Chemical Food Preservation

Sean Jacobson

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Food Preservation

Have you ever eaten methi paranthas in the month of June? If yes, where did the methi come from? Not from the vegetable market, because it is not available in the month of June! On a certain day, if the dishes are not to your liking, you prefer to eat food with pickle or mango chutney. Have you ever wondered how preparations such as pickles, potato chips, tomato sauce, etc., are present in your house throughout the year? Why do they not get spoilt? There are definite months in a year when pickles, papads, chips, squashes, etc., are prepared and stored for the year. In this lesson let us learn about those foods which can be stored for long periods without getting spoilt.

WHAT IS FOOD PRESERVATION

The dictionary meaning of the word "preserve" is to keep safe, retain quality, prevent decomposition or fermentation. When we apply this meaning to food preservation it can be defined as: A process by which certain foods like fruits and vegetables are prevented from getting spoilt for a long period of time. The colour, taste and nutritive value of the food is also preserved. Let us understand this definition in a little more detail. The definition says *preventing foods from getting spoilt.* When you keep fruits, vegetables or left over dal in the refrigerator or in a cool place, will this be called food preservation? No, because you can store fruits and vegetables or left over dal in this state for a few days only. The definition of food preservation states that the preserved food should *retain their colour and taste.*

This means that the colour and taste of food which is present at the time of preservation should not change. Let us take the example of preserving grapes as raisins. Raisins are prepared by sun drying grapes. During the drying process the grapes change colour from green to brown, and taste, sweeter. However, once they are dried and stored, they do not change colour or taste. Like colour and taste, a well preserved food should *not change texture.* When your mother makes mango murraba at home, have you observed the texture of the mango pieces? It is firm . In a well made murraba, this firmness of mango pieces should not change after sometime.

WHY DO WE NEED TO PRESERVE FOODS

Now that you have understood the definition of food preservation, did you think about why we should preserve foods? Can you think of a few reasons for preserving foods? Let us find an answer to this question by taking an example of one food item. Let us take the example of a fruit, say mango. There are many ways by which mangoes can be preserved.

These are: juice, murraba, squash, aam papad, pulp, chutney, pickle, raw mango powder.

You may be able to add a few more to the above list. Mango is a summer fruit and grows in large quantities during the months of April to August. Different varieties of mango are grown in different parts of our country.

Usually all the quantity grown in a region cannot be consumed by the people staying there as there is always an excess. What does the farmer do with this excess quantity? He makes arrangements to transport the excess quantity to regions where either mango is not grown or where that particular variety of mango is not available. If he does not do this, the excess produce will rot and go waste.

The farmer will then lose money. There is still some quantity which is left after the fresh fruit is consumed by the people. It is this quantity which has to be preserved for consumption during the months when mango is not available. Preservation of foods is done during the months when food is available in large quantity and therefore at low cost.

- One of the important reasons for preserving foods is to take care of the excess produce. There are many other reasons for preserving foods. Let us learn about these.
- The second reason for preserving foods is that they add variety to our meals. Have you ever got tired of eating the same vegetables which are in season? Is it not nice to eat peas when they are either very expensive in the market or are not available ? Eating cauliflower in pulav or cauliflower vegetable during the summer months adds to the interest in meals.

In the same way, eating some chatni, papad or pickle along with the meals adds to the variety. Preserving foods when they are in season makes this possible.

- Reaches areas where the food item is not grown. In some areas of Rajasthan which are desert areas and in Himalayan regions that are covered with snow most of the time, very few foods can be grown. Availability of some preserved foods can add to the variety and nutritive value of meals. For example inclusion of dehydrated peas, green leafy vegetables, canned fruits etc., in the meals is a good idea in such areas.
- Makes transportation and storage of foods easier. Preservation of foods usually reduces bulk. This makes their transportation and storage easier since it requires less space. For example, if you dry green leafy vegetables such as mint, methi, corriander, etc, their weight and volume reduces, thus making their storage easy.

WHY DOES FOOD GET SPOILT

The definition of food preservation states that preservation is keeping food in such a state that they do not get spoilt for a long period. Before we look at the reasons of food spoilage, let us understand, when is a food spoilt. When you keep bread outside the refrigerator for few days, a spongy growth is seen on it, which may be white, green on black in colour.

The bread thus gets spoilt due to growth of mould and becomes unfit for consumption. Likewise, if cooked dal or vegetables is left outside for sometime, it develops a bad smell and bubbles due to fermentation. The dal and vegetables are thus spoilt and cannot be eaten. Can you now say when is a food spoilt? Food is said to be spoilt if there is rotting, i.e., bad smell, fermentation, i.e., bubbles/gas in the food or mould i.e., spongy growth on the foodstuff.

Formation of soft spots or soft brown spots on fruits and vegetables is also food spoilage. Why do foods get spoilt? If you know the reasons of food spoilage, you can remove these conditions while preserving food items. Foods get spoilt mainly due to the presence of micro-organisms, enzymes (present in foods), insects, worms, and rats.

PRESENCE OF MICRO-ORGANISMS

Micro means small. Micro-organisms are very small organisms which cannot be easily seen. Micro-organisms spoil food items when the condition for their growth are appropriate. What are these appropriate conditions? Like all living beings micro-organisms require air, moisture, right temperature and food to grow and multiply. The situations which provide appropriate conditions for growth of micro-organisms, can be listed as:

- Food having high moisture content.
- Air around the food containing micro-organisms.
- Foods kept for a long time at room temperature.
- Skin of fruits and vegetables getting damaged, thus exposing the food to micro-organisms.
- Foods with low salt, sugar or acid content.

PRESENCE OF ENZYMES

Enzymes are chemical susbtances found in all plants and animals. Are enzymes harmful to foods? No, enzymes help in ripening of fruits and vegetables. A raw green mango after a few days becomes sweet in taste and yellow in colour due to the enzymes action. What will happen if you keep this yellow, ripe mango for a few more days?

It will become soft, develop black spots and will start smelling bad. This is due to continued action of enzymes. No one likes to eat such as over ripe, spoilt mango. You know that even when the skin of fruits is not cut or damaged, it gets spoilt. This is due to enzyme action.

PRINCIPLES OF FOOD PRESERVATION

After learning about the causes of food spoilage, it should not be very difficult to list the principles of food preservation. Remember, a good method of food preservation is one that slows down or prevents altogether the action of the agents of spoilage. Also, during the process of food preservation, the food should not be damaged.

In order to achieve this, certain basic methods were applied using the knowledge gained form observation of the effects of natural conditions on different types of foods. For example in earlier days, in very cold weather condition, ice was used to preserve foods.

Thus, very low temperature became an efficient method for preventing food spoilage. Let us now list the principles of food preservation:

- *Removal of Micro-organisms or Inactivating Them*: This is done by removing air, water (moisture), lowering or increasing temperature, increasing the concentration of salt or sugar or acid in foods. If you want to preserve green leafy vegetables, you have to remove the water from the leave so that micro-organisms cannot survive. You do this by drying the green leaves till all the moisture evapourates.

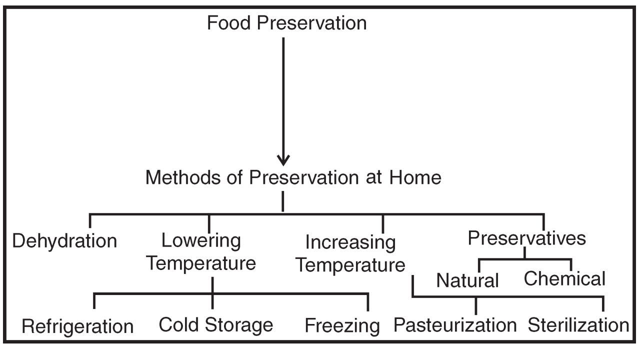
- *Inactivating Enzymes*: Enzymes found in foods can be inactivated by changing their conditions such as temperature and moisture, when you preserve peas, one of the methods of preservations is to put them for a few minutes in boiling water. This method inactivates enzymes and thus, in preserving the food.
- *Removal of Insects, Worms and Rats*: By storing foods in dry, air tight containers the insects, worms or rats are prevented from destroying it.

METHODS OF PRESERVING FOODS AT HOME

Foods can be preserved at home by the following methods:

- Dehydration
- Lowering temperature
- Increasing temperature
- Using preservatives.

Let us now discuss each method in some detail.



DEHYDRATION

Can you name some dried food items that are stored in your kitchen for a period of one year or more? Are these potato chips, sevia (vermicilli), methi, cauliflower, papad, ginger powder? These are foods which have been preserved by the dehydration method. The word dehydration means removing water or moisture from foods. The home method of dehydration is sun drying. We will now discuss this method in some more detail. Some foods are dried as they are, eg., green leafy vegetables (methi, pudina, corriander etc.), cauliflower, grapes, amla, onion, raw mango, etc. Some foods are cooked and then dried. For example, potato chips, papad, banana, chips, wadis, etc. The most appropriate weather to dry foods is when the air is dry and there is strong sunshine. Let us understand the basic method of dehydration before we learn to apply it to individual foods:

- Step 1: Clean all tins, plates, etc., to be used to dry and store the food. Dry in sun. Storage tins should have airtight lids.
- Step 2: Wash the vegetables/fruits to be dehydrated. Cut, if required. Remove the stem, seeds, skin. Remove any decaying portions.
- Step 3: Blanch vegetables, i.e., put them in boiling water. Time for blanching varies with hardness of fruit/vegetables. Remove when the food is soft (blanching reduces enzymed activity).
- Step 4: Put vegetables in cold water containing salt and potassium metabisulphite for 5-10 minutes. This prevents blackening of foods. Green leafy vegetables and other dark vegetables should not be put in this solution.
- Step 5: Spread on a clean cloth in the sun. Cover with a thin cloth to avoid dust and flies getting into the food.

- Step 6: When the food is dry (test by looking at hardness), cool to room temperature. Store in an air tight container.

When you want to use dehydrated fruits and vegetables, wash and soak in water for some time. Now let us look at how you can use this method to preserve a specific food items, eg., methi and potato.

DEHYDRATING METHI

Can you list the steps for drying methi?

- Wash methi and remove the stems.
- Put on a cloth in the sun, cover it.
- Cool to room temperature and store in air tight tins.

MAKING POTATO CHIPS

- Wash and peel potatoes. Cut in thin round slices.
- Put in boiling water for 3-4 minutes.
- Make a solution in cold water with 4 tsp salt, ¾ tsp potassium metabisulphite (for 4 kg potato).
- Put the blanched potato chips in this solution for 10 minutes.
- Spread each chip separately on a plate in the sun. Cover with a thin cloth.
- When dry, cool and store in air tight containers.

So, even if the basic principle of dehydration remains the same, you have to adapt the method depending on the food you are preserving.

LOWERING TEMPERATURE

Using low temperature to preserve foods works on the principle that low temperature slows microbial and enzyme action. The food is thus prevented from spoilage. Are you using this method of preservation at home? Yes, if you have a refrigerator you can use it because a refrigerator works on this principle. Foods can be preserved at low temperature by:

- Refrigeration 40°C to 70°C
- Cold storage–10°C to– 40°C
- Freezing–180°C or below.

The duration for which the food can be preserved by using low temperature varies with the type of food and the temperatures. The lower the temperature, longer is the duration for which food can be preserved. Of the three methods, freezing uses the lowest temperature.

FREEZING OF PEAS

- *Step 1*: Select about half a kilogramme of fresh, tender peas and shell them.
- *Step 2*: Take enough water in a stainless steel pan in which the peas can be completely immersed. Add 1 teaspoon of salt for half litre of water, dissolve and bring the solution to boil.
- *Step 3*: Completely immerse the peas in the boiling solution for about 2 minutes.
- *Step 4*: Drain the peas immediately on to a stainless steel sieve and let it cool for 10-15 minutes.
- *Step 5*: Pack the peas in polythene bags, remove the air by pressing and seal the bags.
- *Step 6*: Put the packets of peas into a freezer.

Note: Similarly other vegetables such as cauliflower, beans, carrots etc., can also be frozen.

USING FROZEN VEGETABLES

- Take out the frozen packet from the freezer one and a half hours or two hours before use and let it thaw to room temperature. Put peas in a sieve and keep under tap water for a few minutes. Drain and use.
- Frozen vegetables can be stored up to six months in a freezer.

PRECAUTIONS WHILE FREEZING FRUITS AND VEGETABLES

- Packaging material, that is, polythene bags should be strong enough to withstand expansion of food material on freezing.
- The food once brought out of the freezer and up to room temperature should not be refrozen.
- Small packets should be prepared, as food once thawed must be consumed. So there is less chance of the unrequired food material being spoilt. This also helps to avoid refreezing of the unutilized food material.
- Exclude the air carefully and completely from the package before sealing.
- The freezer should not be opened too frequently.

Thaw: A process by which something frozen is brought to room temperature without applying artificial heat.

INCREASING TEMPERATURE

By increasing the temperature, enzymes and micro-organisms are destroyed, leaving the food safe from spoilage. Do all organisms get killed by increasing temperature? No, there are some micro-organisms which do not get destroyed at high temperature. If these organisms are not killed, they can spoil food items once the temperature is lowered. There are mainly two methods of preserving foods by using high temperature:

- *Pasteurization*: When you think of pasteurization, which food item comes to your mind? Yes, its milk. We have often heard about pasteurized milk packets. In this method food is heated to a high temperature and then quickly cooled. The micro-organisms are not able to withstand the sudden change in temperature and are destroyed. However, some organisms still survive this method.
- *Sterilization*: What does the word sterilization mean? It means free from any living organism. The high temperature used in this method destroys all the microorganisms in the food. The foods are exposed to high temperature for longer time and in some cases under pressure. When a pressure cooker is used to cook, the food lasts longer because most microorganisms get destroyed. You can also sterilize bottles and other equipments used in preservation.

USING PRESERVATIVES

What are preservatives? Any substance that is added to foods to make it last for a longer time is called a preservative. You have learnt that increasing the concentration of salt, sugar or acid in a food prevents its spoilage. Therefore, salt, sugar or acid are substances which act as preservatives. There are two types of preservatives:

- *Natural Preservatives*: Salt, sugar, lemon juice, vinegar, oil and spices are natural preservatives.

- *Chemical Preservatives*: Potassium metabisulphate, citric acid and sodium benzoate are chemical preservatives.

Let us discuss the natural preservatives:

- *Salt*: When you make pickle at home, salt is one of the ingredients used. Did you think that salt is added only for taste? Besides adding to taste, salt has a specific function, i.e., to act as a preservative. If the proportion of salt in pickles is less, it can get spoilt after sometime. How does salt act as a preservative? Increasing the quantity of salt in the food changes its composition. Due to the presence of salt in the food, osmosis takes place. As a result, water comes out of the food. When there is no or less water in the food, the micro-organisms are not able to grow and the food becomes safe. Salt also reduces the activity of enzymes, thus preventing the food from getting spoilt. Salt is used as a preservative in pickles, chatni, sauce, canned food, etc. Salt is rubbed on fish which helps to preserve it.
- *Sugar*: Can you think of some preserved foods where sugar is used as a preservative? Yes, these are jams, jellies, murabbas, squashes. Like in pickle, chatni, etc., sugar is added to these foods not only for taste but also as a preservative. The proportion of sugar has to be correct to protect them from spoiling. How does sugar prevent food spoilage? The sugar dissolves in the water avail able in the food item. This results in less water being available for the growth of micro-organisms. Hence the food becomes safe.

- *Acids*: Can you think of any sour food items used as preservative? These are lemon juice, vinegar, citric acid, etc. Vinegar is used to preserve onions, tomato ketchup; lemon juice is used in pickles; citric acid is used in squashes. Acids increase the acidic content of food items, thus preventing the activity and growth of micro-organisms.
- *Oils and Spices*: These are used as preservatives in pickles. Can you think of a spice which is commonly used as a preservatives? Yes, mustard powder is one of them. It prevents the growth of micro-organisms, thus preventing spoilage. When pickle is made at home, have you observed that oil is poured to cover the mango, lemon or other vegetables which are being pickled. The oil acts as a protective cover and has two advantages:
  (i) Prevents contact of micro-organisms with the food, hence they cannot spoil the food.
  (ii) Prevents contact of air with food, hence the micro-organisms cannot grow and spoil the food.

PRESERVING FOODS

Unless food is preserved in some manner, it begins to spoil soon after it is harvested or slaughtered. The main methods of food preservation that will keep food safe are canning, freezing and drying.

Preserving food at home means having:

- An abundant supply of a variety of foods when the fresh products aren't readily available;

- Specialties such as strawberry-fig preserves or green tomato relish that can't always be purchased;
- The satisfaction of preserving foods yourself.

However, preserving food at home may not save you money, depending on costs of buying or raising the food, the needed equipment, energy and time.

CANNING

Canning is the process in which foods are placed in jars or cans and heated to a temperature that destroys microorganisms and inactivates enzymes. This heating and later cooling forms a vacuum seal. The vacuum seal prevents other microorganisms from re-contaminating food within the jar or can. High-acid foods such as fruits and acidified tomatoes can be processed or "canned" in boiling water, while low-acid vegetables and meats must be processed in a pressure canner at 240°F.

PICKLING

Pickling is another form of canning. Pickled products have an increased acidity that makes it difficult for most bacteria to grow. Pickled products are also heated in jars at boiling temperatures to destroy other microorganisms present and form a vacuum in the jar.

JAMS AND JELLIES

Jams and jellies have a very high sugar content. The sugar binds with the liquid present making it difficult for microorganisms to grow. To prevent surface contamination after the product is made and possible yeast or mold growth jams and jellies are canned, frozen or refrigerated.

FREEZING

Freezing reduces the temperature of the food so that microorganisms cannot grow, yet many still live.

Enzyme activity is slowed down but not stopped during freezing:

- *Enzymes in Vegetables:* These must be inactivated by blanching to prevent loss of colour, flavour and nutrients. The vegetable is exposed to boiling water or steam for a specified time and then quickly cooled in ice water to prevent cooking. Blanching is essential for top quality frozen vegetables and helps to destroy microorganisms on the surface of vegetables.
- *Enzymes in Fruits:* These can cause browning and loss of vitamin C, and are controlled by the addition of ascorbic acid.

DRYING

Drying removes most of the moisture from foods. Thus microorganisms cannot grow and enzyme action is slowed down. Dried foods should be stored in airtight containers to prevent moisture from rehydrating the products and allowing microbial growth.

UNSAFE CANNING METHODS

OPEN-KETTLE METHOD

This outdated method of canning is now considered unsafe. In this method, foods were heated in a kettle, then poured into jars and a lid was placed on the jar. No processing was done. With this method there was often spoilage because bacteria, yeast and molds that contaminated the foods when the jars were filled were not killed by further processing. The growth of these microorganisms, in addition to spoiling the food, often caused any lids that did seal to later come unsealed. This method resulted in a very real danger of botulism.

STEAM CANNING

This is a newer method of canning that is not considered safe at this time. The jars are heated by steam. However, safe processing times have not been developed and steam canners are NOT recommended for either high-or low-acid foods. Low-acid foods canned in these canners are potentially deadly because of possible botulism contamination. Also, both low-and high-acid foods are often underprocessed and therefore could spoil.

OTHER UNSAFE METHODS

Canning food in the microwave oven, electric ovens, slow cookers or crock pots can be extremely dangerous, especially with low-acid foods, and is not recommended. So-called canning powders are useless as preservatives and do not replace the need for proper heat processing.

ADJUSTMENTS FOR ALTITUDES

As altitude increases, water boils at lower temperatures. Because the lower temperatures are less effective for killing bacteria, processing time must be increased for boiling water bath canning at higher altitudes. For pressure canning, the pressure is increased. The directions for canning foods are usually for an altitude of 0 to 1000 feet. If you are canning at an altitude over 1000 feet, check for altitude adjustments needed for canning each type of food. Ask your county extension agent to help you determine your altitude or check with your local airport.

ON GUARD AGAINST SPOILAGE

Don't taste or use food that shows any kind of spoilage! Look closely at all jars before opening them. A bulging lid or leaking jar is a sign of spoilage. When you open the jar, look for other signs, such as spurting liquid and off-odours or mold.

Spoiled canned foods should be discarded in a place where they will not be eaten by humans or pets. Spoiled meats, seafood and low-acid vegetables, should be detoxified to destroy any poisons that might be present before they are discarded.

To detoxify canned low-acid foods that have been spoiled, carefully remove the lid from the jar. Be extremely careful when following these directions not to spread or come in contact with suspect food or liquid. Place the open jar(s) of food and the lids in a saucepot. Add enough hot water to cover the jar(s). Boil for 30 minutes and then cool. Drain water and dispose of food and lids. The jars may be reused. Improperly canned low-acid foods can contain botulinum toxin without showing signs of spoilage.

Low-acid foods are considered improperly canned and not safe if any of the following are true:

- The food was NOT processed in a pressure canner.
- The gauge of the canner was inaccurate.
- Up-to-date researched processing times and pressures were NOT used for the size of the jar, style of pack and kind of food being processed.

- Ingredients were added that were NOT in an approved recipe.
- Proportions of ingredients were CHANGED from the original approved recipe.
- The processing time and pressure were NOT correct for the altitude at which the food was canned.

Because improperly canned low-acid foods can contain botulinum toxin without showing signs of spoilage, they should also be detoxified and then discarded. Surfaces that come in contact with spoiled or questionable food should be cleaned with a solution of 1 part chlorine bleach to 5 parts water. Wet the surface with this solution and let stand 5 minutes before rinsing.

PRESERVING FOOD FOR SPECIAL DIETS

It is possible to preserve food at home for people who are watching their salt or sugar intakes. Simply use methods that don't require sugar or salt for their preservative properties. If preserving food for someone trying to cut sugar consumption, the food may be dried, or fruits may be canned or frozen in water or juice instead of a sugar syrup. The sugar specified in canning and freezing is only needed for its effects on flavour and texture. There are also many pickle recipes that call for little or no sugar.

Sugar is the major means by which most jams, jellies and preserves are safely preserved. These products are not suitable for a person on a low-sugar diet. However, there are special low-methoxly pectins and recipes designed to make jams and jellies with no added sugar. It is also possible to preserve food at home for people who are watching their salt intake. The salt used in canning, freezing or drying foods is used only for its flavour or colour protection quality. Pickling, especially when fermentation is involved, usually requires salt for preservative effect. Read the recipe. If it calls for a large quantity of salt, this cannot be eliminated or replaced with a salt substitute. However, if the recipe calls for a large amount of vinegar and only a teaspoon or two of salt for flavour, the salt can be left out.

Table. Approximaqte Yields for Canned or Frozen Fruits and Vegetables.

Raw Products	Measure and Weight	Approximate Quart Jars or Containers Needed	Approximate Pounds Needed for 1 Quart Jar or Container
Fruits			
Apples	1 bushel (48 pounds)	16 to 20	2½ to 3
Apples (for sauce)	1 bushel (48 pounds)	15 to 18	2½ to 3½
Apricots	1 lug (24 pounds)	9 to 12	2 to 2½
Berries (except strawberries & cranberries	24-quart crate (36 pounds)	12 to 18	1½ to 3 (1-to 2-quart boxes)
Cantaloupes	1 crate (60 pounds)		1 large melon
Cherries (with stems)	1 bushel (56 pounds)	22 to 32 (unpitted)	2 to 2½
	1 lug (box) (15 pounds)	6 to 7 (unpitted)	2 to 2½
Cranberries	1 bushel (100 pounds)	100	1
	1 box (25 pounds)	25	1
Figs	1 box (6 pounds)	2 to 3	2 to 2½
Grapes	1 bushel (48 pounds)	10 to 12	4
Grapes, Western	1 lug (28 pounds)	7 to 8	4
Grapes, Eastern	12-quart basket (18 pounds)	3 to 4	4
	4-quart basket (6 pounds)	1	4
Grapefruit Florida, Texas	1 bag or ½ box (40 pounds)	5 to 8	4 to 6 fruits
and California	1 box (65 pounds)	8 to 13	4 to 6 fruits
Nectarines	Flat (18 pounds)	6 to 9	2 to 3
Peaches	1 bushel (50 pounds)	19 to 25	2 to 2½
Pears	1 bushel (50 pounds)	20 to 25	2 to 2½
	1 box (46 pounds)	19 to 23	2 to 2½

	1 crate (22 pounds)	8 to 11	2 to 2½
Pineapple (with top)	1 crate (70 pounds)	20 to 28	2½ (2 average)
Plums	1 crate (70 puunds)	28 to 35	2 to 2½
	1 bushel (56 pounds)	24 to 30	2 to 2½
Rhubarb	15 pounds	7 to 11	2
Strawberries	24-quart crate (36 pounds)	12 to 16	6 to 8 cups
	1 crate (60 pounds)	17 to 23	2½ to 3½
	1 lug (32 pounds)	9 to 12	2½ to 3½
Tomatoes (for juice)	1 bushel (53 pounds)	12 to 16	3 to 3½
	1 crate (60 pounds)	17 to 20	3 to 3½
	1 lug (32 pounds)	8 to 10	3 to 3½
Vegetables			
Asparagus	1 bushel (24 pounds)	8 to 12	2 to 3
	1 crate (30 pounds)	10 to 15	2 to 3
Beans, lima (in pods)	1 bushel (30 pounds)	5 to 8	4 to 5
Beans, green or wax	1 bushel (30 pounds)	15 to 20	1½ to 2
Beets (without tops)	1 bushel (52 pounds)	17 to 20	2½ to 3
Broccoli	1 crate (25 pounds)	10 to 12	2 to 3
Brussels Sprouts	4 quarts	1 to 1½	2
Cabbage	1 bag or 1 crate (50 pounds)	16 to 20>	2½ to 3
Cabbage, Western	1 crate (80 pounds)	26 to 32	2½ to 3
Carrots (without tops)	1 bushel (50 pounds)	16 to 20	2½ to 3
Cauliflower (37 pounds)	1½-bushel crate	12 to 18	2 medium heads
Corn, Sweet (in husks)	1 bushel (35 pounds)	8 to 9 (as kernels)	4 to 5
Cucumbers	1 bushel (48 pounds)	24 to 30	1½ to 2
Eggplant	1 bushel (33 pounds)>	15 to 18	2 average
Greens	1 bushel (18 pounds)	8 to 9	2 to 3
Okra	1 bushel (30 pounds)	19 to 21	1½
Peas, Field	1 bushel (25 pounds)	6 to 7	3½ to 4
Peas, Green (in pods)	1 bushel (30 pounds)	6 to 8	4 to 5
Peppers	1 bushel (25 pounds)	17 to 21	1^{1}D3
Potatoes, Irish	1 bushel (60 pounds)	18 to 22	2½ to 3
Pumpkin			1½ to 3
Spinach	1 bushel (20 pounds)	4 to 9	2 to 6

Squash (Summer)	1 bushel (40 pounds)	16 to 20	2 to 3
Squash (Winter)			3
Sweet Potatoes (cured)	1 bushel (50 pounds)	16 to 25	2 to 3

HOME CANNING EQUIPMENT

Canning is the process in which foods are placed in jars or cans and heated to a temperature that destroys micro-organisms and inactivates enzymes. This heating and later cooling forms a vacuum seal. The vacuum seal prevents other microorganisms from recontaminating the food within the jar. High-acid foods such as fruits and tomatoes can be processed or "canned" in a boiling water canner while low-acid vegetables and meats must be processed in a pressure canner at 240 °F.

WATER BATH CANNER

A water bath canner is a large covered cooking pot with a rack. Any large metal container may be used as long as it is deep enough for 1 inch of briskly boiling water to cover the jars.

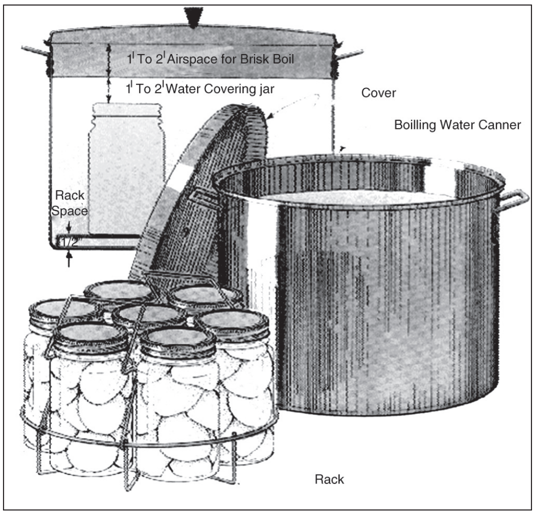


Fig. Boiling Water Bath Canner.

The diameter of the canner should be no more than 4 inches wider than the diameter of your stove's burner to ensure proper treatment of all jars. Using a wash kettle that fits over two burners is not recommended because the middle jars do not get enough heat. For an electric range, the canner must have a flat bottom. The canner must have a tight-fitting lid and a rack. The rack keeps the jars from touching the bottom of the canner and allows the water to circulate freely under the jars. If the rack has dividers, jars will not touch each other or fall against the sides of the canner during processing. A deep pressure canner can be used as a boiling water bath canner. Just be sure there is enough space above the jars to allow for 1 inch of briskly boiling water. Place the lid loosely on the canner—don't fasten it. Leave the vent wide open, so that steam escapes and pressure does not build up inside.

VENT OR PETCOCK

This is a short, hollow pipe that sticks up above the canner lid. When open, it allows air and steam to escape from the canner. When closed, it holds the steam inside. On newer canners the vent is closed or opened using a separate pressure regulator weight. On older canners, the vent may be closed using a valve or screw that you can turn.

PRESSURE GAUGE

This registers the pressure inside the canner. A dial gauge will actually show the temperature and/or pressure inside the canner. The weighted gauge will rock gently or make a "jiggling" noise periodically to show that correct pressure is being maintained. Read the manufacturer's instructions to see how often the weight should rock or jiggle. Some canners have a three-piece weighted gauge that can regulate 5, 10 or 15 pounds of pressure. For 10 pounds of pressure, one piece of the weight is left off. Dial gauges and weighted gauges actually register slightly different pressures at their same settings. Because of this, dial gauges are operated at 11 pounds pressure up to an altitude of 2,000 feet. At altitudes over 2,000 feet, corrections must be made for dial-gauge canners. Weighted-gauge canners can be operated at 10 pounds pressure up to an altitude of 1,000 feet. At altitudes over 1,000 feet, correction must be made for weighted-gauge canners.

PRESSURE CANNER

A pressure canner is a specially-made heavy pot with a lid that can be closed to prevent steam from escaping. The lid is fitted with a vent, a dial-or weighted-pressure gauge, and a safety fuse. Newer models have an extra coverlock as an added precaution. It may or may not have a gasket. The pressure canner also has a rack. Because each type of a canner is different, be sure to read the directions for operating your canner and keep them for future reference.

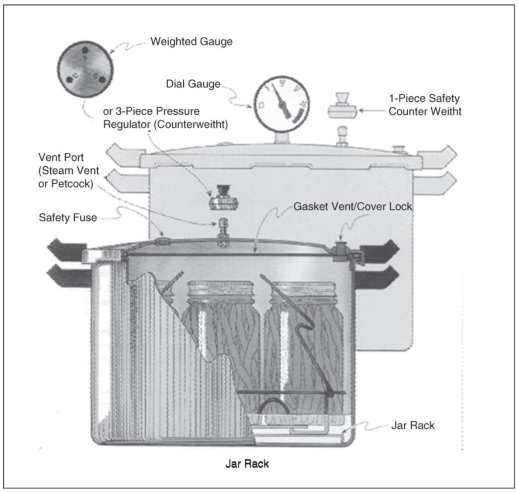


Fig. Pressure Canner.

GASKET

This is a rubber or rubber-like compound that helps seal the edges of the canner and lid to prevent steam from escaping. Gaskets may be removable for cleaning or replacement.

SAFETY CHECKS FOR PRESSURE CANNERS

For safe operation, the vent, safety valve and edges of the lid and canner must be clean at all times. To clean the vent, draw a string or narrow strip of cloth through the opening. The dial gauge on a canner should be checked for accuracy yearly. Check with your county Extension agent well in advance of each canning season for instructions on how this can be done. If the gauge is off more than 2 pounds at the pressure used for your altitude, replace it. Make pressure adjustments for the difference up to 2 pounds. Follow the manufacturer's directions for care of the sealing edges of your canner.

PRESSURE SAUCEPANS AND OTHER UNSAFE MODELS

Small pressure saucepans are not recommended for home canning. Also, outmoded and potentially unsafe pressure canners should not be used. Compare old canners with newer models to be sure that what you have is actually a pressure canner and not an old sterilizer or steamer. Before using an old canner, make sure all parts have been checked and are working properly. Buying an old second-hand canner may not be a bargain. Sometimes replacement parts are no longer being made.

CLEANING AND STORING CANNERS

After use, clean your canner, being careful not to immerse the dial gauge on your pressure canner, if it has one. Dry the canner and store it with crumpled newspapers or paper towels in the bottom and around the rack. This will help absorb moisture and odours. Place the lid upside down on the canner. Never put the lid on the canner and seal it.

The darkened surface on the inside of an aluminum canner can be cleaned by filling it above the darkened line with a mixture of 1 tablespoon cream of tartar to each quart of water. Place the canner on the stove, heat water to a boil, and boil covered until the dark deposits disappear. Sometimes stubborn deposits may require the addition of more cream of tartar. Empty the canner and wash it with hot soapy water, rinse and dry.

CANNING JARS AND LIDS

Mason-type jars specifically designed for home canning are best. Commercial mayonnaise jars may not seal and may break, especially in a pressure canner.

Old antique glass canning jars of any type are prized collector's items. These jars are often too brittle to withstand the heat treatment involved in canning and have a great likelihood of breaking during heat processing. They are best for uses other than canning. Canning jars come in a variety of sizes from half-pint to half-gallon jars. Pint and quart jars are the most commonly used sizes. Processing times have not been developed for many foods in half-pint, 12-ounce or 1½ pint jars. If the recipe does not specify processing in one of these jars, process half-pint and 12-ounce jars for the same time as pints. Process 1½ pints for the same time as quarts. For jellied fruit products only, pint and 12-ounce jars can be processed for the same time as half-pint. Half-gallon canning jars are recommended only for very acid juices.

Jars also come in both the regular and wide-mouth styles. If properly used, jars may be reused indefinitely.

TWO-PIECE LIDS

Most of the canning jars sold today have two-piece, self-sealing lids. This type consists of a flat metal disc that has a sealing compound around the outer edge and a separate metal screw band. The lid is used only once; the screw band may be used over and over, unless it rusts. Do not use any old, dented or deformed lids or those with gaps or flaws in the sealing compound. These may not seal. Lids should be good for at least five years after manufacture. Never reuse lids from commercially canned foods for home canning.

ZINC LIDS AND BAIL-TYPE JARS

These used a rubber ring that fit on the jar's sealing ledge, but are no longer recommended and are not being manufactured. Some new imported bail-type jars are available in this country. Many of these are not heat tempered and while these jars come with one rubber ring, no replacement rings are available for reuse. These jars are be tter used for food storage and decorative purposes than for home canning.

ADDITIONAL CANNING UTENSILS

The following items are helpful for home canning:

- A jar lifter, essential for easy removal of hot jars from canner.
- A jar filler or funnel helps in packing of small food items into canning jars.
- A bubble freer for removing air bubbles from the jars. This could be any plastic knife or spatula. Metal

objects should not be used because they can scratch the glass. Making the jar more susceptible to breakage.

- A lid wand has a magnet on the end to help remove treated lids from hot water.
- Clean cloths for wiping jar rims and general cleanup.
- Knives for product preparations.
- Timer or clock to determine end of processing time.
- Clean towels.
- Cutting board.

A number of other home canning accessories such as corn cutters, apple slicers, decorative labels and special canning spoons are available. Some of these items may simplify the procedures but are not essential. Jar lid tighteners and wrenches are not recommended.

HOME FREEZING EQUIPMENT

The type of freezer to purchase will depend on family size, whether fresh produce or large quantities of meat will be frozen, available floor space, and efficiency and defrosting features preferred. The standard capacity of a freezer is about 35 pounds of frozen food per cubic foot of useable space. Families that freeze garden produce should allow six cubic feet of freezer space per person. If other methods of food preservation are used, allow three cubic feet per person. Additional space is needed if large amounts of meat are kept in the freezer.

TYPES OF FREEZERS AVAILABLE

There are three types of freezers on the market: upright, chest and refrigerator-freezer combinations. The upright and refrigerator-freezer are available as manual-defrost or frost-free models. Though less convenient, manual-defrost freezers are more cost-efficient. They also maintain higher quality food than frostless models because they don't have a fan running to remove the moisture that would turn to frost. The constant removal of moisture from the freezer could cause freezer burn in improperly wrapped food. Frost-free chest freezers are not available, but frost builds up in them less readily.

UPRIGHT FREEZERS

These appliances have the same general shape and appearance as home refrigerators. They have one or two outside doors and from three to seven shelves for storing food. Freezers of this type are popular due to their convenience, the small floor space they require and the ease with which food may be put in or removed. However, more cold air escapes each time the door is opened.

CHEST FREEZERS

Freezers of this type require more floor area than the uprights but are more economical to buy and operate. These freezers lose less cold air each time they're opened. Make sure this type of freezer is equipped with sliding or lift-out baskets to permit easy loading and removal of food.

REFRIGERATOR–FREEZER COMBINATION

This is a single appliance with one or two doors. It has one compartment for frozen foods and another for refrigerated foods. The freezing compartments may be above, below or to one side of the refrigerated area. If selecting this type, be certain that the freezer is a true freezer and not just a freezing compartment.

CARE OF THE FREEZER

Regardless of the type of freezer selected, it should be placed in a convenient, cool, dry and well-ventilated place; never place it by the stove, water heater or in the sun. This would make it more difficult to maintain a temperature of 0°F or lower. Do not push the freezer flush against a wall. Leave space for air circulation and cleaning. Be sure the freezer sits level.

DEFROSTING FREEZERS

Manual-defrost freezers need defrosting at least once a year or when there is more than one-fourth inch of frost over a large area of the freezer. Accumulated freezer frost reduces storage space and increases operating costs. Defrosting should be scheduled when the food inventory is relatively low and defrosting can be completed within one to two hours. A manual-defrost model should be disconnected from the electrical supply before defrosting. Frozen packages should then be placed in large cardboard cartons or insulated ice chests. With a cardboard carton, several layers of newspapers may be used for extra insulation. Clean the freezer as quickly as possible, following your manufacturer's instructions. A few manufactures recommend placing pans of hot water in the freezer and closing it. Then, remove the frost as it loosens and replace the water as it cools.

Make sure the freezer is completely cool before restarting it. Other manufactures do not recommend using pans of hot water because in their freezers, refrigerator pressure could build up in the evaporator, making restarting the freezer difficult. These manufactures recommend allowing the frost to thaw naturally or with the aid of a fan. Place towels in the bottom of the freezer to catch water and frost. The loose frost can be removed using a wooden or plastic scrapper. When all the frost has been removed, sponge out the interior with a cleaning solution made of one tablespoon of baking soda per quart of water. Sponge with clean water and dry with an absorbent cloth. Turn the freezer on and close the door to allow the freezer to become chilled before returning the food. If food packages are frosty, scrape or wipe them to remove frost or moisture before placing the food back in the freezer in an organized manner. Mark these packages for first use.

CARE OF FROST-FREE FREEZERS

A frost-free freezer does not need defrosting. However, it should be cleaned out once a year or more often if dirt or food residues are visible. Turn off the power source. Empty the freezer, wipe it with a baking soda solution, rinse, towel it dry and then replace the food.

REMOVING ODOURS

If food has spoiled in a freezer because of a power failure or some other reason, undesirable odours can develop. To eliminate the odour, remove the food and wash the inside of the freezer with one tablespoon of baking soda in a quart of tap water or with one cup of vinegar in a gallon of tap water. Let surface dry.

If the odour still persists, use activated charcoal. This type of charcoal is extra dry and absorbs odours more quickly than cooking-type charcoal. It can be purchased at a drug store or pet supply store. To use it, unplug the freezer. Put the charcoal in pans or on paper in the bottom of the freezer for several days.

If the odour remains, put in new charcoal. When the odour is gone, rinse and dry the inside of the freezer. Turn on the freezer and it is ready for food. When odour gets into the freezer's insulation, write the company for any suggestions it may have for solving the problem. However, sometimes, there is nothing than can be done.

CONTAINERS FOR FREEZING

Foods for your freezer must have proper packaging materials to protect flavour, colour, moisture content and nutritive value from the dry climate of the freezer. Do not freeze fruits and vegetables in containers with a capacity over one-half gallon. Foods in larger containers freeze too slowly to result in a satisfactory product.

Packaging materials must have certain characteristics:

- Resistant to moisture and vapors.
- Durable, leakproof, easy to seal and mark
- Not become brittle and crack at low temperatures
- Resistant to oil, grease or water
- Protective against absorption of off-flavours or odours
- There are two types of packaging materials for home use:
  - Rigid containers and
  - Flexible bags or wrappings.

RIGID CONTAINERS

These are made of plastic or glass, are suitable for all packs and especially good for liquid packs. Straight sides on rigid containers make the frozen food much easier to get out. Rigid containers are often reuseable and make the stacking of foods in the freezer easier. Cardboard cartons from cottage cheese, ice cream and milk are not sufficiently moisture and vapour resistant to be suitable for long-term freezer storage, unless they are lined with a freezer bag or wrap.

Regular glass peratures. The wide mouth allows easy removal of partially thawed foods. If standard canning jars are used for freezing, leave extra headspace to allow for expansion of foods during freezing. Expansion of the liquid could cause the jars to break at the neck. Some foods will need to be thawed completely before removal from the jar. Covers for rigid containers should fit tightly. If they do not, reinforce the seal with freezer tape. Freezer tape is especially designed to stick at freezing temperatures.

FLEXIBLE BAGS OR WRAPPINGS

Bags and sheets of moisture-and vapour-resistant materials, laminated freezer papers, and heavy duty aluminum foil are suitable for dry-packed vegetables and fruits, meats, fish, or poultry. Bags can also be used for liquid packs. Protective cardboard cartons may be used to protect bags and sheets against tearing and to make stacking easier. Laminated papers are also used as protective over wraps. Plastic freezer bags are available in a variety of sizes. There are two types of closures. One type is twisted at the top, folded over and wrapped with twist ties included in the package. The other is zipped or pressed to seal a plastic channel. Regardless of type, press to remove as much air as possible before closing.

VACUUM PACKAGING

Vacuum packaging also works best for dry packs. Vacuum packaging removes more air from the packages than can be pressed out and seals the air out. Vacuuming packaging can help prevent oxidation which can lead to off-flavours and can save space in the freezer. Follow the directions that come with the vacuum packages carefully. To avoid the risk of botulism from some vacuum-packaged foods, keep foods frozen until ready to use.

2

Packaging Technology for Processed Foods

Modern food packaging technology brings traditional foods into a global arena which increasingly emphasizes their commercial and economic aspects. This means that food and packaging technologists become involved in the entire food supply system. This system ranges from the sea, village farm, plantation, to the markets and consumers in towns and cities, not only in their own country, but also in distant overseas markets.

The surplus foods grown in the village have a need to be more carefully harvested, protected from spoilage and damage, packaged, and transported by various means to these markets. Unless the goods are sold with minimum spoilage and at their peak flavour, appearance, and nutritional value and presented in an attractive way, they may not be eaten at all. This is a worse situation than if the crop had never been grown and can represent serious loss and waste to a community. In addition, careful emvironmental conside-rations need to be given to minimum packaging forms to avoid pollution problems and ensure sustainabilty. Very little investment has been made so far in developing traditional technologies or in applying scientific knowledge in most of the developing countries; meanwhile the more expensive products of imported technologies have further slowed the development of indigenous technologies.

It has been increasingly recognized that the time has come when these traditional technologies must be upgraded through scientific application of packaging principles and then integrated with other packaging functions such as marketing and advertisement. Technologies are called traditional if, unaffected by modernization, they have been commonly applied over a long period of time. In general, traditional technologies tend to be cheap, easy to produce, apply, maintain, and repair. They are generally labour-intensive, which can be economically beneficial, but as far as food packaging technologies are concerned, the final products are often hygienically sub-standard and they usually have a short shelf-life.

Many traditional foods have nonetheless remained unchanged in process or package for centuries, due to the fact that they developed in a particular location and are deep rooted in the natural, cultural, religious, and socio-economic environment. Some have disappeared without a trace as a result of modern influences, while others have expanded on a global scale, becoming household products, e.g., soysauce, now a multimillion dollar industry. The reasons for this phenomenon need to be examined.

TRADITIONAL FOOD PACKAGING TECHNOLOGIES

FOOD SYSTEMS

Population drift from rural to urban areas has caused drastic changes in the food supply network from farm to the consumer in many emerging nations. One traditional belief which can no longer be sustained is the old saying that, "There are always fish in the rivers and lagoons, and rice, taro, or sweet potato in the fields; therefore let there be no concern for the next meal."

It is more likely that the farmer has gone to the city or even overseas, and is earning a labourer's wage to keep his family in food during the off-season. So food is now brought to the market by many and various means, and redistributed to these new consumers. There are new vistas for traditional food markets where the technologies are tested beyond their limits.

Given the circumstances in which many developing countries are today, the challenge for their traditional technologies is that often they do not contribute sufficiently to meeting socio-economic imperatives. This is true also of those food technologies where many of the processing methods have remained unchanged for centuries, and are becoming inadequate to cope with modem needs, because they are too labour-intensive and depend now too much on natural environmental conditions.

It is now clear that there is a need to lessen the dependence on nature, reduce the drudgery, shorten the time of the work involved and upgrade the preparation, quality, packaging, presentation, and shelf-life of these traditional foods and their packaging.

WOMEN AND FOOD PROCESSING

Women play a major role in most traditional food processing and packaging. They dry leaves, pulses, and cereals, make curds and cheese, smoke meat and fish, ferment, grate, dry sweet potato and carry out a wide range of food preservation and packaging processes.

It is indispensable, therefore, that women view the proposed technology improve-ments as capable of reducing their labour, without diminishing their role and status, or, in the case of marketable products, their profit. It should be borne in mind that the upgrading of traditional food and food packaging technologies is a sensitive area, for which reason the subject should be approached with caution and due regard paid to the social, economic and cultural factors involved, in addition to the gender issues.

Further sensitivity needs to be applied to the small business operation in the preparation and packaging of traditional foods. Programmes for mass production of a particular food, many have dire consequences for the small business operator. In the consideration of the structural characteristics of traditional food industries, in particular the application of new food technologies and the use of labour saving continuous large-scale processing, the task needs to be approached thoughtfully.

UPGRADING OF FOOD PACKAGING

Upgrading of traditional food packaging technologies in many cases, introduces exogenous factors, i.e., the importation of technology from abroad. Whether or not adapted to local circumstances, the use of imported packaging technologies in many developing countries remains restricted to modern technologies; even when these are locally developed, they are more complex to use, repair, and maintain. They are also expensive and tend to rely on imported components and non-renewable sources of energy.

FOOD PRESERVATION PRINCIPLES AND THEIR INTEGRATION WITH FOOD PACKAGING

FOOD UNIT OPERATIONS

Before food can be packaged, there are many unit operations involved after harvesting the raw materials, including cleaning, grading, disposal of unwanted material, then stabilization of the enzymatic, biochemical and microbial spoilage. If a study of the preservation and packaging of foods is undertaken, a key question is, "What factors cause spoilage and deterioration in foods". The main factors are micro-organisms (bacteria, yeast, and moulds), as well as enzymes, temperature, and biochemical changes in the foods. Food preservation techniques are designed to prevent these spoilage changes and impart a keeping quality or shelf-life to the processed foods.

Packaging is an integral part of the processing and preservation of foods and can influence many of these factors.

It can influence physical and chemical changes, including migration of chemicals into foods. The flavour, colour, texture as well as moisture and oxygen transfer is influenced by packaging.

The effects of temperature changes and light can be modified by packaging materials. Let us consider the more important methods of preservation of foods used by food industries today and how they integrate with the food packaging used in their processing.

- *Cold Preservation*: Used to slow down or inhibit chemical and biological processes in bacteria and spoilage agents in the foods.
- *Fermentation Preservation*: Used to slow down spoilage factors through the production of alcohol or acids which assist in preservation. This technique is often combined with pasteurization.
- *Reduction of Available Water*: Many spoilage factors require the presence of moisture in order to operate. When this available water is removed or reduced then better preservation can be achieved.
- *Pickling or Curing Preservation*: These methods can be used together with smoking and with refrigeration as a combined form of preservation.
- *Chemical Preservation*: Used to inhibit the spoilage factors and to complement other food preservation techniques.
- *Gas Environment Control*: Used to inhibit post-harvest deterioration, often used together with refrigeration.
- *Combination and Assorted Methods*: Several food preservation techniques may be effectively combined

to reduce spoilage factors to acceptable levels. These include combinations of those listed, together with the following techniques.

THE INFLUENCE OF PACKAGING ON THE ENVIRONMENT

Packaging in the modern world has a considerable impact on the environment. Food packaging makes up two fifths of the household waste. Packaging also accounts for an increasing share of the costs of the food processing industry, rising from about 4% in 1947 to 10% in 1987, and continuing to rise.

Despite new materials which have reduced packaging weight, the total and relative costs of food and beverage packaging are increasing. On average, the cost of packaging materials represents about one-fifth of material costs, however, in 10 out of 40 food industry sectors, packaging costs exceed the costs of the edible food stuff ingredients. In most countries packaging continues to be driven by consumer demand, with regulatory bodies playing a limited role.

In Europe, however, legislation and taxes on packaging have been established to encourage reduced packaging waste and more sustainable packaging practices.

CASE STUDIES OF SOME TRADITIONAL FOODS AND THEIR PACKAGING

China is one example of an ancient civilization in which the different national minority groups have developed their specific food cultures. These traditional foods are a valuable cultural heritage to the Chinese people.

There are examples of foods which have been introduced by culture transfer and become traditional in time. The processing of rice, wheat, soybean, and sesame was introduced to Japan from ancient China, translated first to the centres of power and religion, later to the regions. Hence, such technology transfer is not a new phenomenon.

There is a vast difference, however, between the early, more leisurely adoption of transferred food cultures and the explosion of new technology at present threatening to overwhelm traditional food processing and packaging techniques and to suppress the original characteristics of the traditional products. The attraction of traditional foods is related to their wide variety and diversity. For example, in Japan there are approximately 500 varieties of “Tsukemono”, a fermented pickle. This attraction may be lost when new technology is applied without careful thought.

Another aspect of traditional foods is the way many of them have simply disappeared without trace, whilst others have expanded on a global scale and have become household products in most countries. One such example is soysauce. Its wide acceptance and commercial expansion may be the result of a wider influence, with regard to meat-like flavours in diets where meat is absent, either by choice or through circumstance. It is found, packaged in a multiplicity of forms, in almost every country.

The question is posed whether there are other traditional foods, which by careful upgrading and packaging can follow the example of soysauce in becoming widely accepted. Also that these foods can begin to generate higher incomes for small business operators. Some examples of traditional foods with potential for expansion are from the following countries:

INDONESIA

This is a vital source of protein in Indonesia, serving as a meat substitute. It is a product of a solid substrate fermentation, using the mould, *Rhizopus oligosporus*, as the active organism. The soybeans are soaked, dehulled, partly cooked, and inoculated, then incubated for 1-2 days. This enables the mould to form fibrous mycelia which knit the soybeans together in a compact cake which can be sliced and cooked.

The traditional form of packaging for tempeh has been banana leaves as a wrapping material. Now a number of tempeh cottage industries are using the tray or the plastic bag technique. The tray of inoculated beans is covered with banana leaves and wax paper, then incubated. The final product is sliced and wrapped in banana leaf, or plastic (polyethylene) bags. A more recent technique is to incubate the tempeh directly in perforated plastic bags or tubes with perforations at 0.25 to 1.3 cm intervals to allow a controlled access of oxygen. The tempeh can be sold directly in this packaging.

THAILAND

In Thailand, fermentation is a favourite means of food processing and over 44 commercial, traditional fermented foods have been identified. These foods are highly acceptable country-wide and are essential components of diets. They are used as condiments and supply specific flavours as well as being sources of protein, calories, and vitamins. The level of traditional fermented technology of the small and medium food manufacturers are generally at the household or slightly larger (backyard) level. The problems faced are maintenance of quality standards, efficient fermentation on an industrial scale and new product and package development.

PHAK SIAN DONG

It is a Thai native fermented vegetable (*Gynandropsis pentaphylla*). It is pickled in a.liquor which is prepared with coconut juice and salt added, or rice water and salt. The "Phak Sian" is wilted in the sun to lower moisture. The fermentation takes only 36-48 hrs. and the shelf-life is only 2-3 days if no further processing is applied. If the process and the packaging were upgraded, this product could give a longer shelf-life.

PAKISTAN

ROTI

An operation for the production of semi-levened bread was set up as the "Roti" Corporation of Pakistan. The Corporation was charged with producing good quality, semi-leavened bread under hygienic conditions, modern packaging, and distribution. Sixteen plants were set up with a capacity of 35,000 "Rotis" per shift, a total of nearly two million "Rotis" per day. The project had difficulties because:

- The taste and texture were different from traditional "Roti".
- The Roti crumbled on rolling.
- People wanted fresh "Roti" bread.
- Women were dislodged from their work at home.
- The overheads and packaging made "Roti" more expensive than home made ones.

Diversification was the only solution to the economic recovery of the plants.

YOGHURT OR "DARI"

A most common dairy product in Pakistan consumed widely in the hot months of the year. Traditionally "Dari" has been prepared by unqualified milk retailers in broad earthenware dishes ("Konondas"). The milk is boiled and cooled to around 38°C then cultured with yoghurt from the previous batch. After 6-8 hrs. it sets, then it is cut and sold fresh. The quality is never uniform.

The product and the process have been upgraded since, with upgrading of the quality control and the packaging. Now the milk is correctly processed, analysed, standardized, pasteurized, inoculated, incubated, and packaged in sanitary polystyrene containers, then refrigerated. The retail cost is relatively higher, but kept minimal by recycling the containers which are washed, sanitized, and reused.

THE IMPORTANCE OF FOOD PACKAGING IN FAO PROGRAMMES

In fruit and vegetable processing, technical projects cover the entire food chain from the harvesting of horticultural produce through storage, processing, packaging, and marketing. Roots and tubers projects range from storage, post-harvest loss reduction, through flour production and bakery products development.

In vegetable oils, assistance has been provided by FAO in the processing of oilseeds, palm and olive oil extraction, small-scale processing and refining of edible oils. Other food processing activities range from advisory work on agro-industrial development, coffee processing, coconut processing, cocoa and chocolate projects, soybean and cashew nut processing.

Other examples include:

- Development of handling and packaging systems for soft fruits in an Asian country.
- Upgrading of dates processing and packaging in the Near East Region.
- Introduction of modern packaging methods for highland vegetables and fruits in an Asian country.
- A coordinated programme of food packaging activities for the Asia and Pacific region covering commodities, packaging materials, equipment, and quality aspects of packaging.
- Projects on the processing and packaging of cereals, including rice, wheat, sorghum, millet, maize, and quinoa have been implemented, and there has been technical backstopping by FAO in many countries for these staple foods.
- Feasibility studies are taken to the pilot processing industry stage. Related technical research, training, and extension programs have been supported in a dozen countries.

The importance of food packaging in the FAO programme is evidenced by the number of projects undertaken so far. Food packaging is seen as a vital link in the overall chain of food production, processing, marketing, and consumption. In the Asia and Pacific Region, FAO has been involved in over 40 projects which involve the upgrading of traditional food technologies.

Food packaging is an integral part of the processing and preservation of these staple foods and can also minimize many of the potential spoilage changes, imparting improved keeping quality, and increased shelf-life to the processed and packaged food. These and other activities and ideas are being proposed in recognition of the importance of food packaging in the containment, transportation, distribution, marketing, and consumption of high quality traditional foods. The mandate of FAO for the improvement of food processing and packaging has placed considerable emphasis on the upgrading of traditional food technologies, particularly for staple foods.

NOVEL IDEAS IN FOOD PACKAGING

Modern society now consists of millions of impatient multitaskers—generations of individuals who want to maximize their time by engaging in two tasks or more simultaneously. This global trend of on-the-go access, convenience, and immediate gratification pervades not only the industries of technology, communications, and entertainment but the food industry as well.

In the 19th century, pioneers such as Nicholas Appert, Louis Pasteur, Samuel C. Prescott, and William L. Underwood developed food packaging and preservation concepts that maintain relevancy today. Twentieth-century inventions such as glass bottles, cellophane wrap, aluminum foil, and plastics shepherded greater utility and flexibility in food packaging.

Other 20th-century packaging developments such as packages incorporating antimicrobials and oxygen scavengers established new precedents for prolonging shelf life and protecting food from environmental influences. Nevertheless, omnipresent global trends such as increased industrial processing of food, greater importation and exportation of food products, and less time for preparation of fresh foods compel the food and beverage packaging industry to investigate newer, more advanced packaging solutions.

Thus, while protecting and preserving food were once perceived as the principal roles of food packaging, facilitating convenience has quickly emerged as equally important. Other elements of increasing importance in food packaging include traceability, tamper indication, and sustainability . Many new and exciting developments in food packaging fulfil these roles and more. A new Scientific Status Summary issued by the Institute of Food Technologists discusses recent innovations in food packaging materials. Written by Aaron Brody, Betty Bugusu, Jung Hoon Han, Claire Koelsch Sand, and Tara H. McHugh, the Summary is titled "Innovative Food Packaging Solution."

ACTIVE AND INTELLIGENT FOOD PACKAGING

Beyond passively delaying environmental elements from affecting food products, active and intelligent food packages use more dynamic techniques to contain and preserve food. For example, two common issues in maintaining the quality of packaged food are oxygen and moisture control.

Oxygen in packages aids the growth of aerobic microbes and moulds. Oxidative reactions in packaging also result in unintended odours and flavours and changes in colour or nutritional quality. Similarly, moisture in food packages may cause powdered products to form lumps or crisp products to soften as well as supporting the growth of microbes.

Conversely, too little moisture can result in dehydrated foods. Active packaging incorporates components that address these issues. Oxygen scavengers remove oxygen from food packages, thereby impeding the growth of microbes and preserving the intended flavour and odor of foods. Carbon dioxide emitters suppress microbial growth in products such as meat, poultry, and cheese.

Moisture-control agents suppress water activity, serving to remove fluids from meat products, prevent condensation from fresh produce, and curb the rate of lipid oxidation. Lastly, maintaining humidity in packages is accomplished by humidity controllers, which can either diminish the loss of moisture from foods or reduce excess moisture in the interstices of package closures.

Other tools in the array of active packaging components include antimicrobials and ethylene absorbers. While active packaging incorporates robust ways to control oxidation, microbial growth, and moisture, intelligent packaging designs facilitate the monitoring of food quality. Time temperature indicators (TTIs), ripeness indicators, biosensors, and radio frequency identification (RFID) are all examples of intelligent packaging components. Most of these smart devices have not had widespread commercial application, but two are gaining more notoriety: TTIs and radio frequency identification.

TTIs can play a critical role in indicating the freshness and safety of a product. They monitor and communicate which food products are safe to eat, which becomes extremely important when food is stored in less than optimal conditions such as extreme heat or freezing. In the case of foods that should not be frozen, a TTI would indicate whether the food had been improperly exposed to cold temperatures. Conversely, a TTI could specify whether foods sensitive to heat had been exposed to unnaturally high temperatures and the duration of exposure. Radio frequency identification provides wireless monitoring of food packages through tags, readers, and computer systems. Its uses within the food industry are numerous and range from facilitating the traceability of food to improving the efficiency of supply chains.

Table. 2 Oxygen Transmission Rate

Film	*OTR*	*WVTR*	*Specification* (μm)
PET	110	15	12
PET/PE	0.93–1.24	0.248–0.372	12/50
PET/PVDC/PE	0.33	0.132	12/4/50
PET/PVAL/PE	0.13	0.26–0.39	12/3/50
PET/EVOH/PE	0.06	0.134–0.268	12/5/50
PET/Al–met/PE	0.06–0.12	0.006–0.03	12/–/50
PET/$Si0_x$	0.006–0.06	0.0024–0.06	12/–
PET/Al–foil/PE	0	0	12/9/50

PE = polyethylene low density; PET = polyethylene terephthalate; PVDC = polyvinylidene chloride; PVAL = polyvinyl alcohol; EVOH = ethylene vinyl alcohol; Al-met = aluminum metallization; $Si0_x$ = silicon oxide; Al-foil = aluminum foil.

But perhaps the ultimate benefits of RFID in food packaging are that it speeds stock rotation and improves tracking. RFID systems are beneficial for many food manufacturing operations and supply chains. Developing an intelligent food packaging application for food quality and safety would require RFID to become more established in the food industry and the integration of food science. Retail chains such as Wal-Mart and Home Depot already use RFID, so its prominence is likely to increase . Because RFID systems provide safety and security benefits by tracking the origin of food supplies, retailers are considering ways to integrate this technology into the management of their supply chains.

CONTROLLING VOLATILE FLAVOURS AND AROMAS

The loss of volatile flavours and aromas is a packaging issue that stems from the mass transfer of components between and within food and its packaging. For example, direct contact between the food and its packaging results in the migration of packaging components into food and the unintended absorption of volatile food flavours by package materials is known as flavour scalping. Most incidences of migration occur in plastic packaging systems, and polyethylene materials are responsible for most of the flavour scalping in foods. Both migration and flavour scalping are unfavourable because they deteriorate food quality and reduce consumer confidence in packaged food items.

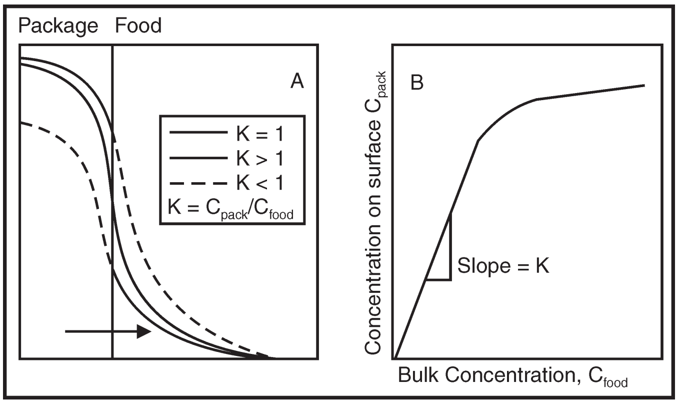


Fig. 2: Effect of Interfacial Partitioning of Molecules on Mass Transfer Between Food and Packaging Materials.

A: Migration of package constituents into foods. B: Scalping of food flavour into packaging materials. K is a partition coefficient of a migrant.

The solution to these issues is packaging components that incorporate absorption and barrier controls. Flavour and odour absorbers usurp unwanted gaseous molecules such as volatile package ingredients, chemical and microbial metabolites, respiration products, or rancid flavours and odours. Flavour and odour absorbers utilize the same transfer mechanism as flavour scalping to remove unintended characteristics in the forms of sulfurous compounds, amines from protein degradation, aldehydes and ketones, and bitter taste compounds.

High-barrier packaging reduces absorption, desorption, and diffusion of gases and liquids to maintain food quality. It also assists in preventing oxygen and water vapour from penetrating packages. Polymer blending, lamination, and metallization are all ways to enhance the barrier properties of packaging materials.

Other innovative tools for improving the barrier property of packaging material include transparent vacuum-deposited or plasma-deposited coating of silica oxide PET films and composites of plastics with nanoparticles.

EVOLUTION OF FOODSERVICE PACKAGING

Other innovative trends in food packaging are occurring in foodservice. As consumers continue to spend heavily on foodservice products, the role of packaging in ensuring food safety and providing convenience can only increase. Packages designed for tracking and shelf-life extension reduce the risk of food-borne illness in the foodservice industry, but heating issues continue to be tricky.

New packaging products, such as the *CuliDish*, are helping to address these issues. The *CuliDish's* design allows simultaneous microwave heating of food that requires high heat and food that does not (such as salads) in the same tray. Such innovations in the area of heat and heat retention will reduce the safety risk associated with improper cooking.

Food consumers prepare and eat only 60% of meals at home , and 20% of consumers eat while in transit to another location. As a consequence, many of the innovations in foodservice packaging are to accommodate meals eaten in transit and multi-component meals—both of which are trends of convenience. The high demand for on-the-go meals has led to a significant increase in the variety of foods packaged for in-transit dining. Edible films and wraps have emerged on numerous foods, and package designs using modular folding cartons with flip-off lids or pouches with seatbelt flaps have been created for those who dine while driving. Multi-component packaging accommodates the multi-unit meals that are available at quick-service restaurants.

This type of packaging simplifies foodservice preparation, lessens waste, and makes consumption of multi-unit meals easy. Multi-component packaging is available in many forms: Les Petits Grande has reusable trays that clip together to form one larger serving tray, KFC uses triple-dip-strip cartons that allow consumers to dip chicken strips in three different sauces, and numerous coffee houses employ trays for holding more than one cup of coffee.

GREEN PACKAGES

One of the key trends within food packaging is sustainable packaging. The Sustainable Packaging Coalition—an international consortium of more than 200 industry members—characterizes packaging as sustainable if it meets the following criteria:

- It is beneficial, safe, and healthy for individuals and communities throughout its life cycle.

- It meets market criteria for performance and cost.
- It is sourced, manufactured, transported, and recycled using renewable energy.
- It maximizes the use of renewable or recycled source materials.
- It is manufactured using clean production technologies and best practices.
- It is made from materials healthy in all probable end-of-life scenarios.
- It is designed to optimize materials and energy.
- It is recovered effectively and used in biological and/ or industrial cradle-to- cradle cycles.

A package's sustainability is determined by the source of its packaging material. Consequently, corporations and environmental groups are working collaboratively to reduce the effect of packaging on global sources.

NANOTECHNOLOGY IN FOOD PACKAGING

Some of the most exciting developments in food packaging involve nanotechnology; the science about very small materials is poised to have a big impact in food packaging materials. Nano-sized innovation could produce remarkable new packaging concepts for barrier and mechanical properties, pathogen detection, and active and intelligent packaging. At the forefront of nano-sized development in food packaging are nanocomposites. Nanocomposites are materials that are made up of nanoparticle components. Toyota was the first company to commercialize nanocomposite materials, using nano-sized montmorillonite clay to increase mechanical and thermal properties of nylon. In food packaging, montmorillonite clay is being explored as the nano-component in a variety of polymers: polyethylene, polyester, nylon, and starch.

Nanocomposite plastic films block oxygen, carbon dioxide, and moisture from reaching food, so when used as packaging, the material extends the shelf life of food. Nanocomposite food packages are also light, strong, and heat resistant. In addition, research into the development of biodegradable nanocomposite packages is under way. While nanocomposites hold promise in food packaging through improved barrier properties, another type of nanomaterial shows great potential in managing microbial growth. Researchers have discovered that carbon nanotubes exert powerful antimicrobial effects: Direct contact with aggregates of carbon nanotubes proves to be fatal for *Escherichia coli*. The theory is that the long, thin nanotubes puncture *E. coli* cells, causing cellular damage. Another nano-sized solution with positive indications for the future is nanosensors. When integrated with food packaging, nanosensors can detect chemicals, pathogens, and toxins in food.

For example, biosensors have been developed that detect *Staphylococcus* enterotoxin B, *E. coli*, *Salmonella* spp, and *Listeria moncytogenes*. Nanosensors can also detect allergen proteins to prevent adverse reactions to foods such as peanuts, tree nuts, and gluten. Nevertheless, progression in this area moves cautiously because the effects of nano-sized materials on humans are still under investigation.

THE BOTTOM LINE

Since its inception in the 18th century, food packaging has made great advances in active and intelligent packaging solutions. These advances have led to improved food quality and safety. While most packaging innovations have been the result of global trends and consumer preferences, some innovations have stemmed from unexpected sources, such as the emergence of nanoscience. Undoubtedly, new packaging solutions will focus more on food safety (controlling microbial growth, delaying oxidation, improving tamper visibility), product quality (managing volatile flavours and aromas), convenience, and sustainability. These are the most important factors in a fast-paced world where borders are rapidly diminishing and customer bases are increasingly global.

MILK CARTON

Milk cartons are water tight paper containers used for packaging milk for retail distribution. One of the most common supermarket items, and found in nearly every home, the milk carton is nonetheless a precision product, manufactured according to exacting standards. Up until recent times, milk was not usually available as a retail item. Once milk is removed from the cow, it spoils quickly in heat, and is vulnerable to contamination. Until 20th century, the most economical and hygienic way to store milk was to leave it in the animal.

In Europe, a town cow keeper would bring his or her cow directly to the doorstep of the customer, and milk the animal there into a household container. In some places, milk was sold from a shop next door to the cow stall. In either case, the milk could not be safely stored for anything but a small amount of time. A large metal milk container was developed in Europe between 1860 and 1870. Called a churn, the lidded metal container could hold about 21.12 gal (801) of milk. Milk in churns was shipped by rail from farming areas into towns, where the demand for milk was high. Milk in metal churns was also dispensed door to door. Instead of the cow keeper bringing the cow, now the milk was ladled out of the churn into a smaller household bucket or can. The glass milk bottle was invented in 1884.

This offered convenience to milk consumers, since the sterilized bottles could be kept sealed until needed. Milk that was pasteurized (quickly heated to above boiling, then cooled) was resistant to bacterial contamination and spoilage for several days. Bottled milk became prevalent across the United States and Europe through World War II, though glass containers are rarely seen now.

The first paper milk carton was introduced in 1933. Wax was applied to the paper, to make it waterproof. In 1940, polyethylene was introduced as the waterproofing material. Refillable glass bottles reigned for a long time after milk cartons were introduced, but by 1968, over 70% of milk packaged in the United States went into paper cartons. The manufacture of milk cartons is actually a two-step process, at two different locations. The carton manufacturer cuts and prints the carton, which is shipped in a “knocked down” or flattened form to the milk packager. The packager completes the process by forming, filling, and sealing the carton.

RAW MATERIALS

Milk containers are made from paperboard coated with a waterproof plastic, generally polyethylene. The wood pulp that is used to make paperboard for milk cartons is a blend of softwood and hardwood. Softwood is usually a type of pine, though the actual trees used vary depending on the location of the paper mill. Softwood produces long wood fibres that provide strength to the paperboard. Hardwood comes from deciduous trees such as oaks. Hardwood has shorter fibres that make for a better printing surface. Pulp for milk carton board is usually 60% hardwood and 40% soft.

Several other chemicals are used to make milk cartons. One is oxygenated chlorine, which bleaches the wood pulp. Other chemicals specific to each manufacturer are added to the paper to add strength. Chemical pigments in the ink are used for the printing process as well.

THE MANUFACTURING PROCESS

MAKING THE PAPERBOARD

The heavy paper used for milk cartons is categorized as a type of paperboard. It is typically made on a Fourdrinier machine, one of the oldest and most common types of papermaking equipment. The process begins with wood chips. The chips are heated and bathed in chemicals that soften them and break them into small bits of wood fibre. The pulp is bleached in a bath of oxygenated chlorine. The pulp is then washed and passed through several screens, to remove debris. Next, the pulp is fed through a machine called a refiner, which grinds the wood fibres between rotating disks.

The refined pulp flows into the headbox of the Fourdrinier machine. In the headbox, a mixture of water and pulp is spread across a continually moving screen. The water drains away below through the openings in the screen, leaving a mat of damp wood fibre. The mat is drawn through huge rollers that squeeze out additional water. Next, the paperboard is dried, by passing it over steam-heated cylinders.

APPLYING WATERPROOF COATING

The dried paperboard next moves through the rollers of an extruder. As the paperboard is pulled through the rollers, the machine extrudes a small amount of molten polyethylene. The polyethylene clings to both sides of the paperboard in a thin film. Several grades of polyethylene may be combined in the extruder, and the machine actually lays down multiple layers of film in one pass.

The different layers accomplish different tasks, such as reducing moisture penetration, reducing oxygen penetration, and aiding in essential oil retention. As the paperboard comes through the extruder, it passes over a chilled roller, which cools both surfaces.

The paper now has an extremely glossy, waterproof finish. It is wound into a large roll, to be transported to the printing area. The roll is typically 120 in (3.05 m) wide, too big to fit onto the printing and cutting machine. The large roll is slit into narrower rolls, the width determined by the desired dimensions of the finished carton.

PRINTING AND CUTTING THE BLANK

Printing is usually done by the flexo-graphic method, which uses rubber printing plates attached to steel shells. Workers load the roll of polyethylene-coated paperboard into the press. The press prints the words and images of the milk carton onto the paperboard.

A typical milk carton might be printed in anything from one to seven colours. All of the colours are printed at one pass through the machine. Next, the same machine scores the paperboard along what will be the edges of the carton, where the box will fold later.

A die lowers, and stamps out the carton. If you cut open an empty milk carton down one side and across the bottom and unfold it, you can see the shape of the cut piece. This flat, scored, and printed piece is called a blank. The high-speed printing and cutting equipment turns out hundreds of blanks per minute.

SEALING THE BLANKS

Workers at the carton plant next load the blanks into a sealing machine. The machine takes the flat blank and folds it laterally, creating an overlapping side seam. The seam is then heated and squeezed together. The heated polyethylene bonds and the seam are strong and watertight without any additional glue.

Thousands of blanks per minute shoot through the sealing machine. This is the final step at the carton manufacturer. The rest of the process is completed at the dairy. The sealed and folded blanks are loaded into corrugated cartons, and they are shipped.

FORMING AND BOTTOM-SEALING

Dairies use specialized machinery to transform the blanks into open containers. Workers first load the blanks into a chute leading into the forming machine. The blanks are pulled by suction down onto mechanical arms called forming mandrels. The forming mandrels snap the carton open along its scored lines, and overlap the two bottom flaps. The mandrels are aligned like spokes on a turning wheel. As the carton on the mandrel reaches the top of the wheel, the bottom of the carton is pressed against a hot plate that descends and seals the bottom seam. As the wheel continues to rotate, the bottom-sealed carton moves down, and is pulled by suction off the forming mandrel and set down on a conveyor belt.

FILLING AND TOP-SEALING

The conveyor belt moves the carton to the filling area. Milk from the dairy's storage area descends by pipes to the filling machine. A pre-measured amount of milk fills a chamber above the carton. Then the milk is released through a spout into the carton.

The filled carton passes along on the conveyor belt to the top-sealing machine. The top-sealing machine lowers onto the carton and pinches the top together along pre-scored lines. The shape of the conventional milk carton is called gable-topped. The top-sealer forms the gable, and heats and presses the top seam together. As in all the other seams, the polyethylene bonds to itself, and no additional glue is needed.

STAMPING THE DATE

All milk cartons must have a date stamped on the top, indicating how long the milk will stay fresh. At the next stop along the conveyor belt, the filled, sealed carton passes under a stamping machine, which impresses the date along the tope edge of the carton.

At a big milk-processing plant, the whole operation, from folded blank to date-sealed finished product, takes only a few seconds. After the date is stamped, the finished milk carton moves off the conveyor, and is packed either automatically or by hand into a packing case, for shipment to market.

QUALITY CONTROL

Manufacturers make quality checks at every step along the manufacturing process. The pulp must be inspected to make sure it is the proper colour and density, and has the desired fibre characteristics.

As the pulp is a blend of long and short fibres, from soft and hard-wood trees, batches may differ according to the kind and proportion of trees used. The paperboard must pass numerous quality checks, for different reasons. The Federal Drug Administration (FDA) requires that milk cartons meet strict standards for hygiene and safety.

For instance, the FDA must approve any chemicals added to the paperboard and the manufacturer must be able to prove it is meeting its regulated requirements.

The width, thickness, and fibre mix of the paperboard is continually monitored by instruments attached to the paper-making machine, and the board is checked for contaminants as well. At the dairy or milk processing plant, forming and filling of the cartons is done under exacting standards for hygiene and safety.

BY-PRODUCTS/WASTE

The manufacturing process for milk cartons is extremely efficient, and there is very little waste. However, most used cartons are thrown in the trash and end up in landfills. It is possible to recycle them, though, if the appropriate recycling facilities exist. A milk carton recycler collects empty cartons from large users such as schools and hospitals. Then the recycler shreds the cartons, sanitizes them, and ties the shreds into bales. A pulp mill buys the bales from the recycler. At the mill, the polyethylene coating is separated from the paper, and strained off for re-use by a plastics manufacturer. The shredded cartons are then reprocessed into pulp, and can be used to make high grades of printing and writing paper.

THE FUTURE

Milk carton manufacturing has not changed dramatically for many years, because the process is already highly streamlined and efficient. An increasingly popular modification to the traditional gable-topped carton is the addition of a plastic pour spout, but this requires only minor changes in the manufacturing process.

As milk consumption falls in the United States, future changes might be in the graphic design of the cartons, as dairies compete harder for customers. Because the gable-topped cartons are very cost-effective to manufacture, packagers are searching for other products that can be sold in them. However, the polyethylene coating for milk cartons is not appropriate for every liquid. For instance, wine and motor oil have different characteristics than milk, and so need different waterproof barriers. Chemists and design engineers are currently researching new plastic coatings, so that other liquids besides milk can use paper cartons.

3

Food Irradiation

Food irradiation is another sterilising technique in which foods are bombarded by high-energy rays called gamma rays or by fast-moving electrons to kill bacteria, fungi and insects and, in some cases, to delay fruit ripening. A major benefit of irradiation is that it can occur after food is packaged and sealed.

Although irradiation is effective in killing contaminating microorganisms, it may mask the fact that the food had high levels of spoilage or insect infestation prior to treatment: the microorganisms or insects are killed but their carcasses, faeces or toxins remain. As with all preservation techniques, irradiation should be used to prolong the life of appropriate food which is of high quality prior to treatment. Food irradiation involves the use of either high-speed electron beams or high-energy radiation with wavelengths smaller than 200 nanometres, or 2000 angstroms (e.g., X rays and gamma rays). These rays contain sufficient energy to break chemical bonds and ionize molecules that lie in their path.

The two most common sources of high-energy radiation used in the food industry are cobalt-60 (^{60}Co) and cesium-137 (^{137}Cs). For the same level of energy, gamma rays have a greater penetrating power into foods than high-speed electrons. The unit of absorbed dose of radiation by a material is denoted as the gray (Gy), one gray being equal to the absorption of one joule of energy by one kilogram of food.

The energy possessed by an electron is called an electron volt (eV). One eV is the amount of kinetic energy gained by an electron as it accelerates through an electric potential difference of one volt. It is usually more convenient to use a larger unit such as megaelectron volt (MeV), which is equal to one million electron volts.

Food irradiation is a promising new food safety technology that can eliminate disease-causing germs from foods. Like pasteurization of milk, and pressure cooking of canned foods, treating food with ionizing radiation can kill bacteria and parasites that would otherwise cause foodborne disease.

Similar technology is used to sterilize medical devices so they can be used in surgery or implanted without risk of infection. The food that NASA astronauts eat has been sterilized by irradiation to avoid getting foodborne illness in space. The effects of irradiation on the food and on animals and people eating irradiated food have been studied extensively. These studies show clearly that when irradiation is used as approved on foods:

- Disease-causing germs are reduced or eliminated.
- The food does not become radioactive.

- Dangerous substances do not appear in the foods.
- The nutritional value of the food is essentially unchanged.

Irradiation is a safe and effective technology that can prevent many foodborne diseases. Treating raw meat and poultry with irradiation at the slaughter plant could eliminate bacteria commonly found raw meat and raw poultry, such as *E. coli, Salmonella*, and *Campylobacter*.

These organisms currently cause millions of infections and thousands of hospitalizations in the United States every year. Raw meat irradiation could also eliminate Toxoplasma organisms, which can be responsible for severe eye and congenital infections. Irradiating prepared ready-to-eat meats like hot dogs and deli meats, could eliminate the risk of *Listeria* from such foods. Irradiation could also eliminate bacteria like *Shigella* and *Salmonella* from fresh produce. The potential benefit is also great for those dry foods that might be stored for long times and transported over great distances, such as spices and grains. Animal feeds are often contaminated with bacteria like *Salmonella.* Irradiation of animal feeds could prevent the spread of *Salmonella* and other pathogens to livestock through feeds.

ATOMIC ENERGY AND FOOD PRESERVATION

One of the beneficial applications of atomic energy is in preserving foods for extended periods. Food irradiation, as this process is known, is an important milestone in food preservation methodology since the successful development of canning in the 19th century. It has unique merits over conventional methods of preservation such as canning, dehydration, salting, etc., because this process does not lead to loss of flavour, odour, texture and other highly desirable attributes of fresh foods. Poor post harvest practices including inadequate storage and preservation facilities, as well as adverse climatic conditions, cause heavy losses in India's agricultural and marine produce. Food irradiation promises to offer and effective means for minimizing these losses, thereby increasing their availability and stimulating exports.

SPROUT INHIBITION IN POTATOES AND ONIONS

The application of low doses of radiation can arrest sprouting of potatoes and onions. As a result, storage losses due to sprouting of the tubers and bulbs and their dehydration can be reduced substantially. Adoption of the new technology, especially for onions, could mean significant benefits to this country that is the largest producer of onions in the world.

Fig. 1

The development of high-yielding, short duration and disease-resistant varieties of potato in recent years has led to increased production and consequently problems of storage and conservation. Chemical sprout inhibitors are difficult to apply and are not always effective. Sprout inhibiting dose of radiation is also effective in destroying tuber moth, a devastating pest of potato. Irradiation, therefore, offers a satisfactory solution to the storage problems of potatoes.

DELAYED RIPENING OF FRUITS

Low doses of radiation are effective in delaying the natural processes of ripening in fruits. Thus shelf life of mangoes can be extended by about a week and that of bananas up to two weeks.

Fig. 2

This could improve the scope for internal trade and augment export of these commercially important fruits of India. Furthermore, gamma radiation can eliminate the seed weevil, an insect that lodges deep inside the stone of the mango. This can be a satisfactory solution to vexing quarantine problem.

DIS-INFESTATION OF GRAINS

The success of green revolution has enabled India to produce over 160 million tonnes of food grains ever year.

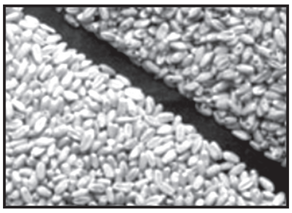


Fig. 3

However, inadequate storage facilities lead to losses, amounting to 10-15% every year, due to insects, pests alone. With progressive increase in the quantity of food grains and necessity for longer storage periods, these losses will escalate unless dis-infestation measures are improved. Chemical disinfestations methods, such as fumigation, require repeated application, as these do not eliminate insect eggs.

They may also leave harmful residues in the treated grains. Low dose irradiation completely kills or sterilizes the common grain pests, and even the eggs deposited inside the grains. Moreover, only a single radiation exposure of grains is sufficient for dis-infestations.

This, therefore, is ideally suited for large-scale operations, thereby offering substantial economic benefits. Irradiation can also serve as an effective process for dis-infestation of certain pre-packed cereal products like atta, soji (rava) and premixes.

PRESERVATION OF SEA FOODS

Fish, an important source of animal protein, is available in plenty all along the 500 km Indian coastline. However, the existing inadequate preservation facilities cannot cope with the rapid spoilage of the catch and thereby limit the availability of seafood in the interior regions.

By selective destruction of spoilage bacteria, moderate doses (200 kilorads) of radiation can extend the acceptability, and, in turn, marketability of iced fish by about two weeks. Combination processes with heat and radiation can also increase the shelf life at room temperature by several weeks. Besides, this is the only method of removal of pathogens from pre-packed frozen product.

MICROBIAL DECONTAMINATION OF SPICES

India is a major spice producing and exporting country. Spice export trade is always faced with stringent quality

Fig. 4

requirements relating to insect infestation and microbial contamination. Fumigation of spices with chemicals like methyl bromide, ethylene oxide and propylene oxide, has inherent disadvantages, especially retention of chemical residues. Single treatment of gamma radiation can make spices free of insect infection and microbial contamination without the loss of flavour components. The treatment can also be used for pre-packed ground spices and curry powders.

SAFETY OF IRRADIATED FOODS

The safety of food processed by radiation has been examined carefully, both at the national and international levels. On the basis of extensive wholesomeness studies with laboratory animals carried out in different countries including India, FAO/IAEA/WHO Joint Expert Committee has recommended that the food items irradiated up to an average dose of 10 kilo gray be accepted as safe from the health angle and do not present any toxicological hazards.

Fig. 5

In fact, the doses of irradiation required for the treatment of commodities are far below this stipulated limit. The committee has further recognised radiation as a physical process like thermal processing and not as a food additive. Currently, about 30 countries have given clearance to over 46 items of irradiated foods. Irradiated foods are available commercially in several countries. India has cleared the application of radiation for preservation of onions, frozen seafood and spices.

Food Irradiation and Processing Laboratory of Bhabha Atomic Research Centre is one of the foremost laboratories of such kind in the world. For over the past two decades, it has carried out research and development work relating to radiation preservation of perishable foods, particularly those of economic importance to India.

Irradiation techniques developed at this Research Centre have been shown to be effective for inhibition of sprouting in potatoes and onions, delayed ripening of fruits, dis-infestation of grains, extension of shelf life of fish and meat, elimination of pathogens from frozen sea food and microbial and insect decontamination of spices. This programme necessitated investigation for answering all possible questions concerning the efficacy of the process, quality of the material and safety of irradiated food for human use. Basic studies were also needed to elucidate the spoilage factors since the major objective of the process has been on the extension of post-harvest storage of different commodities in natural form. In collaboration with growers' cooperatives and other user agencies in the country, tecno-economic feasibility studies have been initiated for irradiation of certain commodities.

BIOLOGICAL EFFECTS OF IRRADIATION

Irradiation has both direct and indirect effects on biological materials. The direct effects are due to the collision of radiation with atoms, resulting in an ejection of electrons from the atoms. The indirect effects are due to the formation of free radicals (unstable molecules carrying an extra electron) during the radiolysis (radiation-induced splitting) of water molecules. The radiolysis of water molecules produces hydroxyl radicals, highly reactive species that interact with the organic molecules present in foods. The products of these interactions cause many of the characteristics associated with the spoilage of food, such as off-flavours and off-odours.

POSITIVE EFFECTS

The bactericidal (bacteria-killing) effect of ionizing radiation is due to damage of the biomolecules of bacterial cells. The free radicals produced during irradiation may destroy or change the structure of cellular membranes. In addition, radiation causes irreversible changes to the nucleic acid molecules (i.e., DNA and RNA) of bacterial cells, inhibiting their ability to grow. Pathogenic bacteria that are unable to produce resistant endospores in foods such as poultry, meats, and seafood can be eliminated by radiation doses of 3 to 10 kilograys. If the dose of radiation is too low, then the damaged DNA can be repaired by specialized enzymes. If oxygen is present during irradiation, the bacteria are more readily damaged. Doses in the range of 0.2 to 0.36 kilograys are required to stop the reproduction of *Trichinella spiralis* (the parasitic worm that causes trichinosis) in pork, although much higher doses are necessary to eliminate it from the meat. The dose of radiation used on food products is divided into three levels. Radappertization is a dose in the range of 20 to 30 kilograys, necessary to sterilize a food product. Radurization is a dose of 1 to 10 kilograys, that, like pasteurization, is useful for targeting specific pathogens. Radicidation involves doses of less than 1 kilogray for extending shelf life and inhibiting sprouting.

NEGATIVE EFFECTS

In the absence of oxygen, radiolysis of lipids leads to cleavage of the interatomic bonds in the fat molecules, producing compounds such as carbon dioxide, alkanes, alkenes, and aldehydes. In addition, lipids are highly vulnerable to oxidation by free radicals, a process that yields peroxides, carbonyl compounds, alcohols, and lactones. The consequent rancidity, resulting from the irradiation of high-fat foods, is highly destructive to their sensory quality. To minimize such harmful effects, fatty foods must be vacuum-packaged and held at subfreezing temperatures during irradiation. Proteins are not significantly degraded at the low doses of radiation employed in the food industry. For this reason irradiation does not inactivate enzymes involved in food spoilage, as most enzymes survive doses of up to 10 kilograys. On the other hand, the large carbohydrate molecules that provide structure to foods are depolymerized (broken down) by irradiation. This depolymerization reduces the gelling power of the long chains of structural carbohydrates. However, in most foods some protection against these deleterious effects is provided by other food constituents. Vitamins A, E, and B_1 (thiamine) are also sensitive to irradiation. The nutritional losses of a food product are high if air is not excluded during irradiation.

SAFETY CONCERNS

Based on the beneficial effects of irradiation on certain foods, several countries have permitted its use for specific purposes, such as the inhibition of sprouting of potatoes, onions, and garlic; the extension of shelf life of strawberries, mangoes, pears, grapes, cherries, red currants, and cod and haddock fillets; and the insect disinfestation of pulses, peanuts, dried fruits, papayas, wheat, and ground-wheat products.

The processing room used for irradiation of foods is lined with lead or thick concrete walls to prevent radiation from escaping. The energy source, such as a radioactive element or a machine source of electrons, is located inside the room. (Radioactive elements such as ^{60}Co are contained in stainless steel tubes. Because an isotope cannot be switched on or off, when not in use it is lowered into a large reservoir of water.) Prior to the irradiation treatment, personnel vacate the room. The food to be irradiated is then conveyed by remote means into the room and exposed to the radiation source for a predetermined time.

The time of exposure and the distance between the radiation source and the food material determine the irradiation treatment. After treatment, the irradiated food is conveyed out of the room, and the radioactive element is again lowered into the water reservoir.

Large-scale studies conducted around the world have concluded that irradiation does not cause harmful reactions in foods. In 1980 a joint committee of the Food and Agriculture Organization (FAO), the International Atomic Energy Agency (IAEA), and the World Health Organization

(WHO) declared that an overall average dose of radiation of 10 kilograys was safe for food products. The maximum energy emitted by ^{60}Co and ^{137}Cs is too low to induce radioactivity in food. The energy output of electron-beam generators is carefully regulated, and the recommended energy outputs are too low to cause radioactivity in foods.

WHAT IS THE ACTUAL PROCESS OF IRRADIATION?

Three different irradiation technologies exist, that use three different kinds of rays: gamma rays, electron beams and x-rays. The first technology uses the radiation given off by a radioactive substance. This can be either a radioactive form of the element cobalt (^{60}Co) or of the element cesium (^{137}Cs). These substances give off high energy photons, called gamma rays, which can penetrate foods to a depth of several feet. These particular substances do not give off neutrons, which means they do not make anything around them radioactive.

This technology has been used routinely for more than thirty years to sterilize medical, dental and household products, and it is also used for radiation treatment of cancer. Radioactive substances emit gamma rays all the time. When not in use, the radioactive "source" is stored down in a pool of water which absorbs the radiation harmlessly and completely.

To irradiate food or some other product, the source is pulled up out of the water into a chamber with massive concrete walls that keep any rays from escaping. Medical products or foods to be irradiated are brought into the chamber, and are exposed to the rays for a defined period of time. After it is used, the source is returned to the water tank. Electron beams, or e-beams, are produced in a different way. The e-beam is a stream of high energy electrons, propelled out of an electron gun. This electron gun apparatus is a larger version of the device in the back of a TV tube that propels electrons into the TV screen at the front of the tube, making it light up.

This electron beam generator can be simply switched on or off. No radioactivity is involved. Some shielding is necessary to protect workers from the electron beam, but not the massive concrete walls required to stop gamma rays. The electrons can penetrate food only to a depth of three centimeters, or a little over an inch, so the food to be treated must be no thicker than that to be treated all the way through. Two opposing beams can treat food that is twice as thick. E-beam medical sterilizers have been in use for at least fifteen years. The newest technology is X-ray irradiation. This is an outgrowth of e-beam technology, and is still being developed. The X-ray machine is a more powerful version of the machines used in many hospitals and dental offices to take X-ray pictures. To produce the X-rays, a beam of electrons is directed at a thin plate of gold or other metal, producing a stream of X-rays coming out the other side. Like cobalt gamma rays, X-rays can pass through thick foods, and require heavy shielding for safety. However, like e-beams, the machine can be switched on and off, and no radioactive substances are involved. Four commercial X-ray irradiation units have been built in the world since 1996.

HOW DOES IRRADIATION AFFECT FOODS?

The foods are not changed in nutritional value and they are not made dangerous as a result of the irradiation. The high energy ray is absorbed as it passes through food, and gives up its energy. The food is slightly warmed. Some treated foods may taste slightly different, just as pasteurized milk tastes slightly different from unpasteurized milk.

If the food still has living cells, (such as seeds, or shellfish, or potatoes) they will be damaged or killed just as microbes are. This can be a useful effect. For example, it can be used to prolong the shelf life of potatoes by keeping them from sprouting. The energy can induce a few other changes. At levels approved for use on foods, levels of the vitamin thiamine are slightly reduced. This reduction is not enough to result in vitamin deficiency. There are no other significant changes in the amino acid, fatty acid, or vitamin content of food. In fact, the changes induced by irradiation are so minimal that it is not easy to determine whether or not a food has been irradiated.

Irradiated foods need to be stored, handled and cooked in the same way as unirradiated foods. They could still become contaminated with germs during processing after irradiation, if the rules of basic food safety are not followed. Because the irradiated foods have fewer microbes of all sorts, including those that cause spoilage, they may have a longer shelf life before spoiling. The safety of irradiated foods has been studied by feeding them to animals and to people. These extensive studies include animal feeding studies lasting for several generations in several different species, including mice, rats, and dogs. There is no evidence of adverse health effects in these well-controlled trials.

In addition, NASA astronauts eat foods that have been irradiated to the point of sterilization (substantially higher levels of treatment than that approved for general use) when they fly in space. The safety of irradiated foods has been endorsed by the World Health Organization (WHO), the Centres for Disease Control and Prevention (CDC) and by the Assistant Secretary of Health, as well as by the US Department of Agriculture (USDA) and the Food and Drug Administration (FDA).

MEASUREMENT OF THE AMOUNT OF IRRADIATION USED

The dose of irradiation is usually measured in a unit called the Gray, abbreviated Gy. This is a measure of the amount of energy transferred to food, microbe or other substance being irradiated. 10 kilograys, or 10,000 grays, is the same as an older measure, the megaRad. A single chest X-ray has a dose of roughly a half of a milligray (a thousandth of a gray). To kill *Salmonella*, fresh chicken can be irradiated at up to 4.5 kiloGrays, which is about 7 million times more irradiation than a single chest X-ray. To measure the amount of irradiation something is exposed to, photographic film is exposed to the irradiation at the same time. The film fogs at a rate that is proportional to the irradiation level.

The killing effect of irradiation on microbes is measured in D-values. One D-value is the amount of irradiation needed to kill 90% of that organism. For example, it takes 0.3 kilograys to kill 90% of *E. coli* O157, so the D-value of *E. coli* is 0.3 kGy. These numbers can be added exponentially. It takes two D (or 0.6 kGy in the case of *E. coli*) to kill 99% of the organisms present, 3 D (or 0.9 kGy) to kill 99.9% and so on.

Thus, once you know the D-value for an organism, and how many organisms might possibly be present in a food, the technician can estimate how much irradiation it will take to kill all of them. For example, if you think that a thousand *E. coli* O157 could be present in a food, then you want to be able to treat with at least 4 D, or 4 × 0.3 kGy, or 1.2 kGy. The D-values are different for each organism, and need to be measured for each organism. They can even vary by temperature, and by the specific food.

The energy of e-beams and of x-rays is measured in the amount of energy developed by the electron gun, and is measured in electron volts (eV). The usual apparatus runs at 5 to 10 million electron volts (MeV).

IRRADIATION AFFECTS DISEASE-CAUSING MICROBES

When microbes present in the food are irradiated, the energy from the rays is transferred to the water and other molecules in the microbe. The energy creates transient reactive chemicals that damage the DNA in the microbe, causing defects in the genetic instructions. Unless it can repair this damage, the microbe will die when it grows and tries to duplicate itself. Disease-causing organisms differ in their sensitivity to irradiation, depending on the size of their DNA, the rate at which they can repair damaged DNA, and other factors. It matters if the food is frozen or fresh, as it takes a higher dose to kill microbes in frozen foods.

The size of the DNA "target" in the organism is a major factor. Parasites and insect pests, which have large amounts of DNA, are rapidly killed by extremely low doses of irradiation, with D-values of 0.1 kiloGray or less. It takes more irradiation to kill bacteria, because they have a somewhat smaller DNA, with D-values in the range of 0.3 to 0.7 kiloGray.

Some bacteria can form dense hardy spores, which means they enter a compact and inert hibernation state. It takes more irradiation to kill a bacterial spore, with D-values on the order of 2.8 kiloGray. Viruses are the smallest pathogens with that have nucleic acid, and they are in general resistant to irradiation at doses approved for foods. This means that they may have D-values of 10 kiloGray or higher. The prion particles associated with bovine spongiform encephalopathy (BSE, also known as mad cow disease) do not have nucleic acid at all, and so they are not inactivated by irradiation, except at extremely high doses. This means that irradiation will work very well to eliminate parasites and bacteria from food, but will not work to eliminate viruses or prions from food.

WHICH FOODS CAN BE IRRADIATED?

At low doses, irradiation could be used on a wide variety of foods to eliminate insect pests, as a replacement for fumigation with toxic chemicals that is routine for many foods now. It can also inhibit the growth of molds, inhibit sprouting, and prolong the shelf life.

At higher doses, irradiation could be used on a variety of different foods to eliminate parasites and bacteria that cause foodborne disease. Many foods can be irradiated effectively, including meat, poultry, grains, and many seafoods, fruits and vegetables. It is likely to have greatest application for raw foods of animal origin that are made by mixing materials from many animals together, such as ground meat or sausage.

However, not all foods are suitable for irradiation. For example, oysters and other raw shellfish can be irradiated, but the shelf life and quality decreases markedly because the live oyster inside the shell is also damaged or killed by the irradiation. Shell eggs can sometimes be contaminated on the insides with *Salmonella*. However, irradiation causes the egg whites to become milky and more liquid, which means it looks like an older egg, and may not serve as well in some recipes. Alfalfa seeds used in making alfalfa sprouts can sometimes be contaminated with *Salmonella*. Using irradiation to eliminate *Salmonella* from the seeds may require a dose of irradiation that also interferes with the viability of the seeds themselves. Combining irradiation with other strategies to reduce contamination with germs may overcome these limitations.

FOODS APPROVED FOR IRRADIATION

A variety of foods have been approved for irradiation in the United States, for several different purposes. For meats, separate approval is required both from the FDA and the USDA.

Table 1

Approval Year	*Food*	*Dose*	*Purpose*
1963	Wheat flour	0.2-0.5 kGy	Control of mold
1964	White potatoes	0.05-0.15 kGy	Inhibit sprouting
1986	Pork	0.3-1.0 kGy	Kill Trichina parasites
1986	Fruit and vegetables	1.0 kGy	Insect control, increase shelf life
1986	Herbs and	30 kGy spices	Sterilization
1990 - FDA	Poultry	3 kGy reduction	Bacterial pathogen
1992 - USDA	Poultry	1.5-3.0 kGy reduction	Bacterial pathogen

1997 - FDA	Meat	4.5 kGy reduction	Bacterial pathogen
1999 - USDA (pending)	Meat	4.5 kGy	Bacterial pathogen reduction

A facility in Florida has been irradiating strawberries and other fruits on a limited basis, to prolong shelf life. On a trial basis, fresh tropical fruits from Hawaii have been irradiated before shipping them to the mainland, instead of fumigating them to eliminate the fruit fly pests that could spread to the mainland.

Some spices for commercial use have been irradiated. In addition irradiation is widely used to sterilize a variety of medical and household products, from hip joint implants to bandaids and baby pacifiers.

Other technologies used to sterilize fruits, spices and medical devices use toxic chemicals, such as ethylene oxide. Use of irradiation can reduce the use of these other hazardous substances.

A distinctive logo has been developed for use on food packaging, in order to identify the product as irradiated. This symbol is called the "radura" and is used internationally to mean that the food in the package has been irradiated. A written description may also be present, such as "Irradiated to destroy harmful microbes."

It is not required to label a food if a minor ingredient of the food, such as a spice, has been irradiated itself. Many consumers are quite willing to buy irradiated foods. This is particularly true if the purpose of the irradiation is clearly indicated.

Consumers are interested in a process that eliminates harmful microbes from the food and reduce the risk of foodborne disease. In test marketing of specific irradiated foods, consumers have shown that they are willing to buy them.

Typically at least half will buy the irradiated food, if given a choice between irradiated product and the same product non-irradiated. If consumers are first educated about what irradiation is and why it is done, approximately 80% will buy the product in these marketing tests.

IRRADIATION REPLACES OTHER FOODBORNE DISEASE

Irradiation is not a short cut that means food hygiene efforts can be relaxed. Many steps need to be taken from farm to table to make sure that our food supply is clean and safe. Irradiation is a major step forward, but it does not replace other important efforts, including efforts to improve sanitation on the farm and in the food processing plant.

For irradiation to be effective, the food that is to be irradiated already needs to be clean. The more initial contamination there is, the higher dose of irradiation it would take to eliminate possible pathogens, and the greater the change in the taste and quality of the food.

The protection of irradiation will be overcome if the contamination levels are too high. The same is true for pasteurized milk. To be pasteurized, milk must be produced in regulated dairy farms, and must be of Grade A quality. Milk that is less than Grade A is not pasteurized for direct sale as milk. Thus, irradiation of food is an important additional step for added safety in the whole farm-to-table continuum of food safety measures.

IRRADIATION OF FOOD IS SIMILAR PASTEURIZATION OF MILK

Irradiation has the potential to be used like milk pasteurization in the future. We have confidence in the safety of pasteurized milk for several reasons. The milk is graded and tested to make sure that the milk is clean enough to pasteurize in the first place.

Careful industry standards and regulations monitor the effectiveness of the pasteurization process. The pasteurization occurs just before the milk goes into the carton, so the chance of re-contamination after pasteurization is nearly zero. Similar strategies and designs can make food irradiation as effective as milk pasteurization.

Currently, pasteurization is applied to foods (like milk) that already meet a defined cleanliness standard, and is applied at a dose that gives a standard defined effect. As the irradiation of food becomes commercialized for various foods, similar standardization will be required. The effectiveness of the treatment in eliminating pathogens will be regulated as a food safety process, by either the USDA or the FDA, often in concert with State authorities, just as is the case now for milk pasteurization or retort canning.

The safety of operations of irradiation facilities is regulated separately. This requires extensive worker training, supervision, and regulatory oversight. Facilities using radioactive sources are regulated by the Nuclear Regulatory Commission (NRC). To be licensed, the facility must have been designed with multiple fail-safe measures, and must establish extensive and well documented safety procedures, and worker training.

The safe transport of the radioactive sources is regulated by the Department of Transportation. E-beam and X-ray sources are not monitored by the NRC, but rather by the part of the FDA that regulates medical X-ray devices, and by the same State authorities that regulate other medical, dental and industrial uses of these technologies. Medical sterilization facilities have been operated in this country for more than 30 years, without a fatal accident.

Over 100 such facilities are currently licensed, along with at least that many medical radiation treatment centres, and bone marrow transplant centres (which also use Cobalt 60 to irradiate patients).

No events have been documented in this country that led to exposure of the population at large to radioactivity. In other countries, a small number of fatal incidents have been documented in which a worker by-passed multiple safety steps to enter the chamber while the source was exposed, resulting in a severe or even lethal radiation injury to themselves.

RADIOACTIVE WASTE IS GENERATED

Cobalt 60 is manufactured in a commercial nuclear reactor, by exposing non-radioactive cobalt to intense radiation in the reactor core. Cesium 137 is a by-product of the manufacture of weapons-grade radioactive substances. Thus the supply of these two substances, like that of other radioactive materials used in medicine, science and industry, is dependent on the nuclear industry.

The food irradiation facilities themselves do not become radioactive, and do not create radioactive waste. The cobalt sources used in irradiation facilities decay by 50% in five years, and therefore require periodic replacement. The small radioactive cobalt "pencils" are shipped back to the original nuclear reactor, where they can be recharged for further use. The shipment occurs in special hardened steel canisters that have been designed and tested to survive crashes without breaking.

Cobalt is a solid metal, and even if somehow something should break, it will not spread through the environment. Cobalt 60 may also be disposed of as a radioactive waste. Given its relatively short half life (5 years) and its stable metallic form, the material is not considered to be a problematic waste. In contrast to metallic cobalt, cesium is a salt, which means it can dissolve in water. Cesium 137 sources decay by 50% in 31 years, and therefore are not often replaced. When they are replaced, the old cesium sources will be sent to a storage site in the same special transport canisters.

If a leak should occur, there is the possibility that the cesium salts could dissolve in water and thus spread into the environment. This happened at a medical sterilizer facility in Decatur, Georgia in 1992, when a steel container holding the cesium cracked, and some cesium leaked into the shielding water tank. E-beams and X-ray facilities do not involve radioactive substances.

EFFECT OF IRRADIATION ON FOOD PACKAGING MATERIALS

The food to be irradiated will often already be in its final package. This raises the question about whether the irradiation has any effect on the packaging that might be transferred to the foods. The effect of irradiation on plastics and other packaging was investigated in the 1960s and early 1970s, in order to identify safe packaging materials for use in the space programme. A limited number of materials have been approved for use in packaging food that is to be irradiated. This limited number reflects the limited needs of NASA, not the difficulty of identifying safe products. Many modern packaging materials have simply not been tested. Testing and approving a wider array of packaging materials is critical to the successful commercialization of irradiated foods.

Do other countries irradiate their food?

Many other countries have begun to irradiate food, including France, the Netherlands, Portugal, Israel, Thailand, Russia, China and South Africa.

CDC'S POSITION ON FOOD IRRADIATION

CDC has stated that food irradiation is a promising new application of an established technology. It holds great potential for preventing many important foodborne diseases that are transmitted through meat, poultry, fresh produce and other foods. An overwhelming body of scientific evidence demonstrates that irradiation does not harm the nutritional value of food, nor does it make the food unsafe to eat.

Just as for the pasteurization of milk, it will be most effective when irradiation is coupled to careful sanitation programs. Consumer confidence will depend on making food clean first, and then using irradiation or pasteurization to make it safe. Food irradiation is a logical next step to reducing the burden of foodborne disease in the United States.

USES OF FOOD IRRADIATION

Ionizing radiation can be used to process food. Its effect on the food is dependent on the dose level (amount) of irradiation to which the food has been subjected. High-dose levels of irradiation (20 to more than 70 kGy) can be used to sterilize foods by eliminating all vegetative microorganisms and spores in the food. Very low doses of irradiation (less than 0.1 kGy) can be used to inhibit sprouting in potatoes, onions and garlic. Low doses have also been shown to be as effective as pesticide fumigants for deinfesting grain products prior to shipment and storage, and for reducing microbial and insect contamination on fresh fruits and vegetables. For example, grapefruit grown in Mexico, Central America, and South America frequently are infested with larvae of the Mexican fruit fly, *Anastrepha ludens*.

To prevent entry of this insect into the United States, grapefruits must be quarantined and treated with ethylene dibromide. A study reported that 20 grays for 0.25, 0.5, 1.0, or 100 minutes reduced adult emergence of Mexican fruit flies from larvae by more than 99%. Therefore, once a quarantine security treatment for the Mexican fruit fly is established, a low irradiation dose rate can be used to reduce adult emergence and should impart little damage to grapefruit peel tissue. Not all fresh produce is suitable for irradiation. The shelf life of mushrooms, potatoes, tomatoes, onions, mangoes, papayas, bananas, apricots, strawberries, and figs can be extended with low-dose irradiation with no loss in quality. However, the quality of some foods (some citrus fruits, avocados, pears, cantaloupes, and plums) is actually degraded by irradiation.

EFFECT OF IONIZING RADIATION ON NUTRIENTS IN FOOD

When foods are exposed to ionizing radiation under conditions envisioned for commercial application, no significant impairment in the nutritional quality of protein, lipid and carbohydrate constituents was observed. Irradiation is no more destructive to vitamins than other food preservation methods.

It was noted that there were small losses of vitamin E and thiamin. According to Thayer *et al.*, thiamin in pork is not significantly affected by the FDA-approved maximum radiation dose to control *Trichinella*, but at larger doses, it is significantly affected. Protection of nutrients is improved by holding the food at low temperature during irradiation and by reducing or excluding free oxygen from the radiation environment. This is accomplished by irradiating vacuum-packaged foods at temperatures below 0°C (32°F).

The effect of irradiation on retention of vitamin E (alpha tocopherol) in chicken breasts was determined when the chicken breasts were irradiated in air with a Cesium-137 source at 0, 1, 3, 5.6, and 10 kGy at 0° to 2°C (32.0° to 35.6°F). The fresh muscle tissue was saponified and the total tocopherols were isolated and quantitated using normal phase high performance liquid chromatography with a fluorescence detector.

Gamma irradiation of the chicken resulted in a decrease in alpha tocopherol with increasing dose. At 3 kGy and 2°C, the radiation level approved by the FDA to process poultry, there was a 6% reduction in alpha tocopherol level. No significant changes were observed for gamma tocopherol. Free radical scavengers were tested for their ability to reduce the loss of thiamin and riboflavin in buffered solutions and in pork during gamma irradiation. In aqueous solution, the tested compounds were twice as effective for the protection of riboflavin as for the protection of thiamin.

The presence of nitrous oxide doubled the rates of loss for thiamin and riboflavin in solution, indicating a predominance of reactions with hydroxyl radicals. In buffered solutions, niacin was not affected by gamma radiation unless either thiamin or riboflavin was present, in which case, the niacin was destroyed rather than the other vitamin.

Ascorbate, cysteine, and quinoid reductants were demonstrated to be naturally present in sufficient quantities to account for the lower rates of loss of thiamin and riboflavin observed during irradiation of pork meat, as compared to irradiation in buffered solution. A study was made of thiamin content of the skeletal muscles and livers of pork, chicken, and beef after gamma irradiation. Gamma irradiation from a Cesium-137 source was used to irradiate the samples with doses of 0, 1.5, 3, 6, and 10 kGy at 2°C (35.6°F). Samples were also titrated with dichlorophenoindophenol to determine the reducing capacity of the tissue.

The rate of loss of thiamin upon irradiation was found to be about 3 times as fast in skeletal muscle as in liver and to be a function of the reducing capacity of the tissues, the loss decreasing with increasing reductant titer. For the same amount of thiamin loss, liver could be irradiated to 3 times the dose as could muscle .

WHOLESOMENESS OF IRRADIATED FOODS

The World Health Organization (WHO) released the following updated policy statement on September 23, 1992:

"Irradiated food produced under established Good Manufacturing Practices is to be considered safe and nutritionally adequate because:

- The process of irradiation will not introduce changes in the composition of the food which, from a toxicological point of view would impose an adverse effect on human health.
- The process of irradiation will not introduce changes in the microflora of the food which would increase the microbiological risk to the consumer.
- The process of irradiation will not introduce nutrient losses in the composition of the food which, from a nutritional point of view, would impose an adverse effect on the nutritional status of individuals or populations."

Review of data and concerns raised during the Food and Drug Administration and Food Safety Inspection Service of the USDA approval process for irradiation of poultry indicates that properly processed irradiated foods are wholesome. Neither short nor multi-generation animal feeding studies have produced evidence of toxicological effects in mammals due to their ingestion of irradiated foods.

In a feeding trial in China, 21 male and 22 female volunteers consumed 62 to 71% of their total caloric intake as irradiated foods for 15 weeks. The diet included rice irradiated to 0.37 kGy and stored for 3 months; rice irradiated to 0.4 kGy and stored for 2 weeks; meat products such as pork sausage irradiated to 8 kGy and stored at room temperature for 2 weeks; and 14 different vegetables irradiated to 3 kGy and stored at room temperature for 3 days. A double-blind design was used and included measurement of total caloric intake, monthly biochemical and physical exams and sensory evaluations of the food. The diet was well received, and there were no adverse findings associated with the consumption of the irradiated foods.

Bhaskaram and Sadasivan (1975) reported that children suffering from kwashiorkor developed a 1.8% incidence of polyploidy after being fed irradiated wheat. It was also reported that there was 0% polyploidy in controls and a test group of children after the removal of the treated diet, even though polyploidy is not unusual in human populations. Experts and governmental agencies (The Government of India; FDA; IFT Expert Panel on Food Safety and Nutrition; WHO/FAO) looking at the safety of food irradiation have discredited this study because of its inconsistencies.

There is a concern that ionizing radiation creates free radicals, and that they may be present in the food at the time of ingestion. Free radicals are also formed when food is fried, baked, ground, and dried. More free radicals are created during the toasting of bread than through ionizing radiation. In foods with a high moisture content, free radicals disappear within a fraction of a second; in dry foods, the free radicals are much more stable and do not dissipate as quickly .

The assessment of the safety for human consumption of irradiated foodstuffs has involved basically four aspects.

- Radiological safety
- Microbiological safety
- Nutritional adequacy
- Toxicological safety.

After reviewing an extensive amount of data on animal feeding studies conducted at several laboratories as well as the radiation chemistry data, the Joint FAO/IAEA/WHO Expert Committee in 1981 concluded that irradiated foods are safe and wholesome.

The committee's main conclusions were that the irradiation of any food commodity up to an overall average dose of 10 kGy presents no toxicological hazard; hence, toxicological testing of foods so treated is no longer required. The irradiation of foods up to an overall average dose of 10 kGy introduces no special nutritional or microbiological problems.

RECENT SUPPORT FOR THE IRRADIATION OF FOODS

In an editorial commentary in the *Journal of the American Medical Association*, Dupont discussed the potential for transmission of bacterial enteropathogens (*Salmonella, Shigella, Campylobacter, Vibrios*) through food vehicles destined for human consumption. It was recommended that the microbiological safety of food in the United States be improved through the use of irradiation. Future health hazards could be reduced if this technique is employed widely for certain high-risk items, including poultry potentially contaminated with *Salmonella* and *Campylobacter*.

The Assistant Secretary for Health, Director, US Public Health Service, Dr. Phillip R. Lee pointed out the importance of using irradiation to prevent foodborne illness in another recent issue of the *Journal of the American Medical Association*. Foodborne illness is one of the largest preventable public health problems in the United States.

Studies by the Centres for Disease Control and Prevention show that foodborne diseases caused by pathogenic bacteria, such as *Salmonella, Campylobacter, E. coli*, and by *Vibrio, Trichinella*, tapeworms, and other parasites, cause an estimated 9,000 deaths and from 6.5 million to 81 million cases of diarrhoeal disease annually.

Unfortunately, it has taken a crisis to raise consumer, industry, and lawmakers' awareness. Media scrutiny about *Salmonella* in poultry and the highly publicized deaths of four children and severe illness of 600 people linked to *E. coli*-tainted hamburger have raised serious questions about food safety.

"There is a need and responsibility for US Public Health Service to use what is known to protect and improve the health of the public. Each modern food-processing advance—pasteurization, canning, freezing—produced criticism. Food radiation is no different."

The *Wall Street Journal* noted that: "Irradiating beef may help save lives, but the meat industry is still waiting for the green light." Agriculture scientists report that small doses of irradiation could wipe out "nearly 100%" of the *E. coli* strain in beef, and has been shown to sterilize meat and produce against practically all bacteria that cause spoilage.

Yet, the Department of Agriculture is holding back because of the concern that the public might link beef irradiation with the government radiation experiments of the 1950s. Proponents of Beef Irradiation include: The National Food Processors Association, the American Medical Association, the World Health Organization, and the American Meat Institute. All say beef irradiation will help reduce deaths from *E. coli.* In December 1993, the American Medical Association (AMA) endorsed food irradiation as "a safe and effective process that increases the safety of food when applied according to governing regulations". The AMA also affirms the principle that "the demonstration of safety requires evidence of a reasonable certainty that no harm will result, but does not require proof beyond any possible doubt [i.e., 'zero' risk does not exist]".

An article in the *Washington Times* reported that irradiation will give food producers another line of defence in preventing foodborne illness, and to prevent its use is to deny them a valuable tool in protecting public health. The US Secretary of Agriculture asked the Food and Drug Administration to approve the use of irradiation on beef. There are many activists who oppose the use of radiation for food. "Instead of using irradiation to enhance food safety, opponents say the answer is increased government regulation, especially increasing the size of the government's meat inspection force.

At this time, the government employs only about 8,000 inspectors, including supervisors, for about 32 million head of slaughtered cattle annually." However, "inspectors cannot see bacteria and other spoilage organisms and no microbiological tests currently exist that would make it practical to perform routine laboratory analysis on raw meat." Gallager and Kwittken reported conclusions of an *E. coli* Consensus Development Conference sponsored by the American Gastroenterological Association Foundation.

"Protection of the public's health requires the immediate implementation of currently recognized scientific technology for ensuring food safety. An emphasis should be placed on science-based monitoring and verification of the nation's slaughter plant operations. The current inspection-based system should be replaced by a science-based risk assessment process with government verification." The 14-member nonadvocate panel was comprised of professionals and public representatives from gastroenterology, epidemiology, public health, microbiology, food science, industry and consumer affairs. Speakers included scientific investigators, government representatives, industry officials, and consumers.

One of the major recommendations made was as follows: "Irradiation pasteurization is a safe and effective intervention strategy, especially in ground beef and should be implemented as soon as possible."

4

Food Preservation by Chemicals

There are three classes of chemical preservatives commonly used in foods:

- Benzoates (such as sodium benzoate)
- Nitrites (such as sodium nitrite)
- Sulphites (such as sulphur dioxide).

If you look at the ingredient labels of different foods, you will frequently see these different types of chemicals used. Another common preservative that you will commonly see on food labels is sorbic acid. All of these chemicals either inhibit the activity of bacteria or kill the bacteria.

CHEMICAL TREATMENT

Chemical preservatives are added to kill or inhibit microorganisms in food. They may be incorporated into the foods, or only on their surface. The wrappers used to cover them may be treated, or there may be the use of gas or vapours around the food. Some chemicals may be effective on selected group of microorganisms while others on a wide variety of them. Chemical preservatives may be harmless if they are added during the storage period and are removed before the food is consumed. But, it they are consumed as such, they may be poisonous to man or animal as well as to microorganisms.

ORGANIC ACIDS AND THEIR SALTS

Several organic acids and their salts are common preservatives as they have marked microbiostatic and microbicidal actives. Benzoic acid and benzoate are used for the preservation of vegetables. Sodium benzoate is used in the preservation of jellies, jams, fruit juice and other acid foods. Salicylic acid and salicylates are used as preservatives of fruits and vegetable in place of benzoate because the latter is considered to be deleterious to health of consumer. Scorbic acid is recommended for foods susceptible to spoilage fungi, e.g., it inhibits mould growth in bread. Wrapping material for cheese may be treated with it. It is also used in sweet pickles and for control of lactic fermentations of olives and cucumbers. Foods prepared by fermentation processes, e.g., milk products, etc., are preserved mainly by lactic, acetic and propionic acids. Flavouring extracts of vanilla, lemons are preserved in 50-70% alcohol as it coagulates cell proteins.

INORGANIC ACIDS AND THEIR SALTS

Most common among the inorganic acids and their salts are sodium chloride, hypochlorites, sulphurous acids and sulphites, sulphur dioxide, sodium nitrate and sodium nitrite.

SODIUM CHLORIDE

Sodium chloride produces high osmotic pressure and, therefore, causes destruction of many microorganisms by plasmolysis. It causes dehydration of food as well as microorganisms, releases disinfecting chlorine ion by ionization, reduces solubility of oxygen in the moisture, sensitizes microbial cells against carbon dioxide and interferes with the action of proteolytic enzymes. These are the reasons why this common salt is used widely for preservation either directly or in brine or curing solutions.

HYPOCHLORITES

The hypochlorous acid an effective germicide provided the organic matter content of the medium is not high. It is oxidative in its action. The commonly used forms are sodium and calcium hypochlorites. Drinking water or water used for washing foods or icing them may be dissolved with hypochlorites.

SULPHUROUS ACIDS AND SULPHITES

Sulphurous acid and sulphites are added to wines as preservatives. Sulphurous acid is used especially in the preservation of dry fruits. It helps retention of original colour of the preserve and inhibition of moulds more than either yeasts or bacteria. Potassium metabisulphite is used in canning.

SULPHUR DIOXIDE

Sulphur dioxide has a bleaching effect desired in some fruits. And also suppresses the growth of yeast moulds. It is used as a gas to treat drying fruits and is also used in molasses.

NITRATES AND NITRITES

Nitrates and nitrites produces an inhibitory effect on bacterial growth and used usually together in meat and fish preservation and for retension of red-colour of the meat. Nitrate is changed to nitrous acid which reacts with myoglobin to give nitric oxide myoglobin. It is the latter which gives a bright red colour to the meat making it more attractive in appearance.

However, both nitrite and nitrate are poisonous if present in potable water or food products in more than minimal amounts. This is why the generous are of these chemicals as preservative in meat and fish products has been questioned.

ANTIBIOTICS

Aureomycin (chlorotetracycline) is the most commonly used antibiotic for the preservation of animal products under chilling conditions. It is extensively used for the preservation of poultry, meat, and fish. The antibiotic is applied to the surface of the fresh meat by dipping it in a solution of the antibiotic or it may be fed to the animal by mixing it with feed or water for one to several days before slaughter. Fish are treated by adding the antibiotic in the ice or water in which they are to be transported.

The indiscriminate use of antibiotics as preservatives, however, should be prevented or the antibiotics used should be such that is demobilished on cooking so that the internal flora of man using such food is constantly exposed to the effect of the antibiotic. It is important because otherwise use of antibiotics would lead to the development of the antibiotic resistant strains of microorganisms in the body. Aside from this, some individuals' sensitive to antibiotics becomes exposed constantly to allergy.

Preservation of foodstuffs has always been a necessity for a number of reasons: the durability of food is limited, numerous foodstuffs are only available during a short harvesting season, the transport routes of food or raw materials from the production site to the consumers are continuously increasing in length and the consumers in modern society characterized by division of labour and changed shopping habits increasingly insist on buying durable products. Beyond this, there are medical-hygienic efforts aimed at inhibiting the growth of micro-organisms in food. The hazard to health which many bacteria carry, has been long known. Recently, a number of fungi have been shown to form toxins during their growth on foodstuffs.

There are two methods of food preservation: the physical and the chemical. The greater proportion of foodstuffs is rendered durable by physical procedures: drying, cooling, deep-freezing and heating. But chemical preservation also plays a prominent role. The use of preservatives is often combined with physical methods. The application of preservatives has a long history, such as the use of common salt, smoke or sulfur dioxide. Some of these agents, such as benzoic acid, are achievements of the last century. Others, such as propionic acid and sorbic acid, result from research during the last few decades.

The preservatives now in use have been thoroughly tested for their toxicological properties. Their use in the food industry is subject to stringent legal regulations. The consumer can be certain of not running any risk by partaking foods which contain preservatives. Methods of food preservation have been known for thousands of years. Preserved samples of food have even been discovered in ancient Greek urns. Chemical preservatives work either as direct microbial poisons or by reducing the pH to a level of acidity that prevents the growth of microorganisms. Acetic acid, better known as vinegar, has also been used as a food preservative since ancient times. Salted, pickled or dried foods were about the only nourishment sailors were offered on long sea voyages before the invention of modern refrigeration and preservation techniques.

CHEMICALS USED TODAY

Two commonly used preservative chemicals are:

- Nitrates and nitrites that are used to preserve meats such as ham and bacon.
- Sulphites that are commonly used to prevent the browning of fruits and vegetables after they've been peeled, and to prevent fungal spoilage.

As important and useful as they are, preservatives have developed a bad name in Western societies such as Australia. Salt is now widely shunned because of its effects on blood pressure. Nitrites and sulphites can both cause asthma, nausea, vomiting and headaches in some people.

For these reasons, consumers have started to demand foods containing lower levels of chemical preservatives. The potential drawback of this is the reduced length of time before conditions favour the rapid multiplication of food-poisoning agents like *Salmonella* and *Listeria*. A number of food-processing techniques have been developed to prolong the shelf-life of foods and permit a reduction in preservative levels.

NATURAL PRESERVATIVES

Scientists are putting increased efforts into the discovery and purification of natural compounds for use as safe alternatives to chemical preservatives.

The new breed of protective compounds are small proteins. They are called bacteriocins and are starting to be used in a wide variety of foods. Anyone who has eaten yoghurt has been protected by bacteriocins without knowing it. Bacteriocins are produced by some good bacteria to kill competing organisms such as *Listeria monocytogenes*.

The whole bacteria that produces the bacteriocin, or the purified bacteriocin itself, can be added to foods such as soft cheeses to reduce the risk of pathogen growth. An example of protection using bacteriocins is the use of nisin in crumpets to restrict the growth of *Bacillus cereus*.

LONG-LIFE TREATMENTS

Modern technology has produced several new processing techniques for prolonging the shelf-life of perishable foods.

UHT

Ultra high temperature treatment (UHT), for example, involves the rapid heating of food to about 140°C. This temperature is maintained for a few seconds to kill bacteria. The product is then cooled rapidly and placed in sterile, airtight containers to prevent recontamination. This treatment is used commonly to produce 'long-life' milk and fruit juices. A disadvantage of the high temperature treatment is that heat-sensitive vitamins such as vitamin C are destroyed. In fruit juices the vitamins are added back after treatment.

MODIFIED ATMOSPHERE PACKAGING

As the name implies, modified atmosphere packaging (MAP) alters the mix of gases-notably oxygen, nitrogen and carbon dioxide-in the atmosphere in which foods are stored. The altered storage atmosphere can limit the growth of spoilage bacteria and fungi and extend the shelf life of food. The technique is used for bread, cakes, fruit, vegetables, meat and seafood, which are stored in special plastic bags that help maintain the atmosphere for a certain length of time.

The technique is also applied to bulk foods in especially equipped storage containers. This is how fruits such as apples can be supplied to consumers throughout the year, long after the apple harvest takes place. Although modified atmosphere packaging (MAP) limits the growth of spoilage micro-organisms, it does not slow the growth of some harmful bacteria. For this reason, MAP is usually used in conjunction with other preservation techniques such as refrigeration.

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Salt and Food Technology

The number of applications fulfilled by salt in foods are as varied as the number of different foods there are. These range from a taste enhancer to a taste suppressant; as a mediator of water activity and a regulator of texture, mouthfeel, juiciness and friability. Blanching in salt water retains colour and crispness in vegetables destined for freezing and salt initiates granule formation producing the unparalleled taste and texture of Parmesano Reggiano cheese.

Salt is not only our oldest known food preservative, but it fulfils a critical anti-microbial function in the most modern hurdle technologies employed in the production of high quality minimally processed chilled foods that have become so popular in recent years.

Despite the myriad established uses of salt in food preparation at home and in the food industry, the overarching attraction of salt for people is sensorial. Simply put—salt makes food taste good. Salt doesn't just deliver salty flavour, it delivers flavour in many ways.

Salt is the oldest, most common and most important single flavouring substance. From a food appeal point of view, salt cannot be considered to be merely desirable, but by far the most satisfying of flavour components for all starchy and protein-based foods. This propensity for humans and animals to prefer a salty taste may originate from our marine evolution or may simply be a mechanism to ensure we receive an adequate amount of this essential nutrient in our diet.

When faced with foods that don't meet their taste expectations, most people will simply take up a salt shaker as add enough to satisfy their needs. Thus, in a country such as Italy, where bread baking traditions result in regional products that vary from high to almost no salt, consumers at home and diners in restaurants will readily make up any taste deficit by voluntarily adding salt at the table prior to consumption.

The same can be said for the consumer response to all other food products—those that demonstrate a deficiency in taste will be corrected by the consumer on a voluntary basis. Throughout history, even during periods when it was a very costly commodity, salt was considered to be an economic necessity of life.

One of the most important uses of salt in taste is to moderate bitterness in certain foods. For example, some of or most nutritious cruciferous vegetables, such as broccoli, spinach, Brussels sprouts, cabbage, kale, mustard greens, radicchio will not be acceptable to consumers unless a certain amount of salt is added.

This is particularly true for children as the most recent results of tests from Ohio State University reveals. Restricting the amount of salt that consumers can add to these foods risks their access to the nutritional benefits they hold. Of course, bitter natural foods such as olives would not be an edible food commodity unless they were fully debittered with salt.

When added in small amounts, salt intensifies the sweetness of many foods such as caramel, taffy, fudge, fruits, mild vegetables and various sauces. For example, lightly salting a slice of watermelon makes it taste sweeter. Salt also make food taste more palatable by suppressing other unpleasant flavours. In these instances the goal of the consumer or manufacturer is not to make a food taste salty, but rather to enhance the overall taste profile and acceptability of the food. Salt has a profound effect on the texture of an incredible array of food products. Because of its functional impact on the gelation properties of proteins, salt is used to respond to consumer preferences for texture, mouthfeel and ease of swallowing for all national and imported cheeses and cheese products, processed meat and fish products. Items such as bologna, frankfurters, restructured beefsteaks, chicken pieces , dry-cured ham, surimi from all fish sources, battered calamari rings, minced fish balls, etc., etc., serve as some examples. Salt has a critical impact on the texture, colour and cooking loss of a range of fresh, processed and dehydrated vegetables, such as runner beans, carrots, cucumbers, broccoli and cauliflower.

Of course, not only food processors love salt. The use of salt by consumers to improve the texture of foods is very common. Preparing for the holidays, a cursory search on Google using the terms 'brining turkey' yields more than 300,000 citations! As an example, a quote from the San Francisco Chronicle reads, "The Chronicle Food section cooked 28 turkeys to find the best method of producing a plump, juicy bird. Our favourite—by far—was the turkey that we brined before roasting."

The level of salt used in bread manufacture significantly affects the physical nature of the final product. Most standard bread is made from doughs containing somewhere around 1.5-2% salt by weight of flour. Salt has a significant physical effect on the properties of wheat gluten, resulting in a less sticky, more manageable dough.

Salt also affects the rate of fermentation, and its addition is timed after the dough has been partly fermented. The role of salt in controlling fermentation is not only due to the increase in osmotic pressure, but also to the actions of sodium and chloride ions on the semi-permeable membranes of yeast cells. Inadequate levels of salt will result in excessive yeast fermentation, resulting in gassy, soured doughs that are difficult to process and result in loaves with an open grain and poor texture. Many types of flat bread have become widely available in recent years. These include single-layered, leavened dough products such as naan, pizza crust, ciabatta and focaccia, batters such as crepes and pancakes as well as double layered products such as pita bread, and unleavened products like chapattis, paratha and tortillas.

Salt is an essential ingredient in most formulations, many of which are sourdough or yeast-leavened products. Salt, temperature, aeration and flour quality are all used to control bread quality. Salt affects the physical nature and properties of biscuit doughs, especially hard doughs, in a similar way to bread. In doughs with significant gluten development, such as crackers and semi-sweet types, salt toughens the gluten and gives a less sticky dough.

It may also slow down the rate of yeast fermentation. Typical levels of addition are generally less than 2%, based on flour, resulting in about 1.5% in the final product. Salt has a variety of technological functions in meat products. While many of the major effects relate to preservation, especially in cured and salted products, it also has other, direct effects on the nature and quality of the product.

Salt is used in the manufacture of both hard and soft cheeses. The salting of some of the most famous Italian, Swiss and Dutch cheeses is carried out after they are formed into rounds. The rounds are then immersed in saturated salt brine, for up to 20 days. For many traditional manufacturers, the saturated brine baths are a source of pride, some having been in continuous operation for more than 100 years (showing perfectly cubic sodium chloride crystals from 5-6 inches on a side, sitting in crystal clear brine).

Salt is the oldest food preservative known to humankind—it has been used for thousands of years. The main mechanism of salt preservation is through the reduction of water activity.

Microorganisms require water to survive and grow and salt preferentially ties up a portion of the water, leaving the microorganisms without sufficient free water. In inhibiting microbial growth, salt interacts with both the acidity (pH) of the medium and its temperature, as well as other factors present.

PROCESSED FOODS AND SALT

Salting is one of the oldest food preservation methods. Salt (sodium chloride) helps prevent spoiling by drawing water out of the food, depriving bacteria of the moisture they need to thrive. Salt is also an antibacterial agent, killing some of the bacteria that cause spoiling. At one time, salting was one of the only methods available to help preserve food. But today food processors have many other methods. These include pasteurization, refrigeration/freezing, dehydration/ freeze-drying, irradiation and using chemical preservatives.

Note: Some chemical preservatives, such as sodium benzoate, sodium propionate, sodium citrate and sodium phosphate, contain small amounts of salt.

Each of these newer processes has resulted in the need for less—if any salt—as an ingredient. So why do food manufacturers continue to add salt to processed foods? Here are some reasons:

- Salt makes food more flavourful.
- Salted foods such as soups seem thicker and less watery.
- Salt increases sweetness in products such as soft drinks, cookies and cakes.
- Salt helps cover up any metallic or chemical aftertaste in products such as soft drinks.
- Salt decreases dryness in foods such as crackers and pretzels.

Most Americans consume more than double the recommended daily amount of sodium per day—in part because of a heavy diet of processed foods. To decrease the amount of salt in your diet:

- Eat fewer processed foods such as potato chips, frozen dinners, and cured meats such as bacon and lunchmeats.
- Choose low-sodium or reduced-sodium processed foods.
- Don't add salt to your food. Instead, use herbs and spices to flavour foods.
- Eat more fresh, unprocessed foods such as fresh fruits, vegetables, lean meats, poultry, fish and unprocessed grains.

HOW DO SALT AND SUGAR PREVENT MICROBIAL SPOILAGE?

Protection of foods from microbial spoilage using salt (usually sodium chloride) or sugar (usually sucrose) has ancient roots and is often referred to as salting, salt curing, corning or sugar curing. (Pieces of rock salt used for curing are sometimes called corns, hence the name "corned beef".) Curing may utilize solid forms of salt and sugar or solutions in which salt or sugar is mixed with water.

For instance, brine is the term for salt solutions used in curing or pickling preservation processes. Examples of foods preserved with salt or sugar include the afore-mentioned corned beef as well as bacon, salt pork, sugar-cured ham, fruit preserves, jams and jellies, among others.

There are numerous descriptions and permutations of curing which may include additional preservation techniques such as smoking or ingredients such as spices. However, all curing processes fundamentally depend on the use of salt and/or sugar as the primary preservation agent(s).

Incidentally, these processes not only prevent spoilage of foods, but more importantly serve to inhibit or prevent growth of food-borne pathogens such as *Salmonella* or *Clostridium botulinum* when properly applied.

There are several ways in which salt and sugar inhibit microbial growth. The most notable is simple osmosis, or dehydration. Salt or sugar, whether in solid or aqueous form, attempts to reach equilibrium with the salt or sugar content of the food product with which it is in contact. This has the effect of drawing available water from within the food to the outside and inserting salt or sugar molecules into the food interior. The result is a reduction of the so-called product water activity (a_w), a measure of unbound, free water molecules in the food that is necessary for microbial survival and growth. The a_w of most fresh foods is 0.99 whereas the a_w necessary to inhibit growth of most bacteria is roughly 0.91. Yeasts and molds, on the other hand, usually require even lower a_w to prevent growth.

Salt and sugar's other antimicrobial mechanisms include interference with a microbe's enzyme activity and weakening the molecular structure of its DNA. Sugar may also provide an indirect form of preservation by serving to accelerate accumulation of antimicrobial compounds from the growth of certain other organisms.

Examples include the conversion of sugar to ethanol in wine by fermentative yeasts or the conversion of sugar to organic acids in sauerkraut by lactic acid bacteria. Microorganisms differ widely in their ability to resist salt- or sugar-induced reductions of a_w. Most disease-causing bacteria do not grow below 0.94 a_w (roughly 10 per cent sodium chloride concentration), whereas most moulds that spoil foods grow at an a_w as low as 0.80, corresponding to highly concentrated salt or sugar solutions.

Yet other microorganisms grow quite well under even more highly osmotic, low a_w conditions. For example, halophiles are an entire class of “salt-loving” bacteria that actually require a significant level of salt to grow and are capable of spoiling salt-cured foods. These include members of the genera *Halobacillus* and *Halococcus.*

Food products that are concentrated sugar solutions, such as concentrated fruit juices, can be spoiled by sugar-loving yeasts such as species of *Zygosaccharomyces.* Nevertheless, use of salt and sugar curing to prevent microbial growth is an ancient technique that remains important today for the preservation of foods.

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Development of Canning Food Preservation

During the first years of the Napoleonic Wars, the French Government offered a hefty cash award of 12,000 francs to any inventor who could devise a cheap and effective method of preserving large amounts of food. The larger armies of the period required increased, regular supplies of quality food. Limited food availability was among the factors limiting military campaigns to the summer and fall months.

In 1809, a French confectioner and brewer, Nicolas Appert, observed that food cooked inside a jar did not spoil unless the seals leaked, and developed a method of sealing food in glass jars. The reason for lack of spoilage was unknown at the time, since it would be another 50 years before Louis Pasteur demonstrated the role of microbes in food spoilage. However, glass containers presented challenges for transportation. Glass jars were largely replaced in commercial canneries with cylindrical tin or wrought-iron canisters (later shortened to "cans") following the work of Peter Durand (1810). Cans are cheaper and quicker to make, and much less fragile than glass jars. Glass jars have remained popular for some high-value products and in home canning. Tin-openers were not invented for another thirty years—at first, soldiers had to cut the cans open with bayonets or smash them open with rocks.

The French Army began experimenting with issuing tinned foods to its soldiers, but the slow process of tinning foods and the even slower development and transport stages prevented the army from shipping large amounts across the French Empire, and the war ended before the process was perfected.

Unfortunately for Appert, the factory which he had built with his prize money was razed in 1814 by Allied soldiers invading France. Following the end of the Napoleonic Wars, the canning process was gradually employed in other European countries and in the US. Based on Appert's methods of food preservation, Peter Durand patented a process in the United Kingdom in 1810. He did not develop the process, selling his patent in 1811 to Bryan Donkin and John Hall, who were in business as Donkin Hall and Gamble, of Bermondsey.

Bryan Donkin developed the process of packaging food in sealed airtight cans, made of tinned wrought iron. Initially, the canning process was slow and labour-intensive, as each large can had to be hand-made, and took up to six hours to cook, making tinned food too expensive for ordinary people.

The main market for the food at this stage was the Army and Navy. By 1817 Donkin recorded that he had sold £3000 worth of canned meat in six months. In 1824 Sir William Edward Parry took tinned beef and pea soup with him on his voyage to the Arctic in HMS Fury, during his search for a northwestern passage to India. In 1829 Admiral Sir James Ross also took canned food to the Arctic, as did Sir John Franklin in 1845.

Some of his stores were found by the search expedition led by Captain (later Admiral Sir) Leopold McLintock in 1857. One of these cans was opened in 1939, and was edible and nutritious, though it was not analysed for contamination by the lead solder used in its manufacture.

Throughout the mid-nineteenth century, tinned food became a status symbol amongst middle-class households in Europe, becoming something of a frivolous novelty. Early methods of manufacture employed poisonous lead solder for sealing the tins, which may have worsened the disastrous outcome of the 1845 Franklin expedition to chart and navigate the Northwest Passage.

Increasing mechanisation of the canning process, coupled with a huge increase in urban populations across Europe, resulted in a rising demand for tinned food. A number of inventions and improvements followed, and by the 1860s smaller machine-made steel cans were possible, and the time to cook food in sealed cans had been reduced from around six hours to thirty minutes. Canned food also began to spread beyond Europe—Robert Ayars established the first American canning factory in New York City in 1812, using improved tin-plated wrought-iron cans for preserving oysters, meats, fruits and vegetables. Demand for tinned food greatly increased during wars. Large-scale wars in the nineteenth century, such as the Crimean War, American Civil War, and Franco-Prussian War introduced increasing numbers of working-class men to tinned food, and allowed canning companies to expand their businesses to meet military demands for non-perishable food, allowing companies to manufacture in bulk and sell to wider civilian markets after wars ended.

Urban populations in Victorian era Britain demanded ever-increasing quantities of cheap, varied, quality food that they could keep at home without having to go shopping daily. In response, companies such as Nestlé, Heinz, and others emerged to provide quality tinned food for sale to working class city-dwellers.

In particular, Crosse and Blackwell took over the concern of Donkin Hall and Gamble. The late 19th century saw the range of tinned food available to urban populations greatly increase, as canners competed with each other using novel foodstuffs, highly decorated printed labels, and lower prices. Demand for tinned food skyrocketed during World War I, as military commanders sought vast quantities of cheap, high-calorie food to feed their millions of soldiers, which could be transported safely, survive trench conditions, and not spoil in transport.

Throughout the war, soldiers generally subsisted on low-quality tinned foodstuffs, such as the British "Bully Beef" (cheap corned beef), pork and beans and Maconochies Irish Stew, but by 1916 widespread boredom with cheap tinned food amongst soldiers resulted in militaries purchasing better-quality food to improve morale, and the complete meals in a tin began to appear.

In 1917 the French Army began issuing tinned French cuisine, such as coq au vin, whilst the Italian Army experimented with tinned ravioli and spaghetti bolognese. Shortages of tinned food in the British Army in 1917 led to the government issuing cigarettes and amphetamines to soldiers to suppress their appetites. After the war, companies that had supplied military tinned food improved the quality of their goods for civilian sale. Today, tin-coated steel is the material most commonly used. Laminate vacuum pouches are also used for canning, such as used in MREs.

HOW CANNING PRESERVES FOODS

The high percentage of water in most fresh foods makes them very perishable. They spoil or lose their quality for several reasons:

- Growth of undesirable microorganisms-bacteria, moulds, and yeasts.
- Activity of food enzymes.
- Reactions with oxygen.
- Moisture loss.

Microorganisms live and multiply quickly on the surfaces of fresh food and on the inside of bruised, insect-damaged, and diseased food. Oxygen and enzymes are present throughout fresh food tissues.

Proper canning practices include:

- Carefully selecting and washing fresh food.
- Peeling some fresh foods.
- Hot packing many foods.

- Adding acids (lemon juice or vinegar) to some foods.
- Using acceptable jars and self-sealing lids.
- Processing jars in a boiling-water or pressure canner for the correct period of time.

Collectively, these practices remove oxygen; destroy enzymes; prevent the growth of undesirable bacteria, yeasts, and moulds; and help form a high vacuum in jars. Good vacuums form tight seals which keep liquid in and air and microorganisms out.

ENSURING SAFE CANNED FOODS

Growth of the bacterium *Clostridium botulinum* in canned food may cause botulism—a deadly form of food poisoning. These bacteria exist either as spores or as vegetative cells. The spores, which are comparable to plant seeds, can survive harmlessly in soil and water for many years.

When ideal conditions exist for growth, the spores produce vegetative cells which multiply rapidly and may produce a deadly toxin within 3 to 4 days of growth in an environment consisting of:

- A moist, low-acid food.
- A temperature between 40° and 120°F.
- Less than 2 per cent oxygen.

Botulinum spores are on most fresh food surfaces. Because they grow only in the absence of air, they are harmless on fresh foods. Most bacteria, yeasts, