MICROBIOLOGY OF SPOILED CANNED FOODS COLLECTED
FROM KHARTOUM MARKET

By

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DEDICATION

TO THE MEMORY OF MY MOTHER AND
MY BROTHER DR. KHALED MEDABER
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ABSTRACT

Sixty-one samples of spoiled canned foods, collected from Khartoum market and Food Research Center, were examined for the detection of the cause of spoilage.

The main cause of spoilage was the growth of mesophilic and thermophilic aerobic and anaerobic spore-forming and non-spore-forming bacteria, molds and yeast. These organisms can grow in acid, medium and low acid foods. They can produce gas, i.e. carbon dioxide, which can swell the cans. These organisms can enter the cans through leakage or the contents were underprocessed.

The time for killing the common organisms, which were isolated and identified, at 250°F was detected by plotting survivor curves.
INTRODUCTION

Canning is a method of food preservation based on heat sterilization of the food in hermetically sealed containers. Although sterilization means the complete destruction of living things and enzymes in the canned food, this is not always the case in reality. Microbial spoilage of the canned food does occur.

In Sudan, the canning industry is not a big business nor is it well-established. The industry began in 1966 with the building of the Karima Factory which engaged in the canning of fruits and vegetables. In 1967 the second factory came into being in Kassala, also based on the preservation of fruits and vegetables. The current policy of the state to develop the food industry has revived interest in the canning of foods and plans are present now to build factories in Gezira and Kassala.

Sudan, however, continues to import all kinds of canned foods from many different countries. Whether the canned foods are imported or whether they come from local factories, still some show spoilage
defects in the grocery. Swollen or burst cans are a common sight in Khartoum markets.

It is the situation that gave interest in this research.
1. Spoilage of Canned Foods

The only visible evidence of spoilage in unopened container is the condition of the ends. If these are bulged to any degree the can may be spoiled (National Canners Association, 1950).

The normal cans are flat or slightly concave at the ends, and a partial vacuum exists within the container. If pressure develops inside, the can goes through a series of distortion as the result of increasing pressure and is called successively a flipper, springer, soft swell or hard swell (Hersom and Hulland, 1969; Frazier, 1967; Stumbo, 1973; Jay, 1970). A breather is a can with a minute leak that permits air to move in or out, but does not necessarily allow microorganisms to enter (Frazier, 1967).

Most spoiled foods will have somewhat turbid brine or syrup. An off-odor is frequently an indication of spoilage, but some spoiled foods have no noticeable off-odor (National Canners Association, 1950).
Defects in the general appearance of the can must be noted before and after opening: dents, rust, perforation, defective side seam or end seal, and corrosion (Frazier, 1967).

The appearance of the glass container of food under gas pressure may have its cover bulged or popped off, or may show leakage of food through the broken seal. It is possible to see any evidence of microbial growth through the glass sides, such as gas bubbles, cloudiness and films of growth.

Deterioration of canned foods due to chemical action, occurs in foods canned in tin containers, e.g. darkening of corn or peas due to formation of iron sulfide or of copper sulfide, Vail et al. (1967), Nahanevich (1976) and others reported that corrosion is evident with acid fruits such as apples and berries. According to Vail et al. (1967) corrosion can be controlled by the removal of oxygen, prior to sealing, by effective exhaustion of the can.

2. Causes of Spoilage

Vail et al. (1967) reported that most of the spoilage in canning is due to inadequate processing.
Despite the use of approved methods, the food may not be sterilized during canning, and it is sometimes allowed to stand too long before canning and is high in bacterial content; or the canning is not done at the proper temperature. Excess contamination may require longer heating. Improper manipulation of the packed food outside the processor is sometimes responsible for spoilage. Allowing packed hot food to stand for some time before processing encourages the development of thermophilic bacteria and scurring frequently occurs. Some foods may be spoiled if not cooled in a reasonable length of time. Delay in sealing the container after the food is processed and the containers which do not give a tight seal may result in food spoilage.

Put et al., (1970) reported that reinfection is frequently apparent in well constructed cans with high quality double seams and side seams. Many cases of food poisoning are associated with postprocess reinfection of canned foods. The cases include typhoid and staphylococcal food poisoning and food poisoning due to Clostridium botulinum.
They continued that the majority of *Streptococcus* originated from vegetables being canned, *Escherichia coli* originated from the cultivated soil while *Sphingobacterium* were found in the can handling equipment and water, in the double seam, and from the manual handling of cans by human operatives. Frazier (1967) found that flat sour bacteria, the thermophilic anaerobic and sulfide organisms originated from equipments. The first two groups also come from manures. Frazier (1967), Nickerson and Sinks (1974) and Wenzel (1963) reported that the sources of thermophiles were starch, sugar, vegetable, equipments and soil.

Mercer and Somers (1957) reported that the addition of chlorine compounds to washing waters and cleaning equipments and also chlorination of cooling heat sterilized cans, will prevent or reduce can spoilage. Dropping chlorine solution onto conveyor belts and other equipment surface inhibited the growth of slime-producing bacteria.

The germicidal efficiency of chlorine in water is attributed to its ability to attack and inactivate enzymes essential for life of the microbial cell.
Hypochlorous acid formed by compounds in solution is shown to be the germicidal agent.

The successful chlorination of food-processing waters require an understanding of the chemical and physical condition which influence the germicidal activity of chlorine solutions. Included in these conditions are the pH of the solution, the concentration of chlorine, the concentration of organic materials, and the temperature of the solution.

Welch and Volinazzo (1959) reported that chlorine dioxide treatment of cano-used water is highly effective in controlling bacterial and slime formation. Works, et al (1949) reported that 2-chloro compounds act on microorganisms by the molecules of the chlorine compounds which act directly and by hypochlorous acid formed by hydrolysis.

Pat and co-workers (1970) reported that the most effective precaution is to dry the area immediately after cooling, to chlorinate the cooling water and regularly to clean and disinfect can and handling equipment. These measures lead to a very appreciable improvement in the hygiene of the canning operation but still there are spoilage organisms, because the surface of water is rarely free from fecal contamination.
or from spores resistant to heat and chemical sterilisation. Chlorination is not very effective when the water contains high concentrations of organic and inorganic matter which make it impossible to have free chlorine available. Under these circumstances where the supply of chlorine is sublethal, adapted or genetically modified bacteria of increased chlorine resistance are encouraged.

3. Acidity Classifications

Frazier (1967) reported that the acidity of canned foods is important in determining the heat process necessary for their sterilisation and the type of spoilage to be expected if the process is inadequate or leakage takes place. Heseltine and Hullah (1969) and Desormier (1970) stated that below pH 4.5 the growth of *Clostridium botulinum*, the most heat-resistant of the food poisoning organisms, is inhibited, and for foods with pH values below 4.5 pressure processing is considered unnecessary. For foods with pH above 4.5 processing under pressure above 100°C is required.
Cameron and Esty (1940) classified canned foods into four groups according to pH, and to each they assigned special spoilage relationship.

Group 1. Low acid (pH 5.0 and higher). Meat
Marine products, milk, corn, lima beans, asparagus and spinach.

Group 2. Medium acid (pH 5.0 to 4.5) meat and vegetable mixture, spaghetti, soups and sauces.

Group 3. Acid (pH 4.5 to 3.7), tomatoes, pears, figs, pineapples, and other fruits.

Group 4. High acid (pH 3.7 and below) kraut, pickles, berries, grapefruit, citrus juices and rhubarb.

Henson and Hullard (1969) reported that the pH of 6.0, rather than 3.7, is a more realistic limiting value for survival, germination and growth of spores in properly heat treated foods. For subdivision of acid foods and high acid foods was necessitated by the inactivation of acid tolerant, spore-forming
bacteria as the spoilage agents in certain canned fruits and tomato products with pH values between 4.5 and 3.7.

Stumbo (1973) reported that pH 4.0 is a more realistic dividing line between acid and high acid foods. Spore-bearing bacteria can not grow in heat-processed foods with pH value of 4.0 or lower. Some of the butyric anaerobes and Bacillus coagulans (B. thuringensis) will grow in laboratory culture or even in foods at pH values as low as 3.7, this especially with very heavy inocula.

Stumbo (1973), Collins and Lyne (1976), Nickerson and Anderson (1974) classified canned foods on the basis of acidity into three groups:

1. Low-acid foods pH above 4.5.
2. Acid foods pH 4.0 to 4.5.
3. High acid foods pH below 4.0.

Stumbo (1973) stated that the dividing line between low-acid and acid foods is taken as 4.5 because some strains of Clostridium botulinum will grow and produce toxin at pH value as low as about 4.5.
The highly heat-resistant saccharolytic monoxen, Clostridium thermosaccharolyticum, grows in semi-acid foods (pH 4.5) and cause spoilage.

Dearmeer (1970) classified the foods into four different groups:

1. Alkaline foods pH higher than 7.0: aged seafood, old egg.
2. Low acid foods pH 5.0 to 6.8: meat, fish, poultry, dairy products and vegetables.
3. Acid foods pH 4.5 to 1.7: fruits, tomatoes, potato salad with vinegar.
4. High acid foods pH 3.7 to 2.3: berries, pickle products and fermented foods and cranberry juice.

4. Microbial Spoilage of Canned Foods

The spoilage of canned foods as caused by the growth of microorganisms after the insufficient heat treatment (under processing), or the leakage of the container after the heat process, permitting the entrance of microorganisms (reinfection) (Put, et al., 1970; Frazier, 1967; Strekel, 1973).
Henson and Hulland (1969) reported that the microbial spoilage of canned foods is due to under-processing, inadequate cooling, infection resulting from leakage through seams, or pre-process spoilage.

5. Thermophilic Spore-Forming Bacteria

Bashford (1940) stated that the thermophiles are of interest to canners, since they produce spores of high resistance to heat, and are responsible for spoilage of non-acid products.

The thermophiles grow in a wide range of temperatures. Stainer, et al. (1971) reported that the minimum temperature for growth of thermophilic microorganisms is 40-43°C. The optimum temperature is 55-75°C and the maximum temperature is 60-60°C. Bashford (1940) reported that the optimum temperature for growth of these organisms is between 55° to 60°C.

Cameron and Stey (1940), Frazier (1967), Collin and Lyon (1976) and Bashford (1940) reported that the main thermophilic organisms that cause spoilage of canned foods are the flat sour bacteria, the thermophilic anaerobes (S. a.), and sulphide spoilage bacteria.
Stumbo (1973) and Devoeier (1970) reported that flat sour spoilage occurs when the cans are either unsterilized or the cans leaked. Cameron and Baxy (1940) and Fraser (1967) reported that the spoilage of canned foods by flat-sour bacteria, chiefly in low-acid foods such as peas or corn, is caused by *Bacillus*. Allen (1953), Asaia u and Ordel (1957), Cameron and Baxy (1940) and Fraser (1967) reported that flat sour spoilage of acid foods, such as tomatoes or tomato juice is caused by facultatively thermophilic species, "*Bacillus coagulans*".

Fraser (1967) reported that obligate thermophiles such as *Bacillus stearothermophilus* and *Bacillus pepsin* could not cause spoilage unless the food held hot for a while or stored in high temperature. Joy (1970) reported that *Bacillus stearothermophilus* grows at 55°C. Campbell (1954) reported that *B. stearothermophilus* can grow at 36°C if special medium is provided, it grows best at 45°C and 55°C. Long and Williams (1959) reported that this bacterium can grow at 37°C in special medium. Cameron and Baxy (1940) reported that *B. stearothermophilus* are the most important.
economically because they are facultative anaerobes and their ability to grow under high or low oxygen levels is responsible for their prevalence in contamination sources. Hornem and Hulland (1969) and Stumbo (1973) reported that B. stearothermophilus is the principal flat-sour organism found in low-acid canned products, which have received a fairly heavy heat-processing and does not result in souring when the products are rapidly cooled and stored under cool conditions. Stumbo (1973) stated that flat sour bacteria lower the pH by as little as 0.1 to more than 1 unit, and usually cause a slight to pronounced sour off-odor. According to Frazier (1967) the souring is due to the production of lactic acid by the organism.

The second thermophilic organism which causes spoilage of canned foods is Clostridium saccharolyticum, which is a sugar-splitting, obligately thermophilic spore-forming anaerobic, which does not produce hydrogen sulphide and grows best at 55°C. The organisms, recognized by their high-resistance spores, produce hydrogen and carbon dioxide, grow in medium and low
acid foods and produce butyric acid (Cameron and Esty, 1940; Deacon, 1970; Jay, 1970; Colins and Lyon, 1975; Stumbo, 1973). Jay (1970) reported that this organism does not grow at 20°C but grows at 17°C - 55°C in medium acid foods (pH 5.1 - 4.5). Stumbo (1973) says that this organism can be a source of real trouble at temperatures of 35°C and above.

Cameron and Esty (1940) reported that the third organism is *Clostridium sordicola*. Frazier (1967) stated that this organism is found uncommonly in low-acid foods like peas and corn. The spores are less heat resistant and their appearance in canned foods is indicative of under-processing. The organism is an obligate thermophile, requiring poor cooling and hot storage for its development. It is detected by black (iron sulfide) colonies, formed in iron sulfide agar at 55°C. Hydrogen sulfide gas is formed and odor is evident when the can is opened. In corn, a bluish-gray liquid is evident in which black and gray kernels of corn float. Peas give the H2S odor, but without marked discoloration.
Collins and Lynne (1970) say that *Clostridium* *butyricum* is found in low-acid foods (pH 4.5 or more). Nickerson and Minesky (1974) reported that this organism grows at pH 6.0, temperature 30-70°C and produce H₂S from proteins.

Cameron and Eddy (1940) reported that *Bacillus* *thermoacidurans*, is a thermophilic organism, associated with flat-sour group, cause spoilage of acid foods such as tomato juice, can not grow in low acid foods, and the lower spores are less heat resistant.

6. **Spoilage by Mesophilic Spore-Forming Bacteria**

Prazier (1967) reported that spoilage by mesophilic spore-former organisms that result from underprocessing are of the genera *Bacillus* and *Clostridium*.

a) **Spoilage by Clostridium species**

*Clostridium* causing butyric acid fermentation in acid and medium acid foods, with the swelling of the container by carbon dioxide and hydrogen gas, may be sugar fermenting organisms such as *C. butyricum* or *C. pestiferum*. Other species like *C. sporogenes*, *C. putrefaciens* and *C. botulinum* are proteolytic or putrefactive, decomposing proteins with the production
of malodorous compounds such as hydrogen sulfides, mercaptans, ammonia, indole and skatole. The putrefactive anaerobes, produce carbon dioxide and hydrogen which cause the swelling of the can. The spores of putrefactive anaerobes are very heat-resistant, and it is among the chief types of biological spoilage together with flat-sour and thermophilic anaerobes which results from under-processing.

The spores of the saccharolytic clostridia, or "butyric" are of low heat resistance. Spoilage by these anaerobes takes place most commonly in canned food which have been processed at 100°C or less, as commercially canned acid foods, and home canned foods. The canned acid foods have been found spoiled by _C. tyrobutyricum_, such spoilage is more likely when the pH of the food is above 4.5. Home acid foods, heated to about 95°F may be spoiled by the saccharolytic bacteria with the production of butyric acid, carbon dioxide and hydrogen.

The putrefactive anaerobes grow best in low-acid canned foods, and grow rarely on medium acid foods, one of these putrefiers, _C. botulinum_, is a cause of
food poisoning. Stanbly (1973) reported that proteolytic or putrefactive organisms other than *Clostridium botulinum* which caused spoilage of low-acid and semi-acid foods include *C. perfringens*, *C. histolyticum*, *C. difformis*, and *C. sporogenes*.

Brown et al. (1954) reported that the fermentation of canned tomatoes by *Clostridium pasteurianum* is related to the pH of the product. If the pH is in the range of 4.3 - 4.4 and the temperature in the center of the can is 91.3 to 95.6°C, this would control the spoilage by this organism.

Ascherl and Jansen (1945) stated that second in order to the flat-sour organisms were the putrefactive anaerobes of which *C. perfringens* and *C. sporogenes* seemed to be typical representative. Their presence as contaminant in insufficiently processed canned foods may be explained by the great heat resistance of the spores and their wide spread distribution in nature.

Cameron and City (1940) reported that putrefactive anaerobic species may show abnormal development resulting in non-gasous spoilage in medium-acid products of
pH 4.5 to 5, Horner and Holland (1968) reported that the spoilage produced by the putrefactive anaerobe is of the gaseous type and often accompanied by disintegration of the food and the production of foul odor. Stumbo (1973) reported that *C. pasteurianum* which is butyric anaerobe, causes swelling accompanied by the odor of butyric acid, in acid foods.

b) Spoilage by *Bacillus* species

The mesophilic species of *Bacillus* are less heat-resistant than thermophilic ones. A few kinds can survive heat-treatment employed in steam-pressure processing. Many species of *Bacillus* are aerobic and cannot grow in a well-evacuated container. *B. subtilis*, *B. megaterium*, and other species grow in low-acid home-canned foods that had been given a heat processing at 212°F. Commercially canned foods have been spoiled by Bacillus species, especially in poorly evacuated cans. Foods so spoiled have been mostly canned seafood, meats and evaporated milk. The aerobacteria, or gas-forming *Bacillus* species (*B. polymyxa* and *B. macerans*) cause spoilage in low and acid...
foods. These bacteria enter the can through leaks. The spores are heat-resistant. Varughese, et al. (1952) reported that \textit{B. polymyxa} and \textit{B. madurae} are incombustible in breather spoilage of canned foods because the 2 species are commonly waterborne, and grow at the temperature range of 40°C to 50°C, and according to Hickerson and Sinskey (1974) \textit{B. polymyxa} grows at pH 5.5 and the temperature range of 20-35°C. \textit{B. madurae}, grows at pH 7.8 and the temperature range of 28 - 50°C. Allen (1953) and Hickerson and Sinskey (1974) reported that both \textit{B. macerans} and \textit{B. polymyxa} produce acid and gas. Herren and Nuland (1969) reported that these organisms (\textit{B. macerans} and \textit{B. polymyxa}) were able to grow at pH 3.8 to 4.0, and the source of contamination is the cooling water which enters through leakage.

7. Spoilage by Non-Spore-Forming Bacteria

In the literature if viable non-spore-forming bacteria are found in canned foods, either a very mild heat-treatment was used or the bacteria enter the container through a leak.
Praizer (1967) stated that vegetative cells of some kinds of bacteria are fairly heat-resistant, and can withstand pasteurization. Among these "thermoduric" bacteria are the enterococci, *Streptococcus thermophilus*, some species of *Lactobacillus* and *Bacteroides*, and *Bifidobacterium*. The heterofermentative species may release enough carbon dioxide to swell the can. Types of bacteria which are found in cooling water can enter the container through leaks and cause spoilage. Examples of such bacteria are the coliform bacteria which produce gas and swell the can. Non-spore-forming, non-gas-forming bacteria that may enter include the genera *Pseudomonas*, *Enterobacter*, *Micrococcus*, *Flavobacterium*, *Proteus* and others.

Praizer (1967) and Nickerson and Sinekey (1974) reported that non-spore-forming bacteria which cause spoilage in under-processed acid canned foods and produce acids are *Lactobacillus* and *Leuconostoc* species.

Praizer (1967) reported that *Streptococcus faecalis* or *S. faecium* are present in canned ham. Kafel and Lyres (1969) reported that enterococci may have antagonistic action on some bacteria.
8. Spoilage by Yeast

Cameron and Psy (1940) and Strumbo (1973) reported that yeast causes spoilage of acid foods such as fruits. Moreau and Huland (1969) reported that apart from spoilage of yeast comes through leakage of container. Yeast and moulds are of relatively low heat-resistance and have no significance in spoilage of low or medium-acid canned foods, with the exception of sweetened condensed milk and canned cured meats such as ham and bacon.

Sweetened condensed milk is not heat-processed, its keeping properties depending on its high sugar content.

Jay (1970) named two types of yeast that cause spoilage of canned foods. *Saccharomyces caudatus* (oval cells) and *Pseudogastria globosa* (round cells), they cause blowing of sweetened condensed milk. The former causes the most vigorous fermentation, and infected cans may burst within a few days. The latter rarely gives rise to more than a distension of the can ends.

These yeasts may be isolated from sound cans showing no trace of spoilage. That is because the strains may
be less sugar-tolerant than usual or that the initial infection was slight and lack of oxygen in the can prevents extensive growth.

Frazer (1967) reported that fruits, such as jams, jellies, fruit juices, sirups, and sweetened condensed milk have been spoiled by fermentative yeasts with swelling of the can by \( \text{CO}_2 \) produced. Frazer (1964) reported that film yeasts may grow on the surface of jellies, pickled pork, r packed pickles or olives, and similar products. Their presence indicates recontamination or lack of heat processing, plus poor evaporation. Hermon and Julland (1963) reported that yeasts are of low heat resistance and so they are not involved in spoilage of low acid foods except in the cases of under processing or leakage.

9. Spoilage by Molds

Molds are the most common cause of the spoilage of home-canned foods, they enter through a leak in the seal of the container. Jam, jellies, marmalades will permit mold growth, when sugar concentration is as high as 70 per cent and in acid products. The most common organisms are Aspergillus, Penicillium, and
Citrussyces (Frazier 1967), Jr (1970) and Hanson
and Mulland (1969) reported that Aamorgillus rumens
forms "buttons" on the surface of sweetened condensed
milk.

Frazier (1967) reported that Bysacholomy c lively
is a post-in-fermenting mold, and has resisted the heat
processing of bottled and canned fruits. Put and
Kruisvik (1964) reported that Bysacholomy c lively,
and nives, can produce enzymes in processed strawberries
and cause disintegration of the fruit, spoilage is
accompanied by a slow decrease in vacuum, but the pH
does not change. These changes are observed after
storage for at least 3 to 6 months at 25°C. The
spores were destructed after 10 minutes at 90°C.
This mold is transferred from soil. (Put (1964)
reported that Bysacholomy c nives, Aamorgillus,
Paecilomyces and Pencillium are all heat resistant
molds.

10. Bepullin

Backford (1940) stated that botulism has been
associated with a number of types of preserved foods
such as sausage, hams, canned and glass-packed goods,
and in fact, the term is derived from the Latin, botulac, meaning sausage. Frazier (1967) stated that botulism is a true food poisoning, caused by the ingestion of food containing the exotoxin produced by *Clostridium botulinum* during its growth in the food. Dissolved tin from cans inhibit growth and toxin production in canned vegetables.

Minimal pH for vegetative cell growth is 4.37 and for spore germination is 5.01. Maximal pH for vegetative growth and production of toxin is 8.89.

The lowest temperature for the growth of *Clostridium botulinum* is 10°C. The optimum temperature 35°C and the maximum temperature 49°C.

Suty and Mayer (1922) reported that the maximum heat resistance of *Clostridium botulinum* type A and B varies from 3-30 minutes at 10°C. The maximum heat resistance of *Clostridium botulinum* spores, produced under the most favourable conditions for growth and heated in a phosphate solution of pH 7.0 is 4 minutes at 120°C, 10 minutes at 115°C, 17 minutes at 110°C and 330 minutes at 100°C.
Scott and Stewart (1949) reported that the toxin of *Clostridium botulinum* is inactivated in 80°C for 4.8 minutes in cans of cabbage and carrots.

The toxin is most resistant at pH 5.0. In cooked meat medium it may be noted that the greatest stability is in the range of pH 5.0 to 5.5 whereas in cabbage the toxin is most resistant between pH 4.5 and 4.9. Frazier (1967) found that the growth of *Clostridium botulinum* in some foods results in a foul, rancid odor that they would be rejected. Low-acid vegetables develop an especially abominable odor. More acid food, those low in protein become toxic without any evidence of putrefaction. Frazier (1967) reported that gas production is not always evident of spoilage by this organism. It is advisable to reject all foods raw or canned that give evidences of spoilage. Vail *et al.* (1967) reported that the spores of *Clostridium botulinum* withstand heating at 100°C for as long as five hours. They stated that it is not wise to taste home canned vegetables and meat before boiling to destroy toxin. Frazier (1967) reported that the toxin of *Clostridium botulinum* is a protein that has been purified and
crystallized. It is so powerful that only a tiny amount is sufficient to cause death. It is absorbed in small intestine, and paralyzed the involuntary muscles of the body. Riemann (1969) reported that botulism is a highly lethal food poisoning.

He reported that fruits, pickles and similar acid products are sometimes reported as a source of botulism. It is known that Clostridium botulinum is inhibited at pH values below 4.5. It is possible that different varieties of fruits and different degrees of ripeness might result in different pH values in the canned product. Botulinum toxin is more stable under acid condition, and once formed it may remain active much longer in acid foods than in neutral foods.

21. Heat Resistance of Bacteria

Fraiser (1967) and Horsan and Holland (1969) reported that death of bacteria results from the coagulation of the cell protein and that factors which affect protein coagulation have a marked influence on bacterial heat resistance. An acid or alkaline reaction increases the coagulation of
protein and also causes a decrease in the heat resistance of bacteria. Currie (1932) and Sugiyama (1951) stated that if death by moist heat is caused by denaturation of some essential proteins, it is plausible to suppose that lipid material in the spore may protect the peptide linkage from hydrolysis or denaturation and thus prolong survival.

12. Factors Influencing Thermal Resistance of Bacteria

Many factors influence the resistance of bacteria to heat. Some factors have been studied for their effect on heat resistance of bacteria, by different workers.

a) The effect of water

Jay (1970) and Kurral and Scott (1966) reported that heat resistance of bacteria increases in a gradual manner as the water concentration of the environment decreases. Nickerson and Sinskey (1974) reported that the moisture content or water activity of a food affects heat resistance. Spores are more easily killed in broth than when suspended in a solid food such as meat.
b) **Influence of number**

Achachev and Jensen (1950) reported that the concentration of the initial number of spores has a great influence on heat resistance. That is, the greater the number of spores, the higher is the heat resistance of spores.

c) **Influence of age of organisms**

Jaty and Meyer (1922) reported that young moist spores of *Clostridium botulinum* are more resistant than old spores. Current's (1934) work with aerobic spore-forming species concluded that ageing up to one year increased the heat resistance of spores. Some worker, using various aerobic and anaerobic spore-former organisms, failed to find any relation between age of the culture and heat resistance over a period of 5 to 30 days. Anderson and Meanwell (1936) observed an increased resistance of thermophilic streptococci during the early logarithmic growth phase.

c) **Effect of environmental condition during spore formation**

Sugiyama (1951) using *C. botulinum* showed that a reduction in Fe^{2+} and Ca^{2+} concentration in the
sperulating medium before a certain value, decreased the thermostability of the spores. Williams (1929) reported that changes in the composition of nutritive medium produce deviations from the normal resistance. Asaka and Odraal (1957) showed that manganese and calcium increased the heat resistance of Bacillus megaterium. Herson and Hulland (1963) reported that the availability of calcium may be affected by the phosphate concentration of the medium. El-Bisi and Odraal (1956) observed that a high phosphate level depressed the thermal resistance of the spores. Levinson and Kyatt (1964) using spores of B. megaterium, found that supplementation with calcium chloride increased heat resistance but addition of L-glutamate, L-proline or phosphate produced spores with reduced heat resistance. Curran (1935) found that spores produced in soil are more heat resistant than that produced artificially.

The temperature may affect the heat resistance of spores. Spores formed at high temperature are more heat resistant than those grown at lower temperature (Williams and Robertson, 1954; El-Bisi and Odraal, 1956).
Sugiyama (1951) said that spores of _C. botulinum_ produced at 37°C are of higher heat resistance than those developed at 41°C, 43°C or 45°C.

f) Effect of the recovery medium

Bacteria which have been exposed to sub-lethal heat treatments are more exacting in their growth requirement than unheated bacteria.

Jarrell et al. (1920) found that the sensitivity to inhibitors of spore germination increases with the severity of the previous heat treatment of the spores. Hyatt and Levinson (1957, 1959) reported that citrate and phosphate are necessary for _Clostridium botulinum_. Gunn and Campbell (1957) reported that _C. botulinum_ spores germinate in glucose-cysteine salts medium, required amino acids and growth factors to support growth.

g) Future of the field

Horsfall and Welland (1969) reported that most spore-bearing bacteria the maximum resistance occurs in neutrality. Nity and Moyar (1922) found that _Clostridium botulinum_ showed maximum resistance between
pH 6.3 and 6.9. Williams (1929) observed that B. subtilis spores were most resistant between pH 6.8 and 7.6.

There are other factors which are studied by some workers to find their effect on host resistance of bacteria. These are (Jay, 1970):

1. The effect of salt
2. The effect of sugars
3. The effect of proteins
4. The effect of fats
5. The effect of inhibitory agents
6. The effect of antibiotics

12. Heat-Treatments Employed in Canned Foods

Frazier (1967) reported that the temperature and time used in the heat processing of a food will depend upon the effect on the food and other preservatives used. He classified heat treatment into three classes: 1) pasteurization, 2) heating to about 100°C and 3) heating above 100°C.

Hornbaker et al. (1978) and Stumbo (1964) reported that processing at a higher temperature for a shorter time result in less loss of nutritional quality and
less loss of favourable textural properties of foods.

Stumbo (1973) reported that, when bacteria are subjected to moist heat, the death of bacteria will be orderly, the number of viable cells reducing experimentally with time of exposure to a lethal temperature. He added that if logarithms of numbers of survivors are plotted against times of exposure, a straight line will be obtained. This is a logarithmic order of death. Many workers proved that the order of death of bacteria is logarithmic.
Sixty-one samples of spoiled canned foods were collected from the groceries distributed in Khartoum province. Twenty samples of these spoiled canned foods were collected from "Food Research Center, Khartoum North".

According to Stumbo (1973) information about the samples were recorded before the bacteriological examination. These informations were:

1. Name and nature of product
2. Net weight
3. Condition of the cans, if there was any evidence of leakage, rusting, dent or signs of buckling and paneling.
4. Also recording the condition of the cans if there was evidence of spoilage as described by one of the following:
   a) Flat or no evidence of swelling
   b) Flipper which appear flat but when it is brought down sharply on a flat surface, one end will flip out; when lightly pressed, this end will flip back in.
c) Spring rolls in which one end is flat and the other is bulged; when pressure is applied to the bulged end it will flip in and the other end will flip out.
d) Soft swells in which both ends have bulged but not tightly.
e) Hard swell in which both ends are bulged tightly.

5. After bacteriological examination of contents, sides of cans should be stripped and any evidence of faulty seating was recorded.

1. Pre-incubation

Swollen cans were not pre-incubated since extensive microbial growth must have already occurred within the can to produce sufficient gas to swell the can. Non-swollen cans were subject to pre-incubation so as to encourage the growth and distribution of viable microorganisms throughout the pack.

Medium and low acid foods (pH 4.5 and above) were pre-incubated at 37°C, and semi-acids and acid foods were pre-incubated at 30°C. Medium and low acid foods
were pre-incubated at 55°C for the growth of obligate and facultative thermophiles. The incubation period was 14 days for all temperatures. During this period, cans were inspected for signs of swelling, (Hornem and Hulland, 1969; Bean, 1976).

2. Opening of the Container

The container, ends and walls were thoroughly cleaned with soap and water, and sterilized by alcohol.

For flat, flipper and springer cans sterilization was done by direct flashing. For soft-swollen and hard swollen cans there was danger of explosion from flashing due to expansion of gases, so they were sterilized by alcohol (Stumbo, 1973).

The alcohol was allowed to set for a minute or two and the excess was dried out. The can was dried by burning off the residue and the area was then flashed gently by rotating the can slowly over a bunsen flame. The end of the can was then covered by a sterile petri dish.

After sterilization, the can was opened and samples were taken for examination.
The swollen can contain gas under considerable pressure and the content may be offensive, so the sterilised can was placed in a metal tray, and a previously sterilised glass funnel was inverted over the can. The diameter of the funnel should be slightly larger than that of the can. A sterile brass rod with a pointed end was passed down the funnel spout until it rested on the can; both were held firmly and the can was punctured by tapping the rod with a hammer, then the rod was withdrawn slightly. The contents of the can was ejected with some force, but the funnel and tray will prevent broadcast.

According to the method of Jay (1970) the gas which is ejected from the can may be hydrogen, carbon dioxide or hydrogen sulfide. Hydrogen sulfide may be noticed by its characteristic odor.

The test for hydrogen which was ejected from the can was by the application of the match near the mouth of the funnel when the gas was coming out from the can. The sound of "pop" was very clear which indicated the presence of hydrogen.
The test for carbon dioxide was done according to the method of Wood and Holliday (1967). Calcium oxide solution was put in a test tube and the gas from the can was passed through it. If carbon dioxide was present then the colour of the solution turned milky according to the reaction.

$$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$$

$$\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 \downarrow + \text{H}_2\text{O}$$

After the gas tests, samples were immediately withdrawn for bacteriological analysis.

To obtain samples for cultures from liquid and semi-liquid products wide-mouth cotton-plugged pipets were used. Samples of solid foods was taken by sterilized forceps.

A sample of 20 gms was taken from each container and placed in a sterile cotton-plugged test tube. Subsamples from this were used to prepare cultures in appropriate medium (Stamb, 1971).

3. **Experimental Number 1**

To detect whether the dye bromocresol purple was inhibiting the spore formation.
Media used were dextrose tryptone agar with bromocresol purple and the same medium without the indicator. The sample examined was spoiled canned food (mango juice).

The results showed that the average total count of the spores in the medium with the dye was much more than the other medium, so that was no inhibitory action resulting from the dye. So the dye was used all over the work, and it was recommended by many workers (Stumbo, 1973; Sosa, 1976; Karasu and Holland, 1969; and Collins and Lyne 1976).

4. Experiment Number 3.

Tests of three different diluent (peptone water, ½ strength ringer solution, and distilled water) were carried out. The sample examined was spoiled canned mango juice. The medium was dextrose tryptone agar.

Results: The average total count from 3 experiments are shown below:

<table>
<thead>
<tr>
<th>The spoiled food</th>
<th>Peptone water</th>
<th>Distilled water</th>
<th>½ strength Ringer's solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango nectar</td>
<td>3.2x10^2</td>
<td>2.1x10^2</td>
<td>7.0x10^7</td>
</tr>
</tbody>
</table>
The best diluent was 1/2 strength Ringer's solution and was used as diluent in all the experiments.

5. Experiment Number 3
To test for the specific medium for the germination of mold and yeast, four media were incubated with spoiled canned food (mango slices).

The media used were:
1. Malt extract agar (Difco)
2. Potato dextrose agar (Difco)
3. Czapek dextrose broth (dehydrated) + 15 g agar/litre. (Difco)
4. Czapek solution agar (Difco)

Samples were incubated 30°C for 7 days.

After the microscopic examination, the results are as follows:

<table>
<thead>
<tr>
<th>The Medium</th>
<th>The Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Malt extract agar</td>
<td>Yeast and fungi</td>
</tr>
<tr>
<td>2. Potato dextrose agar</td>
<td>Fungi and bacteria</td>
</tr>
<tr>
<td>3. Czapek dextrose agar</td>
<td>Yeast and bacteria</td>
</tr>
<tr>
<td>4. Czapek solution agar</td>
<td>Fungi and bacteria</td>
</tr>
</tbody>
</table>
Malt extract agar was the best medium for culturing of molds and yeast, total count and was used all over the experiments.

8. **pH Measurement**
   
   A Uronic pH meter with glass rod was used for the determination of pH of the contents of the cans.

9. **Preparation of 1/2 Strength Ringer Solution**
   
   One tablet of 1/2 strength Ringer solution was dissolved in 500 ml distilled water, and distributed in amounts of 50 ml in dilution bottles, and sterilized by autoclaving at 121°C for 20 minutes (Hendrix and McGee, 1976).

10. **Preparation of Serial Dilutions**
    
    1 ml of the samples were delivered to 90 ml of dilution up to 10^6 dilutions were transferred after shaking several times with hand to sterile petri dishes, each dilution in duplicate.

    Sterilized and melted dextrose tryptone agar (DIFCO) at a temperature of 45°C were poured into the previous dishes and immediately the medium was mixed with the inoculum by shaking in circular movements lasting for 10 seconds.
Diapos were left to solidify and incubated inverted aerobically at 37°C and 55°C, and anaerobically by using the anaerobic jar (F.T.L., manufactured by Baird and Tatlock, London, Ltd.) and incubated also at 37°C and 55°C for 24 to 36 hours (Harrigan and Mansor, 1976; and Collins and Lyne, 1976).

9. Culturing in Broth Medium
   1. Dextrose tryptone broth
      - Tryptone: 10 g
      - Glucose: 5 g
      - 0.4% alcoholic solution of bromocresol purple: 5 ml
      - Distilled water: 1000 ml
      - Sterilized by autoclaving for 20 minutes at 121°C.

Eight large culture tubes containing 20 ml of medium were used and sterilized as above. To one half of the tubes 3 ml of the product were added per tube; to the other half 0.3 ml of the product was added. For products that cannot be pipetted, these quantities may be estimated.

These tubes were incubated aerobically at 37°C for a week and at 55°C for 3 days (Sumbu, 1973).
2. Liver broth (Oxoid)

This medium was also distributed in large tubes, 15 ml of broth were placed, then liver particles, removed to a depth of about one inch, adding the broth first to minimize entrapment of air. The broth was sterilized by autoclaving for 20 minutes at 121°C.

This medium was inoculated similarly like dextrose tryptone broth, but immediately prior to inoculation, the liver broth was exhaustively heated in a water bath and cooled to 45°C or less. Immediately after inoculation, liver broth tubes were stratified with vaseline which must be at a temperature of 80°C to avoid entrapping air bubbles.

The tubes were incubated like the first medium (the dextrose tryptone) for the same period.

11. Identification of Isolates

Identification (the microscopic and chemical tests) was done according to Bergey's Manual (1974).

12. Determination of Thermal Resistance of Isolates

a) Production of spores

Nutrient agar medium (Difco) was melted and
Distributed in a universal (1 oz) bottles with screw caps, sterilized at 121°C for 20 minutes and cooled in slant position.

These slants were inoculated with the previous 10 isolates and incubated for 2 to 4 days at 37°C and 55°C, aerobically and anaerobically according to the type of isolate. When microscopic examination showed a high percentage of mature spores, the slants were removed from incubation and the surface growth was suspended in a sterile distilled water. To suspend the growth, 3 ml of water was added to each tube, and the growth was suspended by scraping the surface with a sterile inoculating loop.

Suspension from a number of slant tubes were collected in a sterile screw-cap dilution bottle. The bottle of suspension was heated for 20 minutes at 80°C to destroy vegetative cells and to activate the spores for germination. This heated suspension was used to inoculate the bottle slants of agar for mass spore production for each isolated organism.

Screw-cap bottles (150 ml) were used, 50 ml of nutrient agar was placed in each and sterilized
by subculturing for 20 minutes at 121°C. After sterilization the bottles were slanted to obtain a smooth agar surface.

Each bottle was inoculated with 2 ml of heated spore suspension. Each bottle was tilted back and forth until the inoculum covered the surface. The inoculated bottles were incubated at 37°C and 55°C until growth and sporulation were completed (during incubation, the bottles were started at an angle of about 45°). After incubation, 2 ml of sterile distilled water was added to each bottle, and the growth was scraped from the agar surface with an inoculating loop. Another 2 ml of sterilized distilled water was added to each bottle and the suspension was combined with the first washings.

The crude spore suspension was distributed in sterile centrifuge tubes, and the spores were spun down by centrifugation at 1000 g for 5 minutes three times. After centrifugation, the suspension was discarded, and the spores were suspended in sterile distilled water and again centrifuged. This washing procedure was repeated three times. After the final
washing the spores were resuspended in an appropriate amount of sterile distilled water and stored at 4°C until used in thermal resistance determinations (Stumbo, 1973).

b) The Determination of the Development

A glass tubing of 4 mm external diameter, 2 mm internal diameter was cut into 100 mm length using a suitable gas flame. One end of each tube was sealed to give a hemispherical end. The other end was plugged with cotton wool and sterilized by autoclaving, (Harrigan and McDaniel, 1976).

The well mixed spore suspension was introduced into eight of the tubes prepared for each isolate. Filling each tube to approximately ½ of the tube length. Rapidly the open end of each tube was sealed by rotation in a bunsen flame, the care was taking to protect the spore suspension from heating.

One of the tubes was left to ascertain the count at zero time (F₀).

Seven of the tubes were immersed in an oil bath set at 121°C. One tube was removed after each of
the following heating period: 1, 3, 5, 7, 10, 13 and 16 minutes. Each tube was cooled rapidly in a bucket of cold water.

The surface of the tube was swabbed with 70 per cent ethanol and a sterile glass cutter was used with aseptic precautions. The tube was then broken by using a sterile glass rod. The contents were mixed well and a dilution series were prepared at 10⁻⁶ (Harrigan and MoDance, 1976).

Plate count was carried out in nutrient agar (Starko, 1973).

The plates were incubated at 37°C and 55°C aerobically and anaerobically according to the types of spores (Harrigan and MoDance, 1976).

2) The survivor curve

The survivor curve was constructed by plotting the logarithm of survivors against time at a constant temperature, from which D-values were directly taken.
Total Viable Mesophilic Aerobes and Anaerobes, Thermophilic Aerobes and Anaerobes, and Yeast and molds

In all samples of spoiled canned foods which were originated from Industrial Development Corporation Product (Sudan) (Table 1a), the mesophilic aerobes and anaerobes were much more than the thermophilic total count. Molds and yeasts were found also in many samples. So these results show that these samples were under-processed or leaked.

The gas produced was mainly carbon dioxide and hydrogen. In (Table 1b) the samples of the spoiled canned foods were imported from outside the Sudan. The total thermophilic aerobic and anaerobic product count was more than the Sudanese, this was mainly due to under-processing, because there were few samples with leakages. Many samples were changed in colour and smell due to spoilage or may be due to the rust of the can.

The gases which were produced were either hydrogen or carbon dioxide or both. In (Table 1c) the samples were collected from the Food Research Center.
The total count of the mesophilic bacteria was also larger than the thermophilic bacteria and the reason was also under-processing or leakage, the colour and smell were also changed, due to the rust or the growth of microorganisms.

The gas produced was mainly the combination of carbon dioxide and hydrogen.

Table 2 was concerned with the average total count of yeast, mold, mesophilic and thermophilic aerobe and anaerobe. It was clear from the table that the average total count of every group of organisms was greater in the imported products, which may be due to the high temperatures of Sudan which encourage the growth of microorganisms.

Table 3 shows the identification of the common isolates. Most of the isolates were mesophilic, aerobe and gram positive rods, and spore formers.

Table 4 shows the incidence of occurrence in spoiled canned foods of the organisms most certainly found throughout the examination of all samples.
*E. coli*, *E. latoscoporum* and *E. aerogenes* were more common and were isolated from many samples of the spoiled canned foods, and they were more common. The second organisms which occurred in the samples were *B. circulans* and *B. coagulans*. Table 5 shows the percentages of spoiled canned foods in the groceries in the market. The Sudanese mango juice showed a high percentage of spoilage, 30% and so did the tomato paste. Sardines also showed a high percentage of spoilage, 20%. Cheese and mixed vegetable showed high percentage of spoilage, 25%. 

This spoilage may be due to the under-processing of the foods, or the can may be leaked, and also the hot climate of the Sudan encouraged the growth of some dormant spores which were not killed by processing.

D-values for isolates are given in survivor curves of figures 1 to 10. The order of death of all the isolates was logarithmic. The greatest D value at 250°C was 6 minutes for *E. coli*, and the lowest D value also at the same temperature was 2.6 minutes for *B. firmus*. 
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<thead>
<tr>
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</table>

Table 2. Determination of the common language.
<table>
<thead>
<tr>
<th>Code</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Front</td>
<td>Inside</td>
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<tr>
<td>B</td>
<td>Front</td>
<td>Outside</td>
</tr>
<tr>
<td>C</td>
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<td>Inside</td>
</tr>
<tr>
<td>D</td>
<td>Back</td>
<td>Outside</td>
</tr>
</tbody>
</table>

Note: The codes are to be used for indicating the presence or absence of certain conditions.
<table>
<thead>
<tr>
<th>Canned food</th>
<th>Percentage of spoilage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango jam</td>
<td>15 %</td>
</tr>
<tr>
<td>Tomato juice</td>
<td>25 %</td>
</tr>
<tr>
<td>Baked beans</td>
<td>10 %</td>
</tr>
<tr>
<td>Mango juice</td>
<td>30 %</td>
</tr>
<tr>
<td>Sulthona tomato paste</td>
<td>20 %</td>
</tr>
<tr>
<td>Sardine</td>
<td>20 %</td>
</tr>
<tr>
<td>Sliced pineapple</td>
<td>25 %</td>
</tr>
<tr>
<td>Tomato paste imported</td>
<td>25 %</td>
</tr>
<tr>
<td>Milk powder</td>
<td>10 %</td>
</tr>
<tr>
<td>Cheese</td>
<td>25 %</td>
</tr>
<tr>
<td>Fruit cocktail</td>
<td>12 %</td>
</tr>
<tr>
<td>Peach sliced</td>
<td>10 %</td>
</tr>
<tr>
<td>Mixed vegetables</td>
<td>25 %</td>
</tr>
<tr>
<td>Potatoes</td>
<td>15 %</td>
</tr>
<tr>
<td>Melon jam</td>
<td>15 %</td>
</tr>
<tr>
<td>Peach jam</td>
<td>11 %</td>
</tr>
<tr>
<td>Beef</td>
<td>22 %</td>
</tr>
<tr>
<td>Apricot</td>
<td>8 %</td>
</tr>
</tbody>
</table>
Figure 1. *S. subtilis*

$D_{250} \text{ value } = 6 \text{ min}$
Figure 2. *B. latgeporum*

$D_{250}$ value = 4.25 minutes
Figure 3. *P. marxianus*

$D_{250} \text{ value} = 3.2$
Figure 4. E. circulans

$D_{250} = 4.0$
Figure 8. *L. brevis*

$D_{250} \text{ value} = 4.0$
Figure 6. R. firasse.

$D_{250} \text{ value } = 2.6$
Figure 7. *B. longipalmis*

$D_{250} = 4.5$
Figure 8. *E. coli* un

D_{50} value = 4.5
Figure 9. H. alvai

D_{50} value = 3.6
Figure 10. *B. Fusilus*

$D_{50}$ value = 4.2
DISCUSSION

The spoilage of canned foods, according to the studies of sixty-one spoiled canned foods, was due to the growth of microorganisms mainly mesophilic and thermophilic aerobic and anaerobic spore-forming and non-spore-forming bacteria, and molds and yeasts. These organisms can grow in acid, medium and low acid foods. They can produce gas such as carbon dioxide and hydrogen which swell the cans, so these organisms can enter the cans through leakage or the cans were under-processed. This agrees with Frazier (1967), Stumbo (1973), Mangoes, Werry et al. (1973), Norcom and Hulland (1969), Jay (1970), Fyke (1964), Nickerson and Binkley (1974), and Dearman (1963).

Allen (1953), Cameron and Easty (1940), Sachford (1940), Fyke (1964), and Anselm and Jansen (1949) insisted that the thermophilic spore-former bacteria was the main cause of the spoilage of canned foods, because the other organisms could be killed by the heat-processing, while the thermophilic spore-former bacteria can resist the heat treatment.

The findings of Ayres and Adams (1953) agree with our results that the total number of aerobically growing bacteria were larger than the anaerobic bacteria.
It was clear in the results that there was a corrosion by rusting in the containers or by acid foods like fruits and some vegetables which were packed in tinplate containers. This agrees with Pyke (1964), Vail et al. (1967), and Mahadeviah (1976) who reported that corrosion was evident with acid foods which reacted with the container.

The odor and colour of the contents was changed due to the growth of microorganisms and corrosion, this agrees with the results of Mahadeviah (1976).

The spoilage of canned foods by molds and yeasts in low acid foods was due to underprocessing or leakage of the container, because molds and yeasts were not heat resistant. This result agrees with Henson and Hulland (1969). Other workers, like Put and Kruiswijk (1974), and Jones and Jones (1941) and Put (1964) found that some molds were heat resistant and can spoil canned foods.

Table 3 shows the most common species of the genus *Bacillus*, isolated and identified from the spoiled canned foods. These were: *Bacillus subtilis*, *B. licheniformis*, *B. megaterium*, *B. circulans*, *B. brevis*,
B. circuli, B. coagulans, B. cereus, B. alvei, B. subtilis
and B. pumilus, Weinzierl (1961) found that the
dominant species of Bacillus causing the spoilage of
canned foods were B. pumilus, B. circuli, B. coagulans,
B. subtilis, B. thermodifficile, B. vulgaris, B. coeleus
and B. cloacae. Merson and Holland (1969) reported
that canned foods were spoiled by the aerobic spore-
formers of the genus Bacillus which were widely
distributed in nature, originating in soil and water
and almost always present in the raw materials used
in canning. The optimum growth temperature lied
between 25°C and 40°C, but many were thermophilic
developing at 55°C. Some were strict aerobes but
others were facultative aerobes and their growth
was not inhibited in canned foods by vacuum, and their
spores were heat resistant.

Bacillari (1933), Allen (1951), Field (1970), Gordon
and Smith (1949) found that the majority of the
spoilage organisms of canned foods including the
aerobic and facultative aerobic thermophiles resembled
B. stearothermophilus and B. coagulans. Aeschelus and
Jonsen (1940) reported that in many cases the spoilage
organism was B. subtilis.
Table 5 shows the percentage of spoiled canned foods in the groceries. The condition of the climate in the Sudan may be favourable for the growth of some microorganisms which could cause the spoilage of these canned foods. The temperature range in the Sudan is 26 - 42°C during summer and 13 - 39°C during winter. So there may be some heat resistant spores which may remain in the can and spoil it. Bashford (1940), Frazier (1967), Vail et al. (1967), Allen (1951), Longcrop and Shaker (1971), Long and Williams (1959), Campbell (1954), Zottel et al. (1978), and Field et al. (1978), reported that products which have heat resistant spores which are not practicable to kill by processing, are neither stored near steam pipes, boiler, nor exposed to hot climate, as under these conditions, temperature may be created for the dormant spores to develop, and spoilage will result.

The spoilage of canned foods were increased in some condition (Table 5) as the percentage of spoilage was so high, and all these spoiled products should not be consumed for the risk of poisoning of human beings.
D values for the spoilage organisms are shown in Figures 1 to 10.

The death of these *Bacillus* species was ranging from 6 minutes to 2.6 minutes when heated at 270°F. It was obvious from the results that the order of death was logarithmic and these agree with the findings of Stumbo (1973), Horsfall and Baldwin (1968), Ruhn (1945a) and Watkins and Wissow (1932), who reported that if logarithms of numbers of survivors are plotted against times of exposure, a straight line will be obtained and this was the logarithmic order of death.


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