Paper No.: 12
Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 08: Corrosion of Metal Packaging Materials

1 INTRODUCTION:

Metals are considered to be important materials for the packaging of foods, combining properties of strength, toughness, ductility and impermeability. However, the structure of metals which gives them their valuable practical properties is also responsible for their main weakness or susceptibility to corrosion. Corrosion is the chemical reaction between a metal and its environment; it is a universal process affecting all metals to a greater or lesser extent. Because the reaction takes place at the metal surface, the rate of attack can be reduced and controlled by modifying the conditions at the surface.

Metals are chemically reactive and can be readily oxidized by oxygen to form useless corrosion products. This vulnerability to oxidation explains the fact that with very few exceptions (copper, silver and gold), metals do not occur naturally in the metallic state but are found combined with oxygen or sulphur in their ores. Substantial amount of energy is required to extract metals from their ores, and the reverse process is strongly favoured as the metal reverts back to its natural state, the rate of return will of course depend on the environment.

All foods interact with the internal surface of the can in which they are packed. The most common form of this interaction is corrosion. In plain tinplate containers, this takes the form of etching or pitting corrosion, and staining of the surface may also occur; but, internal lacquers are available which reduce this effect by providing a barrier between the food and the metal wall. It also allows the use of other forms of metal container like tin-free steel or aluminium, which would otherwise be corroded very quickly. In the unlacquered form, only tinplate has some corrosion resistance to the acids found in foods; all the other metals must have to be lacquered. Even tinplate must be lacquered where particularly aggressive products are packed, such as tomato puree, or where there is a danger of pitting corrosion or surface staining.

2 ELECTROCHEMICAL CORROSION

The reaction of metals in aqueous solutions or under moist conditions (also known as wet corrosion) is electrochemical in nature, including the transfer of electric charge across the boundary of metal surface and its environment. An electrolyte is a medium which conducts electricity by movement of ions, the cations like Fe^{2+} and anions like Cl^- moving in opposite directions. When an electrode reaction takes place at a metal surface, the electron flow in the metal corresponds to an ion flow in the electrolyte. When a metal corrodes, atoms of the metal are lost from the surface as cations, leaving behind the requisite number of electrons in the body of the metal. This dissolution of the metal is called an anodic reaction and takes place at an anode; an anodic reaction always involves the release of electrons or electrochemical oxidation. Simultaneously, reagents in the electrolyte solution react with the metal surface to remove electrons left behind by the departing metal ions. This removal of electrons is termed a cathodic reaction and takes place at a cathode. The cathodic reaction always involves consumption of electrons or electrochemical reduction.

Since practically all metals are covered with an oxide film, this must be removed before the metal can be exposed to an electrolyte. A metal covered with an oxide has different properties in a solution from a bare metal, but in studying electrochemical corrosion, it is simplest to begin with the ideal case of a pure, bare metal electrode on which the only reaction occurring is metal dissolution.

3. FACTORS AFFECTING RATE OF CORROSION

3.1 Polarization of the Electrodes

When a current flows, there is a change in the potential of an electrode; this is known as polarization. As the current begins to flow, the potential of the cathode becomes increasingly negative and the anode increasingly positive. Consequently the potential difference between the anode and the cathode decreases until a steady state is reached when corrosion proceeds at a constant rate. Thus the corrosion current and therefore the corrosion rate will be affected by anything which affects the polarization of the electrodes.

3.2 Supply of Oxygen

The rate at which oxygen is supplied largely governs the rate of corrosion, since corrosion by oxygen reduction requires the presence of oxygen for the cathodic reaction

to proceed. The rate of supply is proportional to the rate at which oxygen diffuses to the metal surface, and this depends on the concentration of dissolved oxygen in solution. This is the justification for the practice of attempting to remove all the oxygen from canned foods prior to seaming on the can end.

3.3. Temperature

The rate of corrosion generally increases with increase in temperature as more reactant molecules or ions are activated and are able to cross over the energy barrier. As well, increasing the temperature have a tendency to increase the rate of diffusion of molecules or ions in a solution, although the solubility of oxygen in water decreases with increasing temperature.

