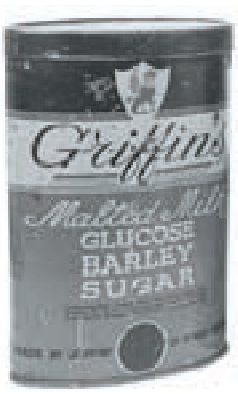
Metals

Metals have a long history as a material for making containers. Their use in packaging is more recent, as it required the manufacturing facilities that the industrial revolution produced.

Although the term 'metal' is widely used, it is not possible to give an exact definition. Metals can be distinguished by their physical properties, such as ductility (can be drawn into wire), malleability (can be hammered or pressed into shapes), high reflectivity, and good electrical and thermal conductivity. Chemically, metals are defined as materials held together by metallic bonds, where atomic nuclei are held in a 'sea' of electrons by electrical charges.

The **most important metals** in packaging are:

- **Iron**, used as steel in cans (steel is iron with the addition of carbon).
- **Aluminium**, used to make cans, as foil, as a very thin layer deposited on plastic film or paper, and to make collapsible tubes.
- **Tin**, used as a thin layer on steel cans (hence the 'tin can') to protect the steel from corrosion.



Tinplate canisters with push-fit closures, such as this old example, used to be common.

Today, some have been replaced by plastic containers, others by plastic bags, either on their own or inside a paperboard box.

However, some metal containers have remained largely unchanged. This container and its graphics have changed little since its introduction in 1905. The metal closure has been replaced with plastic.

A brief history of packaging in metal

Metalworking began about ten thousand years ago when deposits of particles of copper metal in western Iran were hammered into shapes. By about 3500 BC copper was made by smelting. Gold is the only metal commonly found in metallic or 'native' form, usually as particles. Other metals are too chemically reactive to remain in native form and are found in ores mostly as oxides or sulphides and must be extracted by smelting or by electrolysis.

Metal cans are used mostly in the canning of food and drink, aerosol cans, 'tins' of materials such as shoe and floor polishes, and presentation 'tins' of foods such as biscuits. The major properties of metals exploited are ease of forming (for cheap manufacture), impermeability to gases and light (allowing long product life), strength (allowing thinner grades of metal), high impact resistance (cans can withstand situations which would rupture glass and plastic containers), heat resistance (allows heat sterilisation), and shiny surface (good consumer presentation). The major problem to overcome was metal corrosion from the contents and from the atmosphere.

The invention of canning has been attributed to Nicolas Appert, a French chemist. In 1809 he received the award offered by the French government for preserving foods for use by the military. Although Appert had developed a successful canning process based on heat sterilising the contents in sealed containers, it was another fifty years before Louis Pasteur explained the role of microorganisms in food decomposition and the effect of heat sterilisation.

Canning was first done by Appert in glass bottles, but glass was too heavy and fragile for mobile use. Metal cans were developed several years later, with the first UK patent for tinplate cans granted in 1810. The term "tin can" came from the original description of 'tin-plated steel canister'. They are often referred to simply as 'tins'. 'Tin' cans are called steel cans by manufacturers.

Metal cans were the first mass-produced form of long-life consumer food packaging. Today, cans are still the best form of robust packaging for food where a long shelf life and no special storage conditions are required.

Early metal cans were made from tinned iron plate, with hand soldered seams. The iron plate was tinned by dipping it in a bath of molten tin. Today, steel sheet with a very thin electroplated tin layer is used, and the side seams are slightly overlapped and welded, with the top and bottom ends crimped in place. Welded side seams have now displaced crimped and soldered seams, introduced in the early 1900s.

A major problem in canning is ensuring sufficient sterility (note that absolute sterility may not be required). Some microorganisms have heat resistant spores, although they may not be harmful. One harmful bacterium with resistant spores is *Clostridium botulinum* (see p. 19), able to grow in low-acid (pH >4.6) vegetable, meat, fish and dairy products. However, it has been virtually eliminated in New Zealand. Microorganism growth can produces gas, which swells the can.

