point in the tube. These tubes were held stationary in an oil bath heated to a constant temperature of 250°F (121.1°C) while heat penetration readings were taken at pre-determined time intervals. The time-temperature readings were plotted on a semi-logarithmic paper to obtain data needed for lag correction (calculation for determining lag correction is shown in Appendix D). These values were subjected at different temperatures.

Heat Penetration

In the preliminary trials, the slowest heating point in each of the canned product was determined by boring several holes in the can through which thermocouples were inserted. These were located in this manner: one at the middle of the can, another at a point 3/4 inch from the bottom and a third, midway between the two points. Among the meat products, dinuguan, lechon paksiw and caldereta were heated primarily by conduction while all the other products primarily by convection. Hence, for the subsequent trials, thermocouples were located at the middle of the can for conduction-heating products, and at 3/4 inch from the bottom of the can for the convection-heating products.

The heating and cooling curves were plotted on semi-

logarithmic paper to obtain the data necessary for process calculations.

Process Calculations

The integrated lethality concept was applied. It was assumed that the initial spore load of the product was 1.0/g. The target spoilage level was set at one can per 10^5 cans produced. (See Appendices F and G for sample calculations.) The symbols adopted in the mathematical computations are defined in Appendix H.

Cut-out Test

Representative samples from the pilot scale production were incubated at 131°F (55°C) for 7 to 10 days, and at 89.6°F (32°C) for 14 to 21 days. The remaining cans were held at the room temperature. After incubation the cans were examined for the presence of swells.

Microbiological tests were conducted to detect the presence of flat sours and anaerobes by using Dextrose Tryptone Bromcresol Purple Agar (DTBcp) and liver broth, respectively. The vacuum and the pH were also taken.

For samples stored at room temperature, representative cans were examined for external and internal can conditions, can seam length and width, vacuum, headspace, pH, net weight and drained weight of the can contents.

RESULTS AND DISCUSSION

Product Formulations

Vegetables. The objective of canning is not merely to prevent decomposition but also to ensure a high quality of the finished product (Adam, 1962). Preliminary runs on papaya canning showed that papaya cannot withstand the necessary heat treatment as evidenced by its mushy texture. Weier and Stocking (1949) reported that heat affects the his-

tological features of plant tissue resulting in flabbiness or loss of turgor. However, this was easily remedied by soaking in water containing 1% calcium chloride ($CaCl^2$) at 71 to 79°F for at least 15 minutes. The same procedure adopted in canning potatoes showed an improvement in the control of potatoes during canning (Mitchell, 1972). Hoogzand and Doesburg (1961) attributed the favorable effect of low temperature-long time blanching to the activation of pectic enzymes in the plant product which then lowers the degree of esterification of the pectic substances. This in turn enhances the firming effect of the calcium salts added. The calcium ions act as links between the carbonyl groups in the polygalacturonic acid units thereby causing a strengthening of the binding force between cells and, hence, resulting in a firm texture (Mohammadzadeh-Khayat and Luh, 1968).

Similar to papaya, texture was also the main problem in sitao. Though sitao pieces retained their shape after processing and incubation, they were very soft and mushy.

The addition of calcium chloride to the brine did not show any improvement in texture. This might have been due to the slow concentration of pectic substances in sitao or to the high degree of esterification of the pectin present so that it is not precipitated by the calcium salts (Hoogzand and Doesburg, 1961). Cruess (1958) recommended acidification, which is being done in canned asparagus, beans, cauliflower and lettuce. The lowering of pH below 4.5 would allow processing at 212°F.

A preliminary study showed that addition of 1% citric acid to the brine lowered the pH to 4.7. While there was a great improvement of texture as a result of adding 1% citric acid, this was marred by the too acidic flavor. Another trial was performed which included the addition of .5% citric acid. There was a slight improvement in the texture but an acidic flavor was still noted. Hence, citric acid was not incorporated in the brine in the final formulation.

The main problem encountered in langka canning was the pink discoloration. The use of acids such as ascorbic acid, acetic acid, and citric acid lessened the graying discoloration but did not affect the pink discoloration. This was

accompanied by a lowering of the pH from 5.2 to as low as 4.2 depending on the amount of acid added. Inasmuch as lowering of pH did not prove to be successful, an increase of pH using salt such as calcium hydroxide ($Ca(OH)_2$), sodium carbonate (Na_2CO_3), and calcium oxide (CaO) were tried. The pH of the final product was increased to as high as pH 6.7. This was accompanied by the development of an intense red color as compared to the light pinkish gray discoloration in the control samples.

Furia (1968) reported that the addition of sequestrants prior to blanching inactivated the naturally occurring metals and usually prevents undesirable color changes. His findings showed that 100 to 500 ppm of sodium ethylenediaminetetraacetic acid (Na_2 EDTA), citrate or phosphate could inhibit "pinking" in certain canned products. In langka, however, 500 ppm of the Na_2 EDTA in brine as well as 1000 ppm of Na_2 EDTA in blanching water resulted in pinkish-yellow discoloration. Also, the use of 200 ppm trisodium citrate gave a deep pink discoloration.

Blanching not only intensified the brown discoloration but also resulted in a very soft texture in the final product.

Finally, the effects of citric acid on the color of langka were compared but this time accompanied by half-sealing before exhausting. The use of citric acid gave the best results or the whitest product as compared to all the previous tests. However, half-sealing before exhausting and without prior blanching of the product resulted in a very large headspace.

The use of .1% citric acid in the immersion water during cutting helped in the prevention of oxidative browning. Cruees (1958) and Luh and Phitakpol (1972) recommended the use of dilute brine also to prevent oxidative browning.

Mathew and Parpia (1971) attributed both enzymatic and non-enzymatic browning reactions to the polyphenols present in the plant product. These color changes or browning ranging from pink to bluish black, are not acceptable to consumers (Gorin and Jans, 1971).

Luh and Phitakpol (1972) observed a progressive increase in browning of peach halves wherein the post-canning temperature was 37°C or higher. This was accompanied by a

decrease in the leucoanthocyanin content of the peaches. Hence, for better color retention, they recommended efficient and rapid operations, preferably within 10 to 15 minutes after peeling and storage temperatures of canned products of 20°C or lower.

An interesting observation when the experimental samples were compared to a commercial brand showed that the latter changed color from grayish white to blue during sensory evaluation. This could be similar to the rutin discoloration in asparagus which is defined as discoloration occurring after the container is opened and the product exposed to the air (Davis, *et al.*, 1961).

The flavonol glucoside was identified by Stevenson as pointed out by Davis, *et al.* (1961) as rutin. The basic chemical reaction was theorized to be the oxidation of the ferrous (Fe^{++}) ion; the ferric (Fe^{+++}) ion in turn combines with rutin or a rutin complex, causing discoloration. This was controlled, however, by citric acid of concentrations up to 0.05% based on total can contents of canned all-green asparagus. This view was also supported by Hernandez and Vosti (1963).

Chandler's (1964) studies on cauliflower showed that while some products develop pink to green black discolorations on processing, other samples retain satisfactory color when processed under identical conditions. Varieties and variants, agricultural treatments, time of picking, and duration and temperature of storage before processing have all been shown to affect the degree of discoloration. Bate-Smith (1962) in his study of plant polyphenols, stressed the importance of eliminating the undesirable characteristics in food plants by breeding. Phenolic compounds like leucoanthocyanins which are mainly responsible for discoloration during processing are controlled by genes which can be eliminated by plant breeding.

So far, the problems in langka canning have not been solved totally. More effective methods still have to be explored.

The problems encountered in processing waterchestnuts are: difficulty of peeling; maturity of the available wat-

chestnuts since about 80 to 90% are undermature based on the flotation test (floaters in 2% brine); and the pink or gray discoloration on the root end after processing.

The use of brine containing 2.85% salt, 5% sugar and 0.2% citric acid recommended by Rodriguez, *et al.* (1964) did not improve the color at all. Moreover, the flavor of the canned waterchestnut with this brine solution was strong.

Rodriguez, *et al.* (1964) reported that the membrane lying below the pericarp and surrounding the cotyledons contained leucoanthocyanin and on canning, pink color develops in the product.

Again the discoloration problem in waterchestnut is yet far from being solved. An improved product,however, could be obtained if waterchestnut is canned immediately after harvest and that the time lag from peeling to canning is as brief as possible.

In the processing of mushroom, the raw material quality is a critical factor. Mushroom is a delicate and highly perishable vegetable so that if not consumed or processed right after harvest, it immediately develops signs of loss of freshness such as increase in cap diameter, decrease in stem diameter, increase in mushroom height, darkening and shriveling (Cunamay, 1972). Such changes make the mushrooms unsuitable either for consumption as fresh or as raw material for canning.

Blanching is an important step in the canning of mushroom primarily to inactivate the enzymes, particularly tyrosinase, which cause discoloration. In addition, blanching also reduces the microbial load and precooks the product.

Besides enzymatic discoloration, mushrooms also exhibit "chemical browning" or Maillard reaction between the reducing sugars and the amino acids; hence, there is a need for adding a preservative to prevent this occurrence. For this purpose, ascorbic acid was incorporated in the brine.

Canning of baby corn was based on preliminary studies on this variety of corn conducted by Villanueva (1974). Just like in most vegetables, blanching was done to inactivate the enzymes causing harmful changes to the food, to remove much of the tissue gas including oxygen, and to reduce the

bulk (Weiser, Mountney and Gould, 1971).

The brine concentration was established based on its effects on sensory qualities, particularly, color and flavor. A packing medium composed of 2% salt, and 5% sugar was found to bring about a pleasing combination of salty and sweet flavor and the development of a dull yellow color. Findings by Villanueva (1974) revealed that a higher concentration of sugar in the packing medium resulted in a too sweet product and the development of a slightly brown discoloration. The latter effect could be due to Maillard reaction between the reducing sugars and the amino acids in the baby corn.

Meats. The manner of preparation of longaniza as well as the condiments and spices used differ in various regions in the country, but the main ingredients, particularly, potassium nitrate (KNO_3) and salt (NaCl), remain essentially the same.

In the manufacture of longaniza, the quality of the final commodity depends on the raw material quality, the kind and cut of meat used and the proportion of the ingredients. The mixture composition has a decisive influence on the quality factors of the product such as texture, flavor, appearance and nutritive value (Karmas, 1978).

The most important precooking and pre-marketing operation for longaniza is the stuffing-linking operations. After the meat and the ingredients have been mixed together, the resultant mixture is stuffed into natural casing. The resultant strand is formed either manually or, preferably, by mechanical means into links of predetermined length by tying at regular intervals along the length of the strand.

Pre-drying is also another pre-treatment applied to longaniza. This is done in order to reduce the moisture content of the product which in effect makes the longaniza strands firmer. Firm strands afford greater resistance to heat and mechanical stresses during processing.

Recently, greater importance has been given to the role of certain curing ingredients in the development of flavor in meat products rather than to their role in preservation. This

is especially true in sweet-cured products such as longaniza de jamon which is more predominantly sweet than salty. The amount of salt added is adjusted to obtain the desired flavor in the cured product rather than to cause a stabilizing effect against microbial deterioration. Sugar is another ingredient contributing to flavor development. In addition to its sweetening effect, sugar also provides a favorable medium for the growth of flavor-producing bacteria. Nitrates and nitrites are added mainly to fix the meat color. In addition to this primary function, the action of nitrites on the muscle tissue imparts a characteristic flavor (Miller, 1958). Recent findings on the effect of sodium nitrite on the flavor of frankfurters show that a spicy formulation is not sufficient to bring about the desired frankfurter flavor if sodium nitrite is not incorporated in the curing mixture (Wasserman, 1972).

Nitrate (NO_3) does not exercise any direct effect on bacteria but appears to protect in some indirect way the nitrogenous tissue against bacterial infection. The theory states that hydroxylamine is formed during the bacterial reduction of nitrates. This inactivates the catalase, permitting the accumulation of hydrogen small concentrations (Miller, 1958).

Different kinds and cuts of meat exhibit different swelling or water-holding capacity. This phenomenon accounts for the difference in tenderness which is influenced by the degree of hydration of proteins as well as by pH. Studies show that the swelling is minimum at around pH 5.0. According to the zwitter-ion theory, the swelling effect of acids or bases on protein gel is due to the cleavage of electrostatic cross-linkages between peptide chains of proteins. An excess of acid decreases the water-holding capacity of muscles. Here, the marked binding of anions, like that of chloride (Cl^-) ions, probably screens the positive charges of amino acids and imidazol groups. Therefore, the repulsion between these charged groups is lowered; the peptide chain can approach each other and more water is immobilized. This phenomenon together with osmotic phenomena explains to some extent the dryness of salted products (Borgstrom, 1968).

Pork dinuguan, lechon paksiw and caldereta are given

some preservative action by vinegar. The principal action of vinegar on bacteria is due to its acetic acid content. Vinegar has been found to possess bacteriostatic and bactericidal properties in excess of that which can be attributed to pH alone. The inhibitory effect and lethal effect of a mixture of acetic acid and salt is very pronounced. Pathogenic bacteria are destroyed easily in pickle composed of 3% acetic acid (HAc) and 3½% salt (NaCl) (Miller, 1958).

The addition of bread crumbs to lechon paksiw and caldereta and liver spread to lechon paksiw are for texture as well as for flavor development. The amount of bread crumbs added, however, must be only sufficient to create a smooth texture of the sauce and not too much to make it into a paste. The resulting consistency of the product greatly affects its heat penetration characteristics. The more viscous the product, the longer the time it takes for the coldpoint of the product to reach the desired temperature since the mode of heating is by conduction.

Squid. The basic ingredients of squid adobo are vinegar, garlic and pepper. Vinegar, aside from contributing to the development of characteristic adobo flavor, serves as a preservative. The three other basic ingredients were added mainly for flavor. In addition, monosodium glutamate (MSG) was incorporated to intensify the inherent flavor of the food.

Prior to canning, precooking of squid should also be done only until the liquid is about to boil; otherwise, there would be excessive shrinkage and too much softening of the tissue.

Selection of Type of Can

Of great importance in canning is the selection of the type of can to be used. It is well-known that there are microbiological as well as chemical causes of spoilage in canned products, the latter factor being due to reaction of the food with the tin coating of the container.

Chemical spoilage is manifested by corrosion which is responsible for a number of defects in canned food products,

the most notable of which is the production of hydrogen resulting in swelling of the cans. Besides this effect, other signs of corrosion are etching of the surface of the plate, internal rusting of the can, staining of the tin plate or discoloration of the can contents by the corrosion products and dissolution of the tin (Woolen, 1969 as cited by Fonacier, 1977).

The type of can used greatly influences the onset and extent of corrosion; hence, the type of can should be suited to the particular food material. Previously, plain, unprotected tin plate was used almost exclusively for canned foods. However, as a result of development over the past years, there are various types of can with different protective coatings available. These linings act as physical barriers between the metal and the corrosive food material and thereby act as additional protective barrier. Among the types of coating largely employed are oleresinous, heat reactive phenolic, oil reactive phenolic, polybutadiene, epon, vinyl, alkyd and wax (Cruess, 1958 and National Canners Association, 1968).

For the products studied in this research, namely: corn, caldereta, dinuguan, lechon paksiw, longaniza, and squid adobo, the type of can used was the C-enamel (corn-enamel). This has been recommended for foods which are high in protein content. In the processing of such foods, the protein content may be broken down to produce sulfur compounds. Unless the cans are coated with C-enamel, these compounds may react with the iron of the container, thereby producing black iron sulfide. C-enamel is an eleoresinous lining into which finely divided zinc oxide is incorporated. This compound reacts with the sulfur compounds of the foods producing white zinc oxide (Cruess, 1958 and National Canners Association, 1968).

Willett and Germain (1949) as cited by National Canners Association (1968) state that the use of full inside C-enameled cans for products where some plain can parts are specified results in grayish to black discoloration of the canned products, apparently after the cans are opened. This type of discoloration is due to the chemical combination of small amounts of iron derived from the can with tannin or complex derivatives of gallic acid normally found in products

like green beans and asparagus. When the cans are opened, the iron is in the divalent or incompletely oxidized state, in which the iron-tannin compound is colorless; hence no discoloration of products is noticeable. Upon exposure to air the iron is oxidized to the trivalent state in which the iron-tannin compound has a dark color varying from yellow brown to green black. Presence of plain can parts results in the formation of a colorless tin-tannin compound rather than iron-tannin complex which produces the product discoloration (National Canners Association, 1968).

Another type of can used for some vegetables studied, namely: sitao, langka, waterchestnut, papaya and mushroom, is the ORC (phenolic-oleresinous) lacquered can. This has been recommended for fruit juices and highly colored fruits. The acidity of the food has an effect on its corrosive action but the relation is not a direct proportion. Products of the same pH, therefore, do not necessarily have the same corrosive action (Hartwell, 1951 as cited by Salcedo, 1977).

There are other factors such as the presence of depolarizers like anthocyanin, in the case of langka, and the presence of oxygen which contribute significantly to the corrosive action of food. The lacquer hinders the dissolution of tin in the canned food by acting as a physical barrier between the metal and the corrosive liquid. The protective effect of the lacquer therefore depends on the efficiency of lacquer coating.

Internal corrosion of lacquered cans is explained by Remo (1969) as follows: Corrosion starts as discontinuities in the form of pinholes, then fractures occur. The formation of a scratch in a lacquered can then exposes iron, tin and stannous hydroxide ($Sn(OH)_2$). As a result of this mechanical damage, not only is the lacquer film exposed but also the underlying tin coating. This exposes the steel base which reacts with the organic acids of the food, thereby producing hydrogen and hence, bulging of the can.

The change in color of the normal bright tin to dull grey is due to the reduction of the oxide film of stannous oxide by nascent hydrogen and depositing of tin in a spongy state

on the metal surface. The reduction reaction destroys the adhesion of the lacquer film, consequently exposing more tin surface to the food material.

Heat Penetration

In the study of process times, the rate of heat penetration into the canned food is measured by the use of a thermocouple (Alstrand and Benjamin, 1949). Since temperature indicates intensity of heat energy, measurement of the intensity of heat effect at a point over a period of time is done by determining the rate of rise and fall of temperature at the point (Ball and Olson, 1957).

All the six vegetables were heated primarily by convection. Among the meat products, longaniza was heated by convection while lechon paksiw, dinuguan and caldereta were heated by conduction. Squid adobo also exhibited convection heating.

Convection currents in a heated upright can are in a vertical direction. In case a solid material impedes the vertical direction of the current, the flow is diverted around the obstruction to the nearest point at which a vertical motion can be resumed. Hence, even the alignment of food pieces in the can can affect the rate of heat penetration (Ball and Olson, 1957; National Canners Association, 1968). For sitao, green papaya, baby corn and longaniza, the pieces should be arranged in a vertical position to facilitate heat penetration. For convection heating products packed in No. 2 (307 x 409) cans, the point which receives the least amount of heat is located 3/4 inch from the bottom along the vertical axis (National Canners Association, 1968).

In conduction heating, the product is stationary and heat from the surrounding medium is transferred to the outermost layer of food in the container, then inward to the center of the food mass without displacement of any portion of the food. The temperature profiles of conduction heating products, at any given time, are symmetric at the can center. This is the point at which the temperature is minimum, hence the coldpoint or slowest heating point.

The heating and cooling curves of all products studied are shown in Figures 2 to 7. A summary of the average values of the heat penetration parameters of all the products studied are shown in Table I.

The f_h value, which refers to the time in minutes required for the straight-line portion of the heating curve to traverse one log cycle, varies greatly with the different products. It is a measure of the rate of heat penetration in the product. This is markedly affected by the physical properties of the food, the heat transfer characteristics of the packing medium and heat transfer characteristic of the container. The more viscous the consistency of the packing medium, the bigger the f_h value. Hence, as presented in Table I, the f_h values of conduction heating products (lechon paksiw, dinuguan and caldereta) are much bigger than those of convection heating products (papaya, sitao, green langka, waterchestnut, mushroom, baby corn, longaniza and squid adobo).

Thermal Death Time (TDT)

The duration of heating applied to the spore suspension was based on the observation that a suspension with 10,000 or more spores in phosphate buffer could survive 12 to 14 minutes heating at 240°F and could be destroyed in 13 to 15 minutes at the same temperature. Heat resistant spores, however, can survive heating times of 18 to 20 minutes or more at 240°F (National Canners Association, 1968). Based on this finding, the shortest and longest heating times were chosen.

The actual heating time was corrected for lag to account for the heating time during which the contents of the TDT tubes were at temperatures below the oil bath temperature. The value of the heating lag for each product are presented in Table II. (The method of computation is shown in Appendix D.)

At least four trial runs were performed for the TDT study. Results for each product are summarized in Table III. TDT curves are shown in Figure 8.

The heat resistance exhibited by *P.A. 3679* in a particular suspending medium is measured by the D_r and z values. Inasmuch as the only variable was the suspending medium, any change in the D_r and z values could be attributed solely to the ability of the substrate to support the growth of *P.A. 3679* after heating. Variations in the values of D_r and z for the different suspending media were also reported by Reed, *et al.* (1951); Reynolds *et al.* (1953); and Stumbo, *et al* (1950).

Among the meat products, *P.A. 3679* spores suspended in longaniza puree exhibited the least heat resistance. This could be due to the sodium nitrite and sodium chloride added to the product.

Peralta (1977) showed that the heat resistance of *P.A. 3679* spores, expressed in terms of D values, decreased as levels of nitrite increased, with the decrease most marked from 150 to 200 ppm $NaNO_2$ at 0% NaCl. With the addition of salt, a marked reduction in the thermal resistance was noted even at an added nitrite level of as low as 50 ppm.

Many workers have shown that the effect of nitrite on microbial activity are: 1) enhanced destruction of spores by heat; 2) an increased rate of germination of spores during the heat process followed by death of the germinated spores; 3) the prevention of the germination of spores that survived the heat process; and 4) the production of an inhibitory substance from the reaction of nitrite with some component of the meat during the curing process (Ashworth and Spencer, 1972; Perigo, *et al.*, 1967; Spencer, 1967; Duncan and Foster, 1968 as cited by Peralta, 1977).

Process Calculations

By combining mathematically the heat penetration data and the parameters from the thermal death time curve, the minimum process time for a canned product is established.

Table IV shows a summary of the processes for the different products and the specified conditions. The mathematical calculations are shown in Appendix F.

Storage Studies

A pilot scale production of each product, except baby corn, was carried out using the recommended minimum process. Microbiological examination and physico-chemical tests results showed that the products are sound. Storage tests on green papaya, green langka, mushroom, sitao, lechon paksiw, dinuguan ang longaniza have given consistently good results. Storage studies for squid adobo and caldereta are still going on.

Pilot scale production of canned baby corn could not be carried out due to the inavailability of raw materials.

SUMMARY AND RECOMMENDATIONS

This research was conducted with the main objective of establishing the minimum thermal processes for low acid foods which include six vegetable products, namely, dinuguan, longaniza, lechon paksiw and caldereta; and a seafood, squid adobo.

Formulation of these products was based on related studies on the products concerned and on sensory evaluation tests.

To determine the minimum thermal process, two tests were performed — heat penetration and thermal death time (TDT). Measurement of the rate of the heat penetration in each product was facilitated by the use of needle type thermocouples (Ecklund). In the TDT test, the mesophilic, nontoxic and gas producing *Putrefactive anaerobe 3679* (*P.A. 3679*) was used as reference organism. Process calculation was done using the integrated lethality approach recommended by Stumbo (1973).

The established minimum thermal process for each product was tested by pilot production. This was not done, however, on baby corn due to inavailability of raw materials.

For storage study, microbiological examination, physiochemical tests and sensory evaluation were conducted. Results of tests done on products produced on pilot scale and stored at room temperature for at least three months and at incubation temperature for 2 to 3 weeks showed that the canned products were sound. However, for caldereta and squid adobo storage studies are still on going and results have been obtained for only one week incubation at 131°F (15°C) and 89.6°F (32°C).

This research also included preliminary studies on the effect of thermal process established and retention of nutrients particularly thiamine, in the two products — lechon paksiw and sitao. However, due to limited time, initial studies covered only the setting up of standardized procedures for the quantitative determination of thiamine using the thichrome method.

It is recommended that further research on nutrient retention be made not only on the two products mentioned but also on the other meat and vegetable products studied for minimum thermal process.

*Table I. Average values of heat penetration data of the different products at $T_r = 250^\circ F$ and $T_w = 80^\circ F$.**

Product	fh = f_c	$j_{ch} = j_{cc}$
Sitao	4.19	1.62
Mushroom	5.20	1.00
Waterchesnut	8.75	1.47
Baby Corn	9.50	1.29
Squid Adobo**	11.50	2.00
Papaya	12.73	1.91
Langka	13.46	1.57
Longaniza	22.50	1.20
Caldereta**	47.00	2.00
Lechon Paksiw	82.00	2.00
Dinuguan	91.23	1.90

*All products except caldereta and squid adobo were packed in 307 x 409 cans.
**Packed in 307 x 201.25 cans.

Table II. Corrections for lag in the TDT tubes containing phosphate buffer or food sample.

Sample	Lag correction (min)
Phosphate buffer	2.50
Papaya puree	3.00
Sitao puree	3.60
Langka puree	3.10
Waterchestnut puree	3.70
Mushroom puree	1.20*
Baby corn puree	3.20
Dinuguan puree	3.70
Lechon paksiw puree	4.90
Longaniza puree	4.00
Caldereta puree	5.26
Squid adobo puree	4.75

*Due to inavailability of the equipment necessary to carry out the experiment on lag times, the value of lag correction for mushroom was adopted from the study of Sognefest and Benjamin (1944) on heating lag time for different suspension materials.

Table III. Values of z and D of P.A. 3679 suspended in the different media.

Medium	z	D_r
Phosphate buffer	20.0	1.00
Langka puree	13.0	0.20
Sitao puree	16.5	0.47
Papaya puree	16.0	0.40
Waterchestnut puree	17.5	0.73
Mushroom puree	18.5	1.60
Baby corn puree	18.4	0.98
Dinuguan puree	18.0	1.20
Lechon paksiw puree	16.5	1.10
Longaniza puree	20.0	1.05
Caldereta puree	17.5	1.20
Squid adobo puree	17.8	0.94

Table IV. Summary of the processes for different products.

CAN NAME	CAN DIMENSION	Time at 240°F T_{ih}* 70°F	Time at 240°F T_{ih} 160°F	Time at 250°F T_{ih} 70°F	Time at 250°F T_{ih} 160°F	F_o	Maximum Fill-in Wt (g)
Corn							
No. 1 (picnic)	211 x 400	30	27	17	15	4.83	140
No. 2	307 x 409	33	30	20	17	4.82	250
No. 2½	401 x 411	35	32	22	19	4.81	390
No. 10	603 x 700	44	39	30	25	4.80	1350
Langka							
No. 1 (picnic)	211 x 400	**		18	15	2.27	160
No. 2	307 x 409			22	18	2.45	290
No. 2½	401 x 411			25	20	2.56	450
No. 10	603 x 700			36	29	2.99	1600
Mushroom							
8 Z Tall	211 x 304	47	46	17	16	11.82	110
No. 1 (picnic)	211 x 400	48	47	18	17	11.89	140
No. 2	307 x 409	53	51	20	19	12.83	260
No. 2½	401 x 411	53	51	20	20	12.62	400
No. 10	603 x 700	61	58	28	25	13.47	1400
Papaya							
No. 1 (picnic	211 x 400	26	23	16	13	3.39	160
No. 2	307 x 409	30	26	22	18	3.52	290
No. 2½	401 x 411	33	29	24	20	3.62	450
No. 10	603 x 700	45	38	34	28	3.95	1600
Sitao							
No. 1 (picnic)	211 x 400	18	17	8	7	3.70	140
No. 2	307 x 409	21	20	11	10	3.79	250
No. 2½	401 x 411	23	21	12	11	3.91	390
No. 10	603 x 700	28	26	16	14	4.23	1350

Caldereta							
No. 1 (picnic)	211 x 400	119	102	88	71	7.24	300
½ Flat	307 x 201.25	105	91	76	62	6.95	260
No. 2.	307 x 409	170	143	131	104	7.60	607
No. 2½	401 x 411	210	175	165	130	7.74	876
No. 10	603 x 700	425	341	347	263	9.13	3188
Dinuguan							
No. 1 (picnic)	211 x 400	116	97	88	71	6.90	170
½ Flat	307 x 201.25	110	93	69	67	6.87	160
No. 2	307 x 409	165	135	105	103	7.09	330
No. 2½	401 x 411	205	166	164	128	7.19	510
No. 10	603 x 700	407	314	345	259	7.68	1770
Lechon Paksiw							
No. 1 (picnic)	211 x 400	112	92	82	66	7.24	190
½ Flat	307 x 201.25	106	90	77	63	7.20	170
No. 2	307 x 409	158	131	122	97	7.87	350
No. 2½	401 x 411	196	160	154	121	7.97	550
No. 10	603 x 700	394	311	325	248	9.03	1910
Longaniza							
No. 1 (picnic)	211 x 400	44	38	31	25	7.21	220
No. 2	307 x 409	50	43	36	30	7.45	390
No. 2½	401 x 411	55	46	40	32	7.54	600
No. 10	603 x 700	73	60	56	44	7.99	2080
Squid Adobo							
No. 1 (picnic)	201 x 400	39	36	26	22	4.74	330
½ Flat	307 x 201.25	37	34	23	20	4.43	260
No. 2	307 x 409	45	40	30	25	4.76	607
No. 2½	401 x 411	48	43	33	28	4.76	876
No. 10	603 x 700	64	56	46	38	4.77	3188

*T_{ih} — initial temperature

**A longer process time at a lower temperature brings about a more intense discoloration. Hence, prolonged exposure to heat is not recommended.

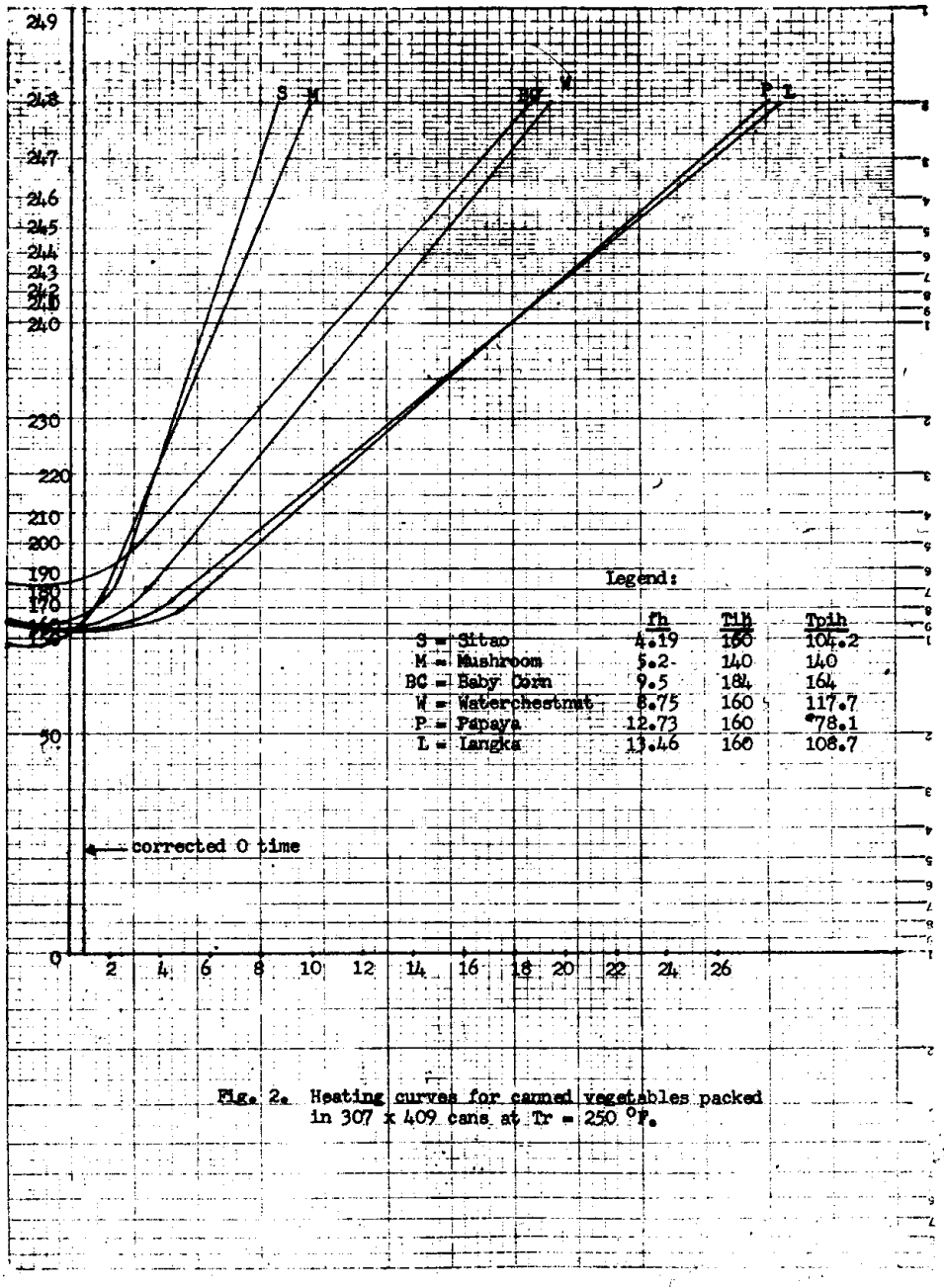

Fig. 2. Heating curves for canned vegetables packed in 307 x 409 cans at Tr = 250 °F.

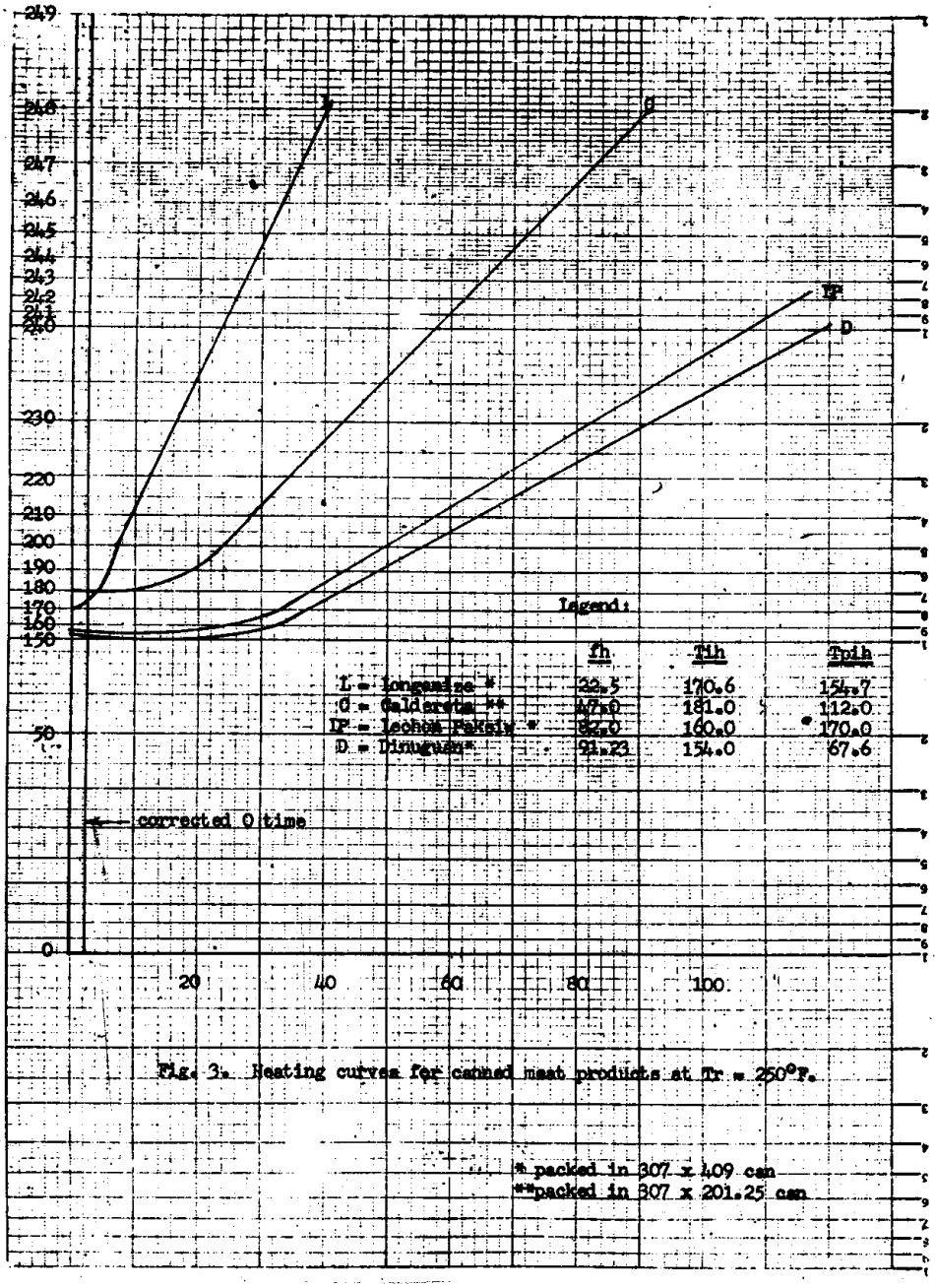

Fig. 3. Heating curves for canned meat products at Tr = 250°F.

* packed in 307 x 409 can
**packed in 307 x 201.25 can

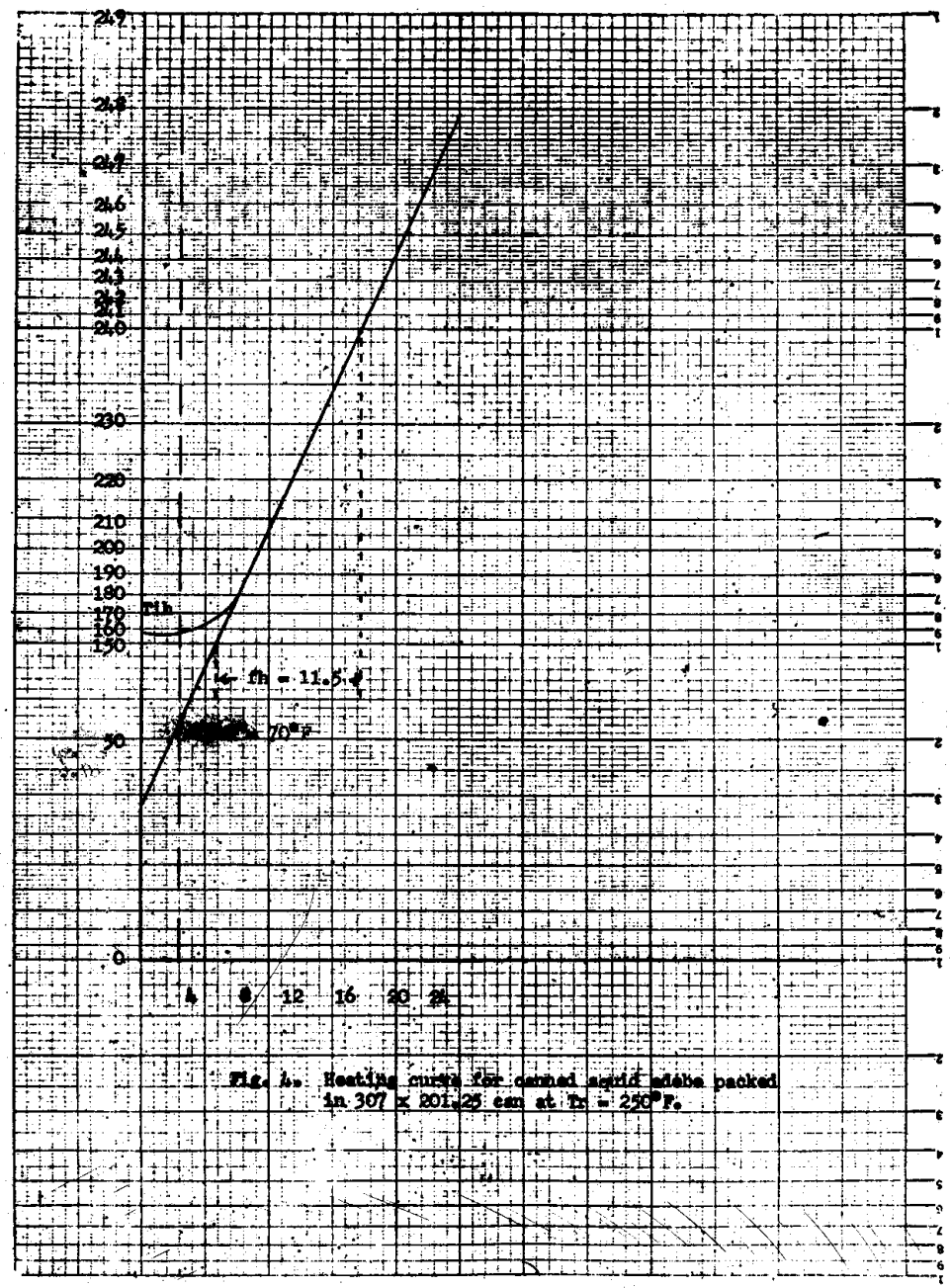

Fig. 4. Heating curve for canned agrid adobe packed in 307 x 201.25 cans at T_R = 250°F.

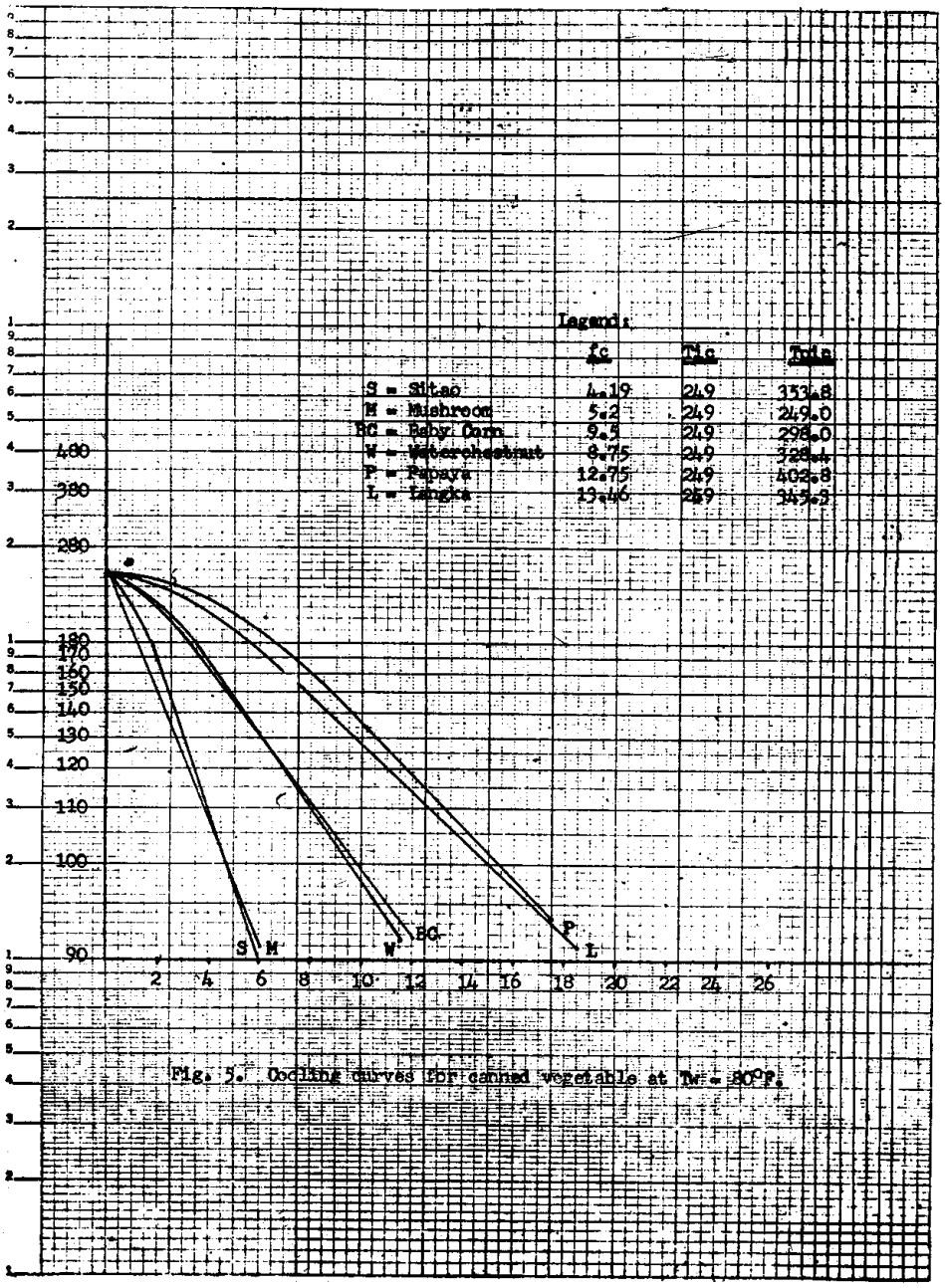

Fig. 5. Cooling curves for canned vegetable at $T_W = 80^{\circ}F$.

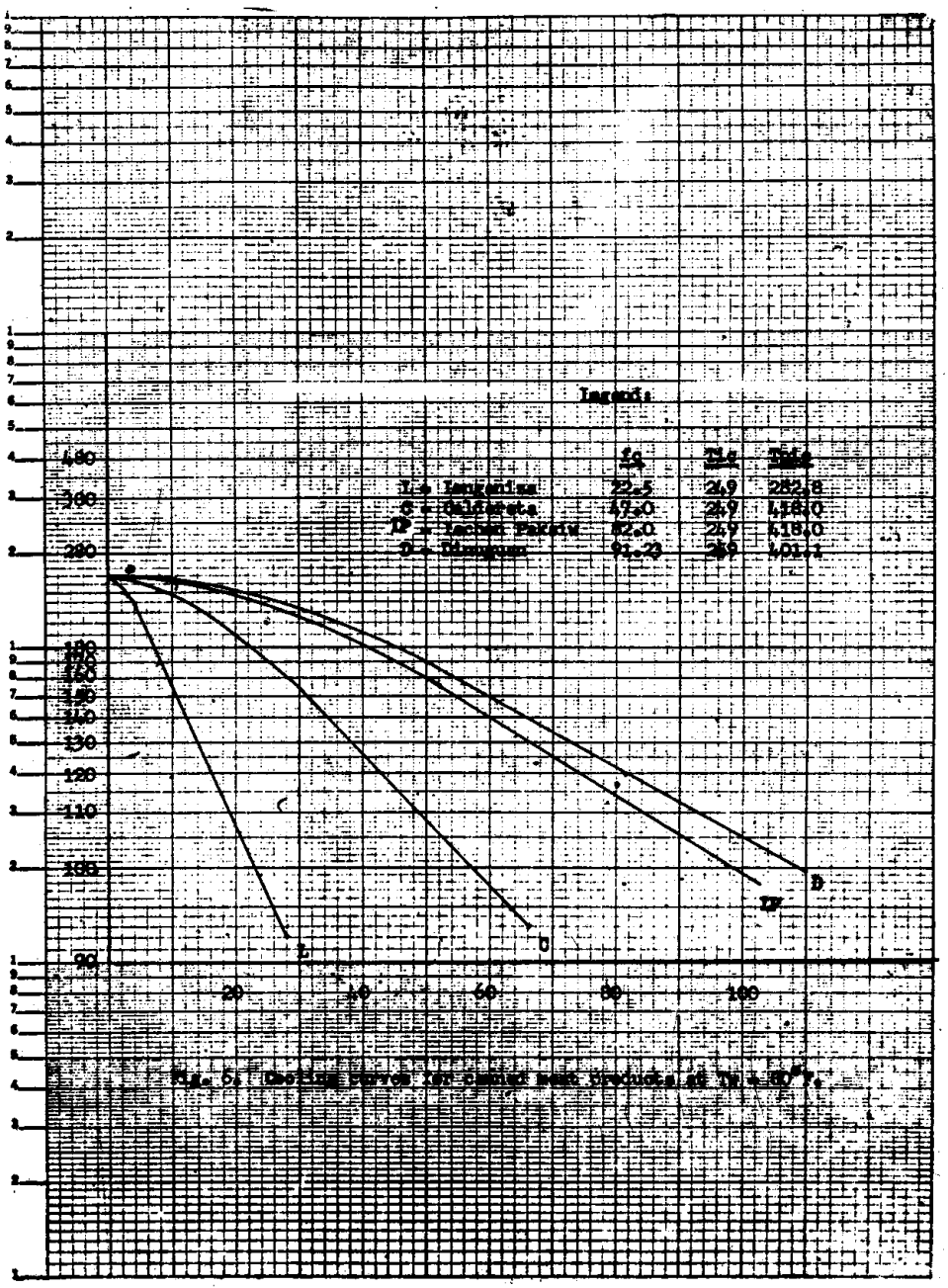

Fig. 5. Decline curves for cumulative production at N = 80%.

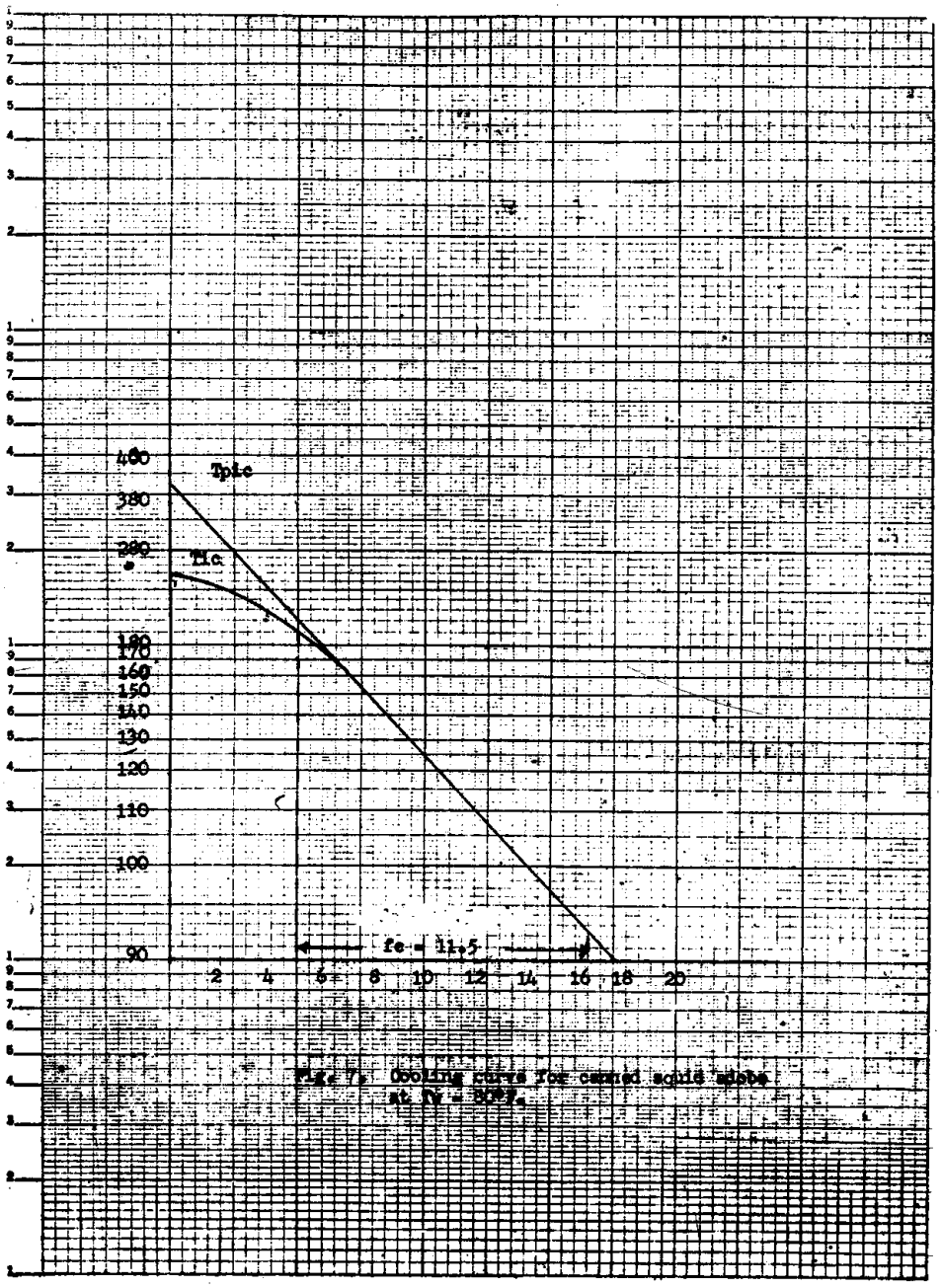

Fig. 7. Cooling curve for canned squid globe at Ny = 80%.

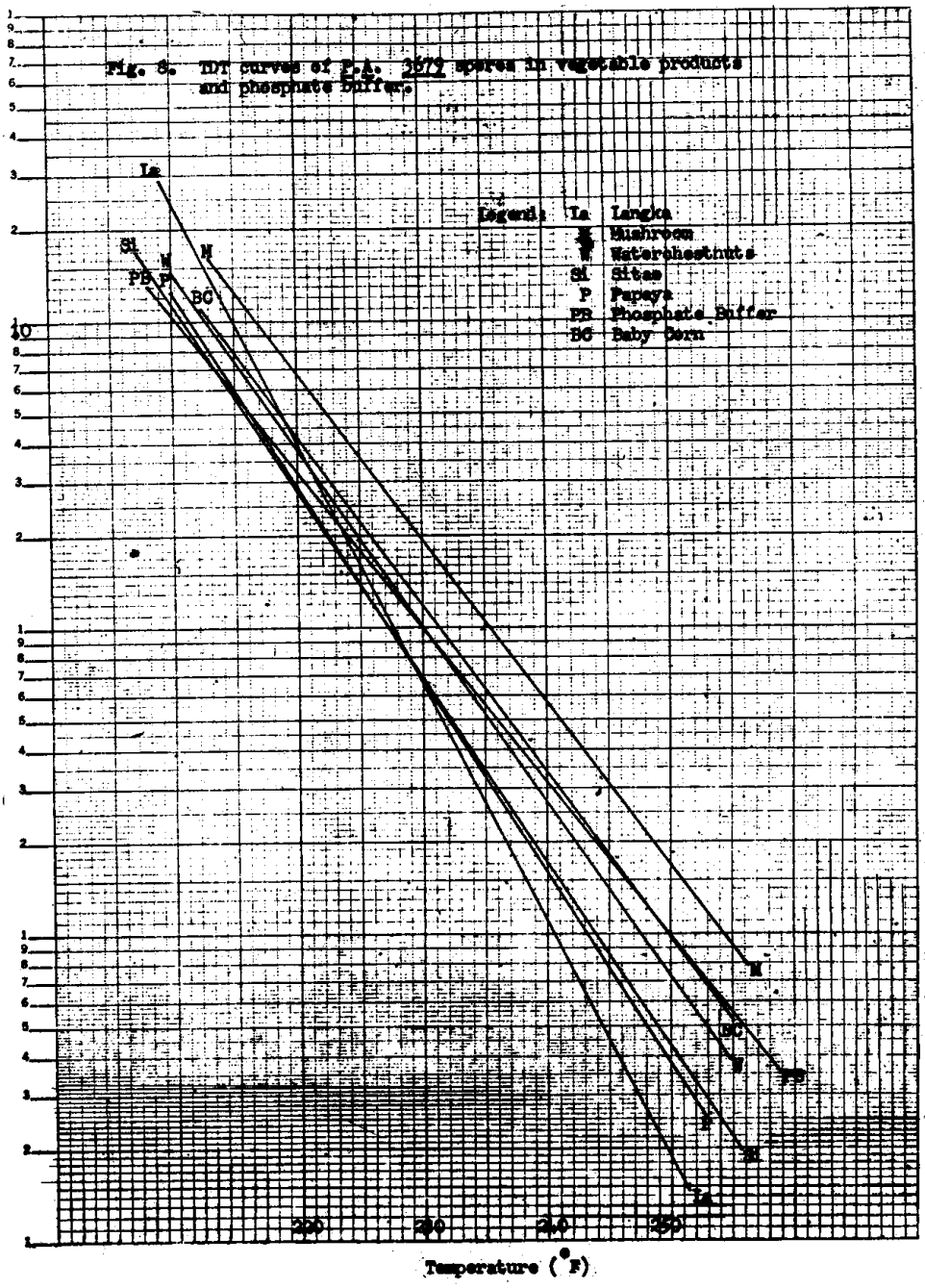
Fig. 8. TDT curves of P.A. 3672 spores in vegetable products and phosphate buffer.
Legend: La Langka
M Mushroom
W Waterchestnuts
Si Sitao
P Papaya
PB Phosphate Buffer
BC Baby Corn
La
Si
M
PB
P
BC
W
240
260
280
300
Temperature (°F)

APPENDIX A

Preparation of Liver Broth Medium (NCA, 1968)

Mix 500 grams of beef liver from which the fat has been removed, with 1,000 ml distilled water and boil slowly for 1 hour. Filter the boiled solution and allow to cool. Adjust the pH to 7.0 with NaOH. Make up the volume of liquid to 1,000 ml with distilled water. Cut the boiled liver into small cubes. To the broth, add the following:

Tryptone	10 g
K_2HPO_4	1 g
Soluble Starch	1 g

Into each tube introduce ½ to 1 inch of boiled liver cubes. Add the liver broth. Cover the tubes with cotton. A layer of the liver should also be put in the bottom of each flask if the medium is to be used for preparing spore crops. It is advisable to save the remainder of the boiled liver cubes by spreading in a thin layer and drying thoroughly at 98° to 135°F (37° to 57°C). When dry, these may be kept indefinitely and used for tubing with the supply of liver broth. An alternative method of preserving the boiled meat is by freezing.

Autoclave the tubes at 250°F for 20 minutes and the flasks for 25 minutes. The pH after sterilization should be 7.0.

APPENDIX B

Determination of "initial" Number of Spores

Stock Culture No. 1 for Phase I of TDT Study:

Halvorson and Ziegler's equation is

$$\bar{x} = \frac{2.3026}{V} \log \frac{n}{q}$$

where $\overline{x}$ = most probable number of spores per ml of the dilution
V = volume of sample per tube
n = total number of tubes
q = total number of tubes in which growth did not occur

$\overline{x}$ times the dilution factor will give the number of spores per ml of the original suspension

$$\overline{x} = \frac{2.3026}{1} \log 54/39$$
$$= 2.3026 \log 1.385$$
$$= 0.33$$

Dilution factor is 10^8

"Initial" number of spores per ml of the original spore suspension is 3.3×10^7

Stock Culture No. II for Phase II of TDT Study:

The Most Probable Number (MPN) Method gave the following:

Dilutions	10^5	10^6 6	10^7	Count
Trials I	2	0	1	.68
Trials II	1	1	0	.40
			Averaeg	.54

"Initial" number of spores used was 5.4×10^9 (Original spore suspension)

APPENDIX C

Calculation of "a", "b" and D values

The original spore suspension was diluted with sterile phosphate buffer to give the desired count that would be dispensed in the TDT tubes.

To compute:

a = initial number of microorganisms in all the replicate samples
= number of spores per tube x number of replicate samples
b = number of microorganisms which survived the heating time U
= n (2.3026 log n/q)
where n = total number of tubes
q = total number of tubes in which growth did not occur

Assuming a logarithmic order of death,

$$D = \frac{U}{\log a - \log b}$$

where U is the time of heating minus the lag correction at the prescribed temperature

APPENDIX D

Determination of Correction for Heating Lag in TDT Tubes (Phu, N.L., 1974)

Supposing all process time B are longer than the heating time required to heat the products to a temperature 0.1°F below retort temperature.

So $g_c = 0.1$, refer to f_h/U:g table (Ball, 1957) for z = 18, find:

$$f_h/U = 0.6$$

Or $U = f_h/0.6$ - lethal value of the process with heating and cooling combined expressed as minutes at retort temperature.

Correction = Come up time - U

APPENDIX E

Sample Scorecard for Subjective Evaluation

Name_____ Date _____

Directions: You are receiving three samples. You are given a reference sample, marked R, to which you are to compare each sample. Test each sample; show whether it is better than, comparable to, or inferior to the reference. Then mark the amount of difference that exists.

Sample No.	293	392	923
Better than R			
Equal to R			
Inferior to R			
Amount of Difference			
None			
Slight			
Moderate			
Much			
Hedonic Scale			
Like extremely			
Like very much			
Like moderately			
Like slightly			
Neither like not dislike			
Dislike slightly			
Dislike moderately			
Dislike very much			
Dislike extremely			

APPENDIX F

Process Calculations Using the Mathematical Method

A. Convection Heating Product

Baby Corn (307 x 409 can)

$f_h = f_c = 9.5$ $\quad z = 18.4$

$j_{ch} = j_{cc} = 1.29$ $\quad D_r = .98$

$$F_s = F_c = D_r (\log a - \log b)$$
$$= .98 (\log 10^5 - \log 10^0)$$
$$= 4.9$$

At $T_r = 250°F, F_i = 1$

$$U_c = F_c F_i = 4.9 (1) = 4.9$$

and

$$f_h/U_c = 9.5/4.9 = 1.94$$

From the f_h/U:g tables find, for $z = 18.4$, $j_{cc} = 1.29$ and
$f_h/U_c = 1.94$
$g_c = 2.09$

Determine the process time, B

At $T_{ih} = 70°F$

$$B = f_h \log j_{ch} I_h - \log g_c$$
$$= 9.5 \log 1.29 (180) - \log 2.09$$
$$= 19.43 \text{ minutes}$$

At $T_{ih} = 160°F$

$$B = 9.5 \log 1.29 (90) - \log 2.09$$
$$16.57 \text{ minutes}$$

At $T_r = 240°F$

$$F_i = \log^{-1} (T - T_r)/Z$$
$$= \log^{-1} (250\text{-}240/18.4$$
$$= 3.49$$

$Uc = F_cF_i = 4.9\ (3.49)$
$= 17.10$

$f_h/U_c = 9.5/17.10 = .555$

From f_h/U:g tables find, for $z = 18.4$, $j_{cc} = 1.29$
and $f_h/U_c = .555$
$g_c = .096$

At $T_{ih} = 70°F$
$B = 9.5 \log 1.29\ (180) - \log 0.096$
$= 32.14$ minutes
At $T_{ih} = 160°F$
$B = 9.5 \log 1.29\ (90) - \log 0.096$
$= 29.28$ minutes

B. Conduction Heating Product

Caldereta (307 x 201.25 can)

Net weight = 250 g
$f_h = f_c = 47.0$
$J_{ch} = j_{cc} = 2.00$
$F_{sd} = D_r (\log a - \log b)$
$= 1.2 (\log 250 - \text{kig } 10^{-5})$
$= 8.88$

$z = 17.5$
$D_r = 1.2$

To determine the F_c corresponding to the F_{sd}

Let $F_{c1} = 6.0$
$F_{c2} = 8.0$

<u>At Tr = 250°F</u>

$U_{c1} = F_{c1}F_i = 6.0$
$f_h/U_{c1} = 47/6 = 7.83$
$U_{c2} = F_{c2}F_i = 8.0$
$f_h/U_{c2} = 47/8 = 5.875$

From f_h/U:g tables find, for z = 17.5 and j_{cc} = 2.00

g_{c1} = 9.76

g_{c2} = 8.07

then

$g\lambda_1$ = 0.5 x 9.76 = 4.88

$g_{\lambda 2}$ = 0.5 x 8.07 = 4.04

From f_h/U:g table find, for z = 17.5 and $j_{\not\lambda c}$ = 1.00

$f_h/U_\lambda 1$ = 4.99

$f_h/U_{\lambda 2}$ = 4.01

Then $U_{\lambda 1} = F\lambda_1 = 47/4.99 = 9.42$

$U_{\lambda 2} = F_\lambda 2 = 47/4.01 = 11.72$

$F_s = F_c + D_r\,(1.084 + \log\,(F_{\lambda 1} - F_c)/D_r)$

$F_{s1} = 6.0 + 1.2\,(1.084 + \log\,(9.42 - 6.0)/1.2)$

$= 7.85$

$F_{s2} = 8.0 + 1.2\,(1.084 + \log\,(11.72 - 8.0)/1.2)$

$= 9.89$

F_c desired $= F_{c1} + [CF_{c2} - F_{c1})/(F_{s2} - F_{s1})$ x

$(F_{s\ \text{desired}} - F_{s1})]$

$= 6.0 + [(8.0 - 6.0)/(9.89 - 7.85)$ x

$(8.88 - 7.85)]$

$= 7.01$

And $U_c = F_cF_i = 7.01$

$f_h/U_c = 47/7.01$

From f_h/U:g tables find, for z = 17.5, j_{cc} = 2.00 and

f_h/U_c = 6.70

g_c = 8.825

Then $B = f_h\,[\log\,(j_{ch}I_h)/\,g_c]$

At T_{ih} = 70°F

$$B = 47\,[\log((2 \times 180)/8.825)]$$
$$= 75.7 \text{ minutes}$$

At $T_{ih} = 160°F$

$$B = 47 \log[(2 \times 90)/8.825]$$
$$= 61.55 \text{ minutes}$$

At $T_r = 240°F$

$$F_i = \log^{-1}[(T - Tr)/z]$$
$$= \log^{-1}[(250 - 240)/17.5]$$
$$= 3.72$$

$$U_c = F_c F_i = 7.01\,(3.72)$$
$$= 26.08$$

and $F_h/U_c = 47/26.08 = 1.80$

From f_h/U:g table find, for $z = 17.5$, $j_{cc} = 2.00$ and

$f_h/Uc = 1.80$

$g_c = 2.15$

The process time

At $T_{ih} = 70°F$

$$B = 47 \log[2(180)/2.15]$$
$$= 104.52 \text{ minutes}$$

At $T_{ih} = 160°F$

$$B = 47 \log[2(90)/2.15]$$
$$= 90.37 \text{ minutes}$$

APPENDIX G

Conversion of Process from One Can Size to Another (NCA, 1968; Stumbo, 1973)

Obtain the appropriate f_h conversion factor from the given to the desired can size from appropriate tables. Multiply the given f_h by this factor to obtain the equivalent value for the new can size.

When the conversion factors are not given, compute for the f_h value using the Schultz and Olson equation for convection heating products or the Stumbo equation for conduction heating products.

A. Convection heating product

Waterchestnut

Conversion of process from 307 x 409 to 603 x 700 can
f_h of 307 x 409 can = 8.75
f_h conversion factor from Table 9-3 (NCA, 1968) = 1.748
f'_h = f_h of 603 x 700 can = 8.75 x 1.748 = 15.3

When the f_h conversion factor is not given use the following Schultz and Olson equation

$$\frac{f_h}{f'_h} = \frac{ry}{r + y} \times \frac{r' + y'}{r'y'}$$

in which f_h = f_h of 307 x 409 can
f'_h = f_h of 603 x 700 can
r and r' = corresponding radii (outside radius minus 1/16 in.)
y and y' = corresponding can lengths (outside length minus 1/4 in.)

Approximate inside dimensions of 307 x 409 can are:
r = (3.4375/2) - 0.0625 = 1.656 in.
y = 4.5625 - .25 = 4.312 in.

Approximate inside dimensions of 603 x 700 can are:

$r' = (6.1875/2) - 0.0625 = 3.031$ in.

$y' = 7 - .25 = 6.75$ in.

$$\frac{8.75}{f'_h} = \frac{1.656 \times 4.312}{1.656 + 4.312} \times \frac{3.031 + 6.75}{3.031 \times 6.75}$$

$$\frac{8.75}{f'_h} = (7.141/5.968)\ (9.781/20.459)$$

$$f'_h = 15.296$$

and $f'_h/U_c = 15.3/3.65 = 4.19$

From f_h/U:g tables find, for $z = 17.5$, $j_{cc} = 1.47$
and $f_h/U_c = 4.19$
$gc = 5.09$

To determine process time B

At $T_{ih} = 70°F$
$B = 15.3\ [\log 1.47\ (18) - \log 5.09]$
$= 26.3$ minutes

At $T_{ih} = 160°F$
$B = 15.3\ [\log 1.47(90) - \log 5.09]$
$= 21.65$ minutes

B. Conduction Heating Product

Caldereta

Conversion of process from 307 x 201.25 to 211 x 400 can

f_h of 307 x 201.25 can = 47.0

When the f_h conversion factor is not given use the following equation:

$$\frac{f_{h1}}{f_{h2}} = \frac{(0.933)d_1^{\ 2}}{(d_1/1_1)^2 + 2.34} \times \frac{(d_2/1_2)^2 + 2.34}{(0.933)d_2^{\ 2}}$$

in which f_{h1} = fh of 211 x 400 can

f_{h2} = f_h of 307 x 201.25 can

d_1 and d_2 = corresponding diameters (outside diameter minus 1/8 in.)

1_1 and 1_2 = corresponding lengths (outside length minus 1/4 in.)

Approximate inside dimensions of 211 x 400 can are:

$d_1 = 2.6875 - .125 = 2.5625$ in.

$1_1 = 4 - .25 = 3.75$

Approximate inside dimensions of 307 x 201.25 can are:

$d_2 = 3.4375 - .125 = 3.3125$ in.

$1_2 = 2.078125 - .25 = 1.828125$ in.

$$\frac{f_{h1}}{47} = \frac{0.933\,(2.56)^2}{(2.56/3.75)^2 + 2.34} \times \frac{(3.31/1.83)^2 + 2.34}{0.933\,(3.31)^2}$$

$= 1.19$

$f_{h1} = 47 \times 1.19$

$= 55.93$

$F_{s\ desired} = F_{sa} + D_r \log (V_b/V_a)$

where F_{sa} = F_s for 307 x 201.25 can

V_b = net weight for 211 x 400 can

V_a = net weight for 307 x 201.25 can

$F_{s\ desired} = 8.88 + 1.2 \log (320/250)$

$= 9.01$

To determine the F_c corresponding to F_s desired

Let $F_{c1} = 7.0$

$F_{c2} = 11.0$

At $T_r = 250°F$

$U_{c1} = F_{c1}F_i = 7.0$

$F_h/U_{c1} = 55.93/7.0 = 7.99$

$U_{c2} = F_{c2}F_i = 11.0$

$F_h/U_{c2} = 55.93/11.0 = 5.08$

From f_h/U:g tables fiend, for $z = 17.5$, $j_{cc} = 2.00$

$g_{c1} = 9.64$

$g_{c2} = 6.87$

Then $g_{\lambda 1} = 0.5 \times 9.64 = 4.82$

$g\lambda_2 = 0.5 \times 6.87 = 3.44$

From f_h/U:g tables find, for $z = 17.5$, $j_{\lambda c} = 1.00$

$f_h/U_{\lambda 1} = 4.61$

$f_h/U_{\lambda 2} = 3.26$

then $U_{\lambda 1} = F_{\lambda 1} = 55.93/4.61 = 12.13$

$U_{\lambda 2} = F_{\lambda 2} = 55.93/3.26 = 17.16$

$F_s = F_c + D_r\ 1.084 + \log [(F_\lambda - F_c)/D_r]$

$F_{s1} = 7.0 + 1.2\ \ 1.084 + \log [(12.13\text{-}7)/1.2]$

$= 9.06$

$F_{s2} = 11.0 + 1.2\ \ 1.084 + \log [(17.16 - 11)/1.2]$

$= 13.07$

$$F_{c\ desired} = F_{c1} + \frac{F_{c2} - F_{c1}}{F_{s2} - F_{s1}} (F_{s\ desired} - F_{s1})$$

$$= 7.0 + \frac{11.0 - 7.0}{13.07 - 9.06}(9.01 - 9.06)$$

$= 6.95$

$U_c = F_cF_i = 6.95$

then $f_h/U_c = 55.93/6.95 = 8.05$

From f_h/U:g tables find, for $z = 17.5$, $j_{cc} = 2.00$ and

$f_h/U_c = 8.05$

$g_c = 9.69$

Then $B = f_h \log j_{ch}\ I_h/g_c$

At T_{ih} = 70°F

B = 55.93 log [2(180)/9.69]

= 87.81 minutes

At T_{ih} = 160°F

B = 55.93 log [2(90)/9.69]

= 70.97 minutes

APPENDIX H

Symbols and Definitions

a Initial population. Number of spores or vegetative cells of a given organism, per some given unit of volume before lethal heat is applied.

b Final population. Number of spores or vegetative cells per the same unit of volume after heating at a constant temperature for some designated time.

B Thermal process time, uncorrected for time required to bring the retort to processing temperature.

D Time required at any temperature to destroy 90% of the spores or vegetative vells of a given organism. Numerically, equal to the number of minutes required for the survivor curve to traverse one log cycle. Mathematically, equal to the reciprocal of the slope of the survivor curve.

D_r Time required at 250°F to destroy 90% of the spores or vegetative cells of a given organism.

F The equivalent, in minutes at 250°F, of all heat considered, with respect to its capacity to destroy spores or vegetative cells of a particular organism.

F_c F value of all lethal heat received by the geometrical center of a container of food during process.

F_o F value of all lethal heat received by any point in the container other than the geometrical center.

F_s Integrated lethal value of heat received by all points in a container during process. It is a measure of the capacity of a heat process to reduce the number of spores or vegetative cells of a given organism, per container.

F_i Time at any other temperature equivalent to 1 minutes at 250° F.

f Time, in minutes, required for straight-line portion of semilog heating or cooling curve to traverse one log cycle.

f_h f of heating curve when it can be represented by one straight line. Also, f of first straight line portion of a broken heating curve.

f_c f of straight-line portion of semi-log cooling curve.

g Difference, in degrees Fahrenheit, between retort temperature and the maximum temperature reached by the food at the point of concern.

g_c g when the point of concern is the geometrical center of the container.

I_h Difference between retort temperature and food temperature when cooling is started.

j A lag factor.

j_{ch} j of the heating curve for the geometrical center of the container. A factor that, when multiplied by I_h, locates the intersection of an extension of the straight-line por-

tion of the semi-log heating curve and a vertical line representing beginning of cooling.

k Thermal diffusivity.

l Time, in minutes, required to bring retort to processing temperature.

L Lethal rate. Reciprocal of time, at any lethal temperature, equivalent to 1 minute at 250°F, or $1/F_i$.

n Total number of samples subjected to one time-t temperature combination in a thermal resistance determination.

P_t Operator's process time. Time, in minutes, from the instant retort reaches processing temperature to the instant steam is turned off and cooling is started.

t time.

T Temperature.

BIBLIOGRAPHY

Adam, W.B. 1962. The quality of fruits and vegetables for processing. *Recent Advances in Food Science.* Vol. II. London: Butterworths.

Alicbusan, R.V. and V.M. Ela. 1952. Mushroom Culture. *Technical Bul.* 5. U.P. College of Agriculture. Los Baños, Laguna.

Alstrand, D.V. and H.A. Benjamin. 1949. Thermal processing of canned foods in tin containers. V. Effect of retorting procedures on sterilization values in canned foods. *Food Research.* 14: 253-260.

Alstrand, D.V. and O.F. Ecklund. 1952. The mechanics and interpretation of heat penetration tests in canned foods. *Food Technol.* 6(5): 185-189.

American Meat Institute Foundation. 1960. *The Science of Meat and Meat Products.* San Francisco: W.A. Freeman and Co.

Arroyo, P. 1974. *The Science of Philippine Foods.* Quezon City: Abaniko Press.

Ball, C.O. and F.C.W. Olson. 1957. *Sterilization in Food Technology.* New York: McGraw-Hill Book Co., Inc.

Baumgartner, J. 1969. Canned Foods. An Introduction to Their Microbiology. 6th ed. London: Churchill Ltd.

Baumgartner, J.G. and A.C. Hersom. 1965. *Canned Foods. An Introduction to Food Microbiology.* 4th ed. London: Churchill Ltd.

Borgstrom, G. *Principles of Food Science,* Vol. I. New York: The McMillan Co.

Bull, S. 1951. *Meat For the Table.* New York: McGraw-Hill Book Co., Inc.

Carillo E. 1974. Development of Squid *(Loligo pealli)* as a Snack Food. Unpublished UP BSFT thesis. Univ. of the Phil. Diliman, Quezon City.

Chandler, B.V. 1964. Discoloration in processed cauliflower. CSIRO. *Food Preservation Quarterly.* 24 (1): 11-14.

Charm, S. 1971. *Fundamentals of Food Engineering.* Conn.: The AVI Publishing Co., Inc.

Christensen C. 1943. *Common Edible Mushrooms.* Minneapolis: The Univ. of Mineapolis Press.,124 pp.

Cruess, W.V. 1958. *Commercial Fruit and Vegetable Products.* New York: McGraw-Hill Book Co.

Cunamay, E. 1972. Canning of Tropical Mushroom (*Volvariella volvacea* Singer) Unpublished UP BSFT thesis. Diliman, Quezon City.

Davis, R. *et al.* 1961. Control of Rutin Discoloration in Canned Asparagus. *Food Technol.* 15(4): 212-217.

De Jesus, P. 1969. *Know Your Plant Foods.* Quezon City: Manlapaz Publishing Co., Inc.

Ellis, R. 1963. Metal containers for food. *Food Processing Operations.* Vol. II. Conn.: The AVI Publishing Co. pp. 267-292.

Fonacier, A. 1977. Determination of Tin Content in Canned Guayabano and Mango Juices. Unpublished UP BSFT thesis. College of Home Economics. Diliman, Q.C.

Furia, T. 1968. *Handbook of Food Additives.* Ohio: The Chemical Rubber Co., pp. 300-302.

Gorin N. and A. Jans. 1971. Discoloration of sauerkraut probably caused by a leucoanthocyanin. *Journal of Food Science.* 36(6): 943-947.

Heid, J.L. and M. Joslyn. 1967. *Fundamentals of Food Processing Operations.* Conn.: The AVI Publishing Co., Inc.

Hernandez, H. and D. Vosti. 1963. Dark discoloration of canned allgreen asparagus. I. Chemistry and related factors. *Food Technol.* 17(5): 95-99.

Herndon. D., R. Griffin and O. Ball. 1968. Use of of computer-derived tables to calculate sterilizing processes for packaged foods. *Food Technol.* 22(4): 129-140.

Hoogzand, C. and J. Doesburg. 1961. Effect of blanching on texture and pectin of canned cauliflower. *Food Technol.* 28(9): 46-48.

Karmas, E. 1972. Sausage Processing. New Jersey: Noyes Data Corp.

Long, T. and J. Alben. 1968. Preliminary studies on mushroom tyrosinase (polyphenol oxidase). Mushroom Science VII. Proceedings of the Second Scientific Symposium and the Seventh International Congress on Mushroom Science. Hamburg: Centre for Agricultural Pub. & Documentation. p. 479.

Luh. B.S. and B. Phithakol. 1972. Characteristics of polyphenol oxidase related to browning in cling peaches. *Journal of Food Science.* 37(2): 264-268.

Lund, D.B. 1973. Effects of heat processing. *Food Technol.* 27(1): 16-18.

Mathew, A.G. and H. Parpia. 1971. Food browning as a polyphenol reaction. *Advances in Food Research.* Vol. 19. New York: Academic Press.

Mendoza, A. 1961. *Philippine Foods, Their Processing and Preservation.* Philippines: Abiva Pub. Inc.

Meyer, L.H. 1960. *Food Chemistry.* New York: Reinhold Publishing Corp.

Miller, A.R. 1958. *Meat Hygiene.* 2nd ed. Philadelphia: Lea and Febiger.

Mitchell. R.S. 1972. An improved method for controlling breaking of potatoes during canning. *J. of Food Technol.* (U.K.) 7(4): 401-408.

Mohammadzadeh-Khayat, Ali and B.S. Luh. 1968. Calcium and oxalate ions. Effect on the texture of canned apricots. *Journal of Food Science.* 33(5): 293-298.

National Canners Association. 1968. Laboratory Manual for Food Canners and Processors. Vol. I. Conn.: The AVI Publishing Co., Inc.

Peralta, E.I. 1977. Thermal Resistance of *P.A. 3679* as Affected by Different Levels of Sodium Nitrite and Sodium Chloride Using a Model System of Pork. Unpublished UP MSFS thesis. Univ. of the Phil. Diliman, Quezon City.

Perigo, J.A., B. Whiting and T.M. Bashford. 1967. Observations on the inhibition of vegetative cells of *Cl. sporogenes* by nitrite which has been autoclave in a laboratory medium, discussed in context of sub-lethally processed cured meats. *J. Food Technol.* (U.K.) 2: 377-397.

Phu. Nguyen Le. 1974. Establishment of Optimum Processing Parameters for Canned Tuna. Unpublished MSFS thesis. Univ. of the Phil. Los Baños, Laguna.

Reed, J.M., C.W. Bohrer and E.J. Cameron, 1951. Spore destruction rate studies on organisms of significance in the processing of canned foods. *Food Research.* 16: 383-408.

Remo, A.C. 1969. Tin Corrosion in Canned Guayabano Juice. Unpublished UP BSFT thesis. College of Home Economics. Diliman, Q.C.

Reynolds, H., A. Kaplan, F. Spener and H. Lichtenstein. 1952. Thermal destruction of Cameron's *P.A. 3679* in food substrates. *Food Research.* 17(2): 153-167.

Rieman, H. 1969. *Botulism — Types A, B and F. Food Borne Infections and Intoxications.*. New York: Academic Press.

Roberts, T.A. and M. Ingram. 1973. Inhibition of growth of *Cl. botulinum* at different pH levels by Na Cl and $NaNO_2$. *Journal of Food Technol.* 8: 467-475.

Rodriguez, R., P.C. Agarwal and N.K. Saha. 1964. Canning of waterchestnut (Singhara Trapa bisphenosa Koxb) *Journal of Food Science and Technology* (India). 1(2): 28-31.

Salcedo, M.R. 1977. Tinplate and Tin Can Quality. Unpublished UP BSFT thesis. College of Home Economics. Diliman, Quezon City.

Stumbo. C.R. 1973. *Thermobacteriology in Food Processing.* 2nd ed. New York: Academic Press.

Stumbo, C.R. 1965. *Thermobacteriology in Food Processing.* New York: Academic Press.

Stumbo, C.R. *et al.* 1975. Thermal processes lethality guide for low-acid foods in metal containers. *Journal of Food Science.* 40, 1316-1323.

Stumbo, C.R., J.R. Murphay and J. Cochran. 1950. Nature of thermal death time curves for *P.A. 3679* and *Cl. botulinum. Food Technol.* (8): 321-326.

Sacharow, S. and R. Griffin. 1970. *Food Packaging.* Conn.: The AVI Publishing Co., Inc.

Sognefest, P. and H.A. Benjamin. 1944. Heating lag in thermal death time cans and tubes. *Food Research.* 9; 234.

Takahashi, T. 1965. Squid meat and its processing. *Fish as Food.* IV. New York: Academic Press. pp. 349-350.

Villanueva, E. 1974. Preliminary Study on the Optimum Packing Medium for a New Variety of Corn. Special Problem in FS 199. Unpublished. U.P. College of Home Economics. Diliman, Quezon City.

Wasserman, A.E. and F. Talley, 1972. The effect of sodium nitrite on the flavor of frankfurters. *Journal of Food Science.* 37(4): 536-538.

Weier, E. and R. Stocking. 1949. Histological changes induced in fruits and vegetables by processing. *Advances in Food Research.* New York: Academic Press. pp. 297-342.

Weiser, H.G. Mountney and W. Gould. 1971. *Practical Food Microbiology and Technology.* Westport, Conn.: The AVI Publishing Co., Inc.