3.4 Passivation

Passivation refers to a material becoming "passive," that is, being less affected by environmental factors such as air and water. Passivation involves a shielding outer-layer of corrosion, which can be applied as a microcoating, or which occurs spontaneously in nature. As a technique, passivation is the use of a light coat of a protective material, such as metal oxide, to create a shell against corrosion.

If the metal can be oxidized to an oxide that is stable in the electrolyte, then the metal is called passivated. Passivation usually requires strong oxidizing conditions. Thus corrosion resistant metals and alloys can withstand an aggressive environment because of the presence of thin films of adherent oxides on their surfaces. The oxide layer will completely stop the anodic reaction which is the direct cause of corrosion, and if the film is insoluble in the electrolyte solution, it will form an insulation barrier which will reduce the rate of the cathodic reaction.

Iron is readily attacked by dilute nitric acid, but is inert in concentrated nitric acid because a thin, protective film is formed. As a result, iron behaves in concentrated nitric acid like a much more noble metal than it actually is. Iron can also be passivated by chromate solutions, as can tinplate, the latter being a very important step in the manufacture of tinplate. Passivation of tinplate can be achieved using an aqueous solution of chromic acid, although an electrolytic treatment in a sodium dichromate electrolyte has gained widespread favour. The resultant film is composed of chromium and chromium

oxides and tin oxide, its properties varying depending on the quantity and form of these basic components

4. CORROSION OF TIN PLATE

4.1 Corrosion of Plain Tinplate Cans

The tinplate surface consists of a large area of tin and tiny areas of exposed tin-iron alloy ($FeSn_2$) and steel as a result of scratches in the tin coating. Hot dipped tinplate had a considerable tin-iron alloy layer, electrolytic tinplate has a much thinner layer which is electropositive to the base and tin, thus acting as a chemically inert barrier to attack on the steel base. The effect of this barrier is to prevent a significant increase in the steel cathode area. Thus the density or degree of continuity of the alloy layer has a material effect on the rate of corrosion. In the case of tinplate exposed to an aerated aqueous environment, tin is noble to iron according to the electrochemical series. Therefore, all the anodic corrosion is concentrated on the minute areas of steel and the iron dissolves, i.e. rusts. In extreme cases perforation of the sheet may occur. This is the process which occurs on the external surface of tinplate containers.

But, inside a tinplate can, the tin may be either anode or cathode depending on the nature of the food. In a dilute aerated acid medium the iron is the anode and it dissolves, liberating hydrogen. In deaerated acidic food, iron is the anode initially, but later reversal of polarity occurs and the tin becomes the anode, thus protecting the steel; tin has been described in this situation as a sacrificial anode. This reversal occurs because certain constituents of foods can combine chemically with Sn^{2+} ions to form soluble tin complexes. As a consequence, the activity of Sn^{2+} ions with which the tin is in equilibrium is greatly lowered, and the tin becomes less noble (i.e. more electropositive) than iron.

Corrosion in deaerated acidic food cans comprises three stages. During the first stage, the oil and tin oxide layers are removed from the can surface and the speed of tin dissolution is high. This stage continues for 4 to 15 days depending on the nature of the food. The mirror surface of the tin coating should change to one in which the shape of the individual tin crystals may be seen with the naked eye

In the second stage, the corrosion speed is slow and almost constant. Continued dissolution of the tin causes broadening of the existing pores and scratches, uncovering

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the alloy layer and the steel. The unprotected steel provides sites for cathodic reaction and the developed hydrogen is taken up by the depolarizers in the food. The area of exposed steel dictates the rate of hydrogen evolution, and as the ratio between the areas of tin and steel decreases (i.e. as more steel is exposed), polarization decreases. This stage is slow and can last for over 2 years.

The third stage is shown by a high rate of tin and iron dissolution. As large areas of steel is exposed, hydrogen produced at a faster rate and accumulates in the can causing swelling. Once the internal pressure in the can causes the ends of the can to bulge, the product is no longer saleable since consumers cannot distinguish between a swollen can caused by microbial spoilage or hydrogen evolution. As well, the metal content of the food may have reached an unacceptable level by this stage. Therefore, this third stage is of little importance since by then the food will have reached the end of its acceptable shelf life.

Four scenarios are possible in plain tinplate cans depending on the nature of the food and the presence of depolarizers. The first is referred to as normal detinning and is an essential process in plain cans of most products. It has already been described above as the second stage and leads initially to etching and later detinning of the can. Food products characteristic of this type of corrosion include low pH products such as citrus, pineapple, peach and apricot packed in plain tinplate cans.

The second is known as rapid detinning. Rapid detinning is caused by the use of tinplate with a tin coating mass that is too light, or by a product that is intrinsically too corrosive or contains corrosion accelerators such as dissolved oxygen or anthocyanins which are chemically reduced. Food products characteristic of this type of corrosion include tomato and aggressive citrus products such as lemon juice, as well as berry fruits.

The third can best be described as partial detinning and pitting. Early failure occurs because of hydrogen swelling or perforation as a result of the exposed steel continuing to corrode. This type of behavior is associated with products such as prunes or pear nectar, or with steel of inferior quality.

The fourth is described as pitting corrosion which is a reversal of the normal situation, with iron being anodic to tin. Thus the tin does not corrode, but pitting corrosion of the base steel occurs. In rare cases pitting corrosion will also occur when the tin is in fact

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corroding but at too slow a rate to provide sufficient electrochemical protection to the exposed steel. Pitting corrosion used to be rare, appearing in highly corrosive products such as pickles and carbonated beverages formulated with phosphoric acid. However, it is becoming more common and, it is the major cause of failure in canned pears and pear products.

4.2 Corrosion of Enamelled Cans

Food cans with enamel (lacquer) coatings are used to protect against excessive dissolution of tin, sulphide staining, local etching and change in colour of pigmented products such as berry fruits. However, the use of enamels will not guarantee the prevention of corrosion, and in some cases may actually accelerate it. Therefore, careful consideration must be given before selecting an enamel for a particular canned food.

The general pattern of corrosion in enamelled cans is very different from that in plain cans, and is generally more complex. The only exposure of metal in an enamelled can is at pores and scratches in the enamel coating and at cracks along the side seam. Some of these discontinuities in the enamel coating may coincide with pores in the tin coating, thus resulting in exposure of the steel. Even if defects in the enamel film expose only the tin coating, the availability of all the corrosion promoters in the can for attack on the limited areas of tin ensures that steel is soon exposed at them. Thus it is easily possible for the use of an enamel to actually reduce the shelf life of a canned product.

Ions are electrically charged, their transfer through the enamel coating is complex and depends not only on their electric charge but also on the concentration of the electrolyte. If the transport rate of cations and anions through the coating differs, the coating itself may become charged. Thus the protection offered by the enamel coating depends on its resistance to ion transfer which may take place even in the absence of pores, scratches or blisters. The performance of enamelled food cans is greatly affected by the thickness of the enamel coating. A thickness of 4 to 6 μm is sufficient for nonaggressive products such as apricots and beans, but aggressive products such as tomato paste require thicknesses of 8 to 12 μm, the heavier coatings having much lower porosities.

Fiasco of enamelled cans is often due to a reduction in the bond between the enamel and the metal surface, resulting in subsequent lifting of the enamel coating. Thus, good adhesion is required to prevent anodic reactions, to counteract forces developed under the

coating due to physical or chemical factors, and to ensure an aesthetic appearance. Loss of adhesion may begin prior to corrosion due to stresses during fabrication, but typically detachment of the enamel coating is a result of breakdown taking place through or under the coating, or to under film corrosion spreading from exposed metal. The quality of the surface of the tinplate prior to enamelling has a major effect on adhesion and enamel performance. The presence of salt residues can cause failure due to their ability to attract water and therefore establish a conducting film beneath the coating, and to provide ions for carrying the corrosion current.

4.3 Corrosiveness of Food stuffs

The most important corrosion accelerators in foods include oxygen, anthocyanin, nitrates, sulphur compounds and trimethylamines. From a corrosiveness point of view, it is convenient to divide foods into five classes: those that are highly corrosive such as apple and grape juices, berries, cherries, prunes, pickles and sauerkraut; those that are moderately corrosive such as apples, peaches, pears, citrus fruits and tomato juice; those that are mildly corrosive such as peas, corn, meat and fish; and strong detinners such as green beans, spinach, asparagus and tomato products. Beverages are conveniently considered as a fifth class. While the above classification offers a good, broad guide, it is important to note that different lots or varieties of the same food can exhibit as much variation in their corrosiveness as may exist between different types of foods. Thus, for example, the same variety of fruit from different growing regions may vary several fold in corrosiveness. The various factors that can influence the corrosiveness of food products and beverages will now be considered in more detail.

4.3.1 Acidity

No direct proportionality exists between the acidity of a product and the degree of corrosion of tinplate. In other words, two products of the same acidity will not necessarily be equally corrosive. It also appears that pure solutions of organic acids are less corrosive than the fruit juices containing them, suggesting that fruit juices contain unidentified depolarizers which enhance the corrosive action of organic acids. It has been well established that the tendency of an acid to form a complex with dissolved tin has an important bearing on the relative polarity of tin and steel, and hence the degree of

corrosion. The type of organic acid is more important than its concentration, and the addition of nitrate increased pitting severity in all acid solutions.

4.3.2. pH

Same as acidity, no direct relation exists between pH and the degree of corrosion of tinplate; this is not surprising when it is considered that the reaction product when a metal is dissolved is not always an ionic species but often a solid oxide or hydroxide. The pH of the system also determines the relative cathodic protection given to steel. In some cases tin is cathodic to steel over a certain pH range (in the case of acetic acid the range is pH 2.0 to 4.5), while in others it offers protection up to pH 4; above that level it may accelerate corrosion.

4.3.3. Sulphur Compounds

Sulphur and sulphur compounds may be introduced into the can in a number of ways: as spray residues from agricultural chemicals; as residues from sulphur-containing preservatives, and as components in sulphur-containing compounds such as proteins in meat, fish and certain vegetables: the proteins are degraded during heat processing, releasing free sulphide or hydrosulphide ions and evolving hydrogen sulphide gas into the headspace. Trace amounts of sulphur compounds from agricultural chemicals can lead to accelerated corrosion and failure of plain tinplate cans containing acid foods such as apricots and peaches. As well, pitting corrosion can occur, and this has been attributed to inactivation of the tin coating by a protective film of sulphide having a more cathodic potential. As a consequence, there is a significant reduction in the tin dissolution rate, and no electrochemical protection of the steel by the tin. Sulphur dioxide may be directly reduced on the tin surface to sulphide or even to sulphur, with tin passing into solution and the development of unpleasant odours and flavours. Residual SO_2 accelerates corrosion through its action as a depolarizer. Trace amounts of SO_2 as low as 1 mg kg^{-1} are sufficient to accelerate corrosion; such corrosion problems may be overcome by the use of enamelled cans.

There are two types of sulphide staining: Iron sulphide staining, also called sulphide black, and the other involves tin sulphides. Neither type constitutes a health hazard nor leads to failure of the can, but both types may cause adverse reactions from the consumer.

Iron sulphide stains are characteristically black and usually occur at isolated points on the can like headspace during or immediately after heat processing. Iron sulphide is not formed at pH values below about 6.0 so that it is uncommon to find it in the portion of the can in contact with the contents. The problem may be overcome by using enamelled cans or plain cans with enamelled ends.

Tin sulphide staining is usually widespread throughout the can and is blue-black or sometimes brown. Two stages are believed to be involved: an oxidation of the tin, followed by deposition of an insoluble tin sulphide precipitate on the surface. It occurs during or soon after heat processing and shows little or no increase in intensity during storage. It may be reduced by using sulphur-resistant enamels into which quantities of zinc oxide or carbonate are added before being applied to the plate surface. These react with sulphur-bearing gases to form almost invisible white zinc sulphide.

4.3.4. Nitrates

Nitrates are found in fruits and vegetables grown in heavily fertilized soils. Vegetables such as green beans, spinach, turnips, lettuce, beets and radishes have been shown to contain on occasion several thousand mg kg^{-1} of nitrates. Nitrates are very efficient cathode depolarizers since they are capable of being reduced all the way to ammonia. They have been responsible for serious economic and toxicological problems in some canned foods, notably tomato products. Although nitrates and nitrites are also present as intentional additives in processed meats, they present no problem; this is because meat products are above the critical pH range (5.5) for detinning to occur via the nitrate-tin reduction system. The reduction of 60 mg of nitrate could account for the dissolution of 470 mg of tin; a tin coating of 11.2 gsm may be dissolved completely within 6 months by tomatoes containing 100 mg kg^{-1} of nitrate.

Overcoming the problem by restricting the use of nitrate fertilizers has proved difficult, it is also possible to avoid the use of waters with a high nitrate content for canning operations; a suggested maximum is 5 mg L^{-1} nitrate. The best solution to the problem at present is the use of enamelled cans, although the development of corrosion inhibitors would offer an alternative solution.

4.3.5. Plant Pigments

Anthocyanin and related pigments are among the most important potential corrosion accelerators since they are easily reduced. Anthocyanin pigments can also act as anodic depolarizers through their ability to form complexes with cations, particularly those of iron and tin salts. Analysis of samples of canned fruit after a period of storage usually shows a greater amount of tin in the drained fruit than in the syrup, indicating that at least part of the tin is combined in an insoluble form with some constituent within the fruit.

The nature of the anthocyanin pigment is also important. For example, raspberries contain cyanidin glucosides which have ortho-dihydroxy groups in their structures; it is these groups which are involved in the formation of blue-tinted complexes with metals such as tin. The major pigment of strawberries is pelargonidin-3-glucoside which does not possess the necessary ortho-dihydroxy groups for complex formation. Therefore, strawberries do not show the same shift to a blue colour in the presence of tin salts as do raspberries.

Combination of metal ions with tannins has been observed in other fruits. For example, discoloration in canned cranberry has been attributed to the formation of a complex between tannins present in the fruit and tin salts. It should be noted that not all reactions between plant pigments and metal ions will produce undesirable colours, although this is usually the case with anthocyanin pigments

4.3.6. Synthetic Colourings

The canned products which most commonly contain synthetic colourings are soft drinks, which consist basically of sugar-based syrups and carbonated water containing flavours, acidulants and colours. The behaviour of soft drinks depends to a considerable extent on the presence of azo dyes and the amount of residual oxygen in the filled can. Both of these components are capable of acting as corrosion accelerators and are potentially active corrosive agents. Tin dissolution may adversely affect the colour of some products, and iron dissolution may lead to perforation and flavour defects. Thus fully enamelled cans are essential.

4.4 Effect of Processing and Storage

4.4.1. Oxygen

Removal of as much of oxygen as possible is an essential part of good cannery practice and a variety of methods are used: hot-filling, vacuum filling, exhausting, closure under

vacuum, steam flow closure and vacuum syruping. As well, positive control of the headspace volume is essential. A larger headspace is likely to contain a higher residual oxygen concentration than a smaller one. However, the larger the headspace, the more room there is for accumulation of hydrogen resulting from corrosion and thus the greater the time required to form a hydrogen swell.

Despite the above procedures, there will always be some oxygen present in the headspace of newly filled cans. The rate of oxygen consumption at this stage is quite rapid but decreases with time, the rate being a function of initial concentration, headspace volume, can vacuum, nature of the product and type of container.

Oxygen acts as a depolarizer, accelerating corrosion by reacting with the hydrogen formed in the can through a cathodic reaction. If the residual pressure in the headspace of a filled can of a common size is 0.5 atmospheres, then the oxygen present would be capable of removing about 0.25 gsm of tin from the coating, producing 15 mg kg^{-1} of dissolved tin in the can contents. Although this is a relatively small amount in comparison with the total coating weight, the action of the oxygen may be localized on a narrow zone of the gas/liquid interface in the headspace. This may result in the production of an unsightly etched line and even exposure of an area of steel much larger than that exposed at pores in the initial coating.

4.4.2. Thermal Processing

Very little is known about the effect of heat sterilization process on corrosion rates, except that the quantity of metal dissolved during the process is very small. This is hardly surprising given the comparatively short processing times relative to the total shelf life of the canned product. However, degradation products formed during thermal processing can cause corrosion, e.g. non-enzymatic browning intermediates and sugar derivatives.

What has been emphasized is the importance of correct cooling: failure to cool cans adequately can lead to increased corrosion since the can centre temperatures may take several days to return to ambient. On the other hand, cooling to too low a temperature may cause panelling of the can walls as well as external corrosion since complete drying of the can exteriors will not occur.

4.4.3 Storage Temperature

The rate of a chemical reaction increases as the temperature is raised, and for many reactions, the rate doubles for each 10°C increase in temperature. Thus to minimize undesirable reactions such as non-enzymatic browning in canned foods, it is preferable that storage temperatures be kept as low as possible.

4.5 External Corrosion of Cans

Tinplate rusts readily in the presence of moisture, rusting occurring more readily the thinner the tin coating. The presence in the atmosphere of sulphur dioxide or oxides of nitrogen accelerate the rate of corrosion since they dissolve to form acids. Chlorides can also cause a rapid increase in the rate of corrosion. Under normal conditions on the outside of a can, tin is cathodic to iron, and when a galvanic cell is set up at pore sites, the attack on the iron is accelerated by the presence of tin. Rust forms as a result of corrosion of the iron. Three stages of exposure to the risk of external rusting may be differentiated: thermal processing; cooling of cans, and storage.

4.5.1. Thermal Processing

The essential ingredient for rusting of cans during thermal processing is the presence of oxygen in the processing vessel. When cans are processed in water at atmospheric pressure as is quite common for high acid, low pH products such as fruits, the risk reaches a maximum at a temperature of about 80°C. Above this temperature, the loss of dissolved oxygen counteracts the acceleration of the reaction rate at the higher temperatures. Therefore, when full boiling is not required, the water should be deoxygenated and preferably treated with corrosion restrainers.

When cans are processed in steam, it is important that proper venting of the retort occurs so that all the oxygen initially present is displaced from the retort by the steam. As well as minimizing any external corrosion, the removal of air from the retort prevents pockets of air from surrounding individual cans and insulating them from the steam, the latter situation leading to under processing.

The addition of additives to steam or water used in thermal processing has been investigated as a possible way of minimizing the external rusting of cans. Although promising results have been obtained with soluble or volatile oils which form a water-repellent film on the metal surface, the cans take on an oily appearance and feel, and difficulty can be experienced with adhesion of paper labels.

4.5.2. Cooling of Cans

Cans are typically cooled after thermal processing by passing water through the retort or placing the cans in cooling canals, but in some canneries hot cans are removed from the retort and left to cool in the air. If cans are cooled with water, it is a regulatory requirement in virtually every country that such water contain a measurable amount of bactericide when it exits the retort. This usually means in the case of chlorine that incoming water has a free chlorine content of around 5 to 10 mg L^{-1}.

When cans are water cooled, they should be around 40°C when they are removed from the retort. If they are warmer than this, there is the risk of thermophilic spoilage, chemical degradation and significant internal corrosion; if they are cooler than this, insufficient heat will remain to evaporate any water adhering to the exterior of the can. Cans should be stacked in such a way so as to enable self-drying to occur prior to labelling and packing. Accelerated drying methods such as the use of hot air, or a steam spray, or rolling cans over a sterile absorbent surface, have advantages in minimizing external corrosion of cans.

4.5.3. Storage

If corrosion is to be prevented during storage, then the atmosphere surrounding the can must be free of corrosive vapours or chemicals, and not promote condensation of moisture. As well, packaging materials in contact with the cans should be as free as possible from soluble chlorides, sulphates or other salts which may promote condensation of moisture and corrosion. Cartons usually have a water content of 10 to 12 %, and when the air temperature rises, moisture evaporates from the cartons in the warmer outer zone and condenses in the cooler centre of the stack.

The shrink wrapping of cans, while protecting them from promoters of corrosion found in the atmosphere, can cause problems of condensation if the air inside the shrink wrap contains a considerable quantity of water vapour and the package is later subjected to a drop in temperature. Rusting can also be caused by unsuitable conditions of transport and storage where sweating occurs. This is especially so when cans are transported from temperate to tropical areas, or temperate to temperate areas via the tropics. Attempts to prevent condensation of moisture by free movement of air have usually been unsuccessful because the centre of a stack of cartons filled with cans takes a long time to

respond to the external temperature change and may remain below the dew point for long periods.

The use since the 1970s of bulk shipping containers each holding about 18 tonnes of cans has become increasing popular for sea transport. Such a container may include two tonnes of carton material; if the moisture content of such material changes from 12 to 10 %, 45 litres of water would be released within the container. Such a change could come about if the upper part of the container were exposed to the sun, causing the water to distil from the warmer to the cooler parts of the container. Despite such possible hazards, the use of large containers makes it much easier to apply measures needed to avoid rust-promoting conditions.

5. CORROSION OF OTHER TYPES OF CANS

5.1 ECCS Cans

Although the chromium/chromium oxide layer on ECCS cans is only approximately one-fiftieth the thickness of a typical tinplate coating, it transforms the base steel into an excellent can making material by providing rust protection, outstanding enamel coating adhesion, good resistance to corrosion and good resistance to under film sulphide staining. Two-piece ECCS cans have significantly lower product iron contents compared with three-piece tinplate cans.

5.2 Aluminium Cans:

Aluminium rapidly forms a protective oxide film when exposed to air or water. The film is extremely thin (about 10 nanometres) but it renders the metal completely passive in the pH range from 4 to 9. Because aluminium oxide is amphoteric it will dissolve in acid or alkali to give the soluble aluminium cation or anion respectively.

In practice it is found that aluminium will corrode in acid solutions (pH below 4) and alkali (pH above 9) but its corrosion resistance is excellent in the range of pH 4 to 9. Having a strongly negative electrode potential, aluminium is liable to undergo severe corrosion if brought into metallic contact with copper, iron or other more positive metals in the presence of an electrolyte, e.g. fruit juice. Thus care must be taken to ensure that situations which could lead to such corrosion are avoided.

Although no foods have a pH greater than 8, cleaning solutions used in food processing plants frequently have pH values of 13. It is therefore important that these solutions do

not come into contact with aluminium packaging materials, and that any package-contact surfaces which are cleaned with these solutions are thoroughly rinsed with water afterwards.

6. Conclusion

In general, the shelf life of a can will depend upon the product, the can specification and the storage conditions in which it is held. Every can is a unit of sale and as such each and every can must comply with the legislation relevant to it. For this reason, and because of the many variables associated with the product, from the grower through to the retailer, it is very difficult to assign a specific shelf life to any product. The experience of the packer is most critical in arriving at sensible conclusions. Overall, however, due to the many different factors affecting shelf life, it is often impossible to predict, and tests with the actual product are the best course of action. Present solution for prevention of corrosion of metal packaging materials is to use of enamelled cans or avoid the conditions which are favourable for corrosion of metal. Studies are going on to use of anti-corrosive additives to be added during can manufacture, but are still in their infancy.

Reference:

Board PW, Steele RJ. 1975. Diagnosis of Corrosion Problems in Tinplate Food Cans, Technical Paper No. 41, CSIRO Division of Food Research, Sydney, Australia

Breedlove AL, Davis DR. 1983. Effect of Selected Organic Acids on the Pitting of Tinplate Cans in Model Systems. *J. Food Sci.* 48: 1148 -1150.

Britton SC. 1975. Tin Versus Corrosion, ITRI Pub. No. 510, International Tin Research Institute, Middlesex, England

Mannheim C, Passy N. 1982. Internal corrosion and shelf-life of food cans and methods of evaluation. *CRC Crit. Rev. Food Sci. & Nutn*. 17: 371-407

Page B, Edwards M, May N. 2003. Metal Cans. *In*: *Food Packaging Technology (Eds: Coles R, Mcdowell D and Kirwan MJ)*, Blackwell Publishing, Oxford, UK

Robertson GL. 1993. *Food Packaging Principles and Practice*. Marcel Dekker INC. New York