Reaction of the can contents with the tinplate was also a problem, now eliminated by using coatings which match the product characteristics. High acid foods, such as fruits, attacked the tin and then the steel beneath, liberating hydrogen gas which swelled the can, with the corrosion eventually destroying it. Some products are also affected by the tin, either being bleached or stained, both harmless but unsightly. This is also eliminated by using appropriate internal coatings.

Although extremely rare, and today usually a result of can damage, any can appearing to have swelled due to internal pressure (the ends usually bulge outwards) must not be used. It indicates microbial growth or corrosion, both a risk to health.

Packaging is affected by social change. After World War II there were many small mixed farms in NZ. Cream was one product and was shipped to butter factories in tinned steel cans, as shown above. Today, farms are much larger, and the higher product volumes, as well as more stringent product specifications, meant that the 'cream can' was no longer a useful package.

Properties of metals utilised in packaging

The properties of metals of **advantage** in packaging are:

- **Easy to form:** Because metal is malleable and ductile it can be pressed and drawn into many shapes, from cans to opening devices. This enables high-volume and economical manufacture.
- **Impermeable:** Metal, like glass, is totally impermeable to gases and liquids, a most useful characteristic for food preservation. Unlike glass, it is naturally totally opaque to light, an important characteristic for food preservation. Metal cans can be left in the sun with no deterioration from the light. However, the clarity of glass does allow the consumer to see the contents and to assess the quality. Metal cans generally have labels with illustrations of the contents to overcome this presentation disadvantage.

  Metal retains its impermeability even when very thin. Foil above 0.017 mm is totally impermeable, but when thinner the increasing number of pinholes increases permeability. Even extremely thin coatings of metals still have considerable barrier qualities. Metals are deposited on plastic films to reduce their gas permeability.
- **High impact strength:** One great advantage of metal cans is their toughness. They dent rather than break or rupture, even under conditions which would rupture plastic containers.
- **Resistance to temperature extremes:** Metal cans and foils can withstand both very high and very low temperatures. This makes

An aluminium foil top on a glass bottle of milk. The foil can be shaped and placed by machine on the bottle and is economical in cost and in materials. It does not react with the milk, is impermeable, easy to open, and provides tamper evidence.

them suitable for in-container heat sterilising and is the packaging of choice for extreme conditions. There is some aseptic canning, where the contents and the cans are separately sterilised and brought together under sterile conditions, but most canning sterilises the metal cans and the contents after filling and sealing.

- **Thermal and electrical conductivity:** This property is utilised in deposited metal coatings on plastic films for microwave heating.
- **Shiny:** Only metals can produce a mirror-like surface to reflect light (as distinct from a glossy surface). This attribute is utilised especially in applying thin coatings to plastic films to give a shiny surface.
- **No refrigeration required:** As the contents of cans are sterile, no refrigeration is required when unopened, an important quality for many parts of the world. Metal cans can be stored in almost any conditions, providing the atmosphere will not corrode the cans. Canned food is ideal to store as part of disaster preparation.
- **Recyclable:** All metal cans can be recycled. Steel cans can be easily separated from waste by large electromagnets, allowing low-cost recovery. Aluminium cans have to be collected separately. Recycling metals, especially aluminium, saves considerable energy.

Disadvantages of metals are:

- **Reactive:** All metals will react with other substances under particular conditions. Steel will quickly rust (oxidise) if it is not protected. Tin is adequate under most situations, but reacts with some products and may need to be lacquered. Aluminium relies on a thin coating of oxide, which, unlike the oxides of iron (rust), remain firmly attached to the metal and protect it from further corrosion. However, in many food applications, oxygen is removed to prevent loss of flavour, so aluminium loses its natural protective layer. In these situations (e.g. carbonated drink cans) it is lacquered on the inside to protect it from corrosion.

  If well protected, metal cans provide extremely long lasting food preservation, comparable only to glass, but tougher.

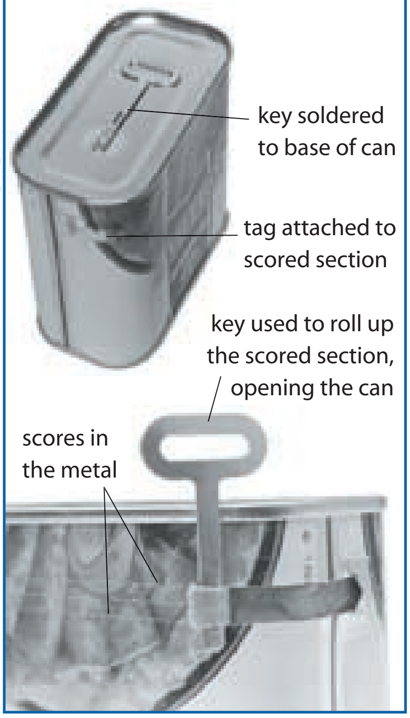
  Metals can also react with each other (electrolytic corrosion), so care must be taken if there is the likelihood of having different metals touching in the presence of water.
- **Weight:** While lighter than glass, metal is heavier than plastics. Modern metal cans have thinner walls than older cans to reduce their weight and to use less steel.
- **Opening:** The high strength of metal cans makes them difficult to open. The first cans had no provision for opening them and had to be opened with a chisel! Today, we have a choice of many can-opening devices, with an increasing range of cans having pre-scored metal 'tab' opening or key-opening sections. The side-bar on the left shows three methods of opening.

Opening metal cans

There are many types of can openers, some almost as big as the can!

Pull-tabs to open the can along a scored section, first used on drink cans, are becoming more common on other products.

Providing a key to open a can along a scored line is common for meat products likely to be eaten in conditions where a can opener may not be available. In the example below, the can is tapered and, after opening with the key, the top can be easily lifted off to leave the product on the can base for serving.



Forms of metals used in packaging

There are four main forms in which metals are used in packaging:

1 In **sheet** form to make containers, most commonly as two- and three-piece cans, and closures for glass containers. Metal drums are constructed from heavy gauge sheet and used for bulk products, although increasingly being replaced by plastic drums.

2 In **foil** form (very thin metal less than 0.15mm thick), used to wrap foods and as seals for pharmaceutical packaging. It is more commonly used in laminations with paper and plastic. These provide the strength, the foil provides the gas barrier. Foil laminated with plastic is heat sealed to enclose pharmaceuticals. Aluminium foil is shiny, impermeable if thicker than 0.017mm, can hold a fold very well (good dead-fold properties), can be sterilised, and heavier foils can be shaped into trays.

3 As an extremely thin **coating** deposited on plastic film or plastic items. Plastic closures may be electroplated with metal to mimic solid metal, generally restricted to high cost items such as cosmetics. The most common use is to improve barrier properties and presentation.

4 In **slug** form (a thick piece of metal) which is impact extruded into seamless tubes. The most common examples are collapsible tubes for glues and pastes, and tubes for felt-tip pens. Collapsible tubes used to be made from lead, but most are now made from aluminium Plastic tubes have replaced lead tubes for products such as toothpaste. In impact extrusion a metal slug is placed on a shaped surface (usually for the closure end) and a punch strikes it with such force that the metal is forced into the shaped end and also flows up and around the body of the punch to form a tube.

Made from sheet metal, this can has changed little in 100 years.

A collapsible metal tube. Note the tube opening, shown below, has to be pierced before using the product. In storage, this retains the impermeability of the metal essential in packaging a product with volatile solvents, as in this glue. It also provides tamper evidence. The tube end has been securely crimped.

The pet food industry is a major user of metal cans. The photograph shows a two piece steel can with a pull-tab end. The can body is drawn from one piece of metal. Heat processing produces a lower-than-atmospheric pressure within the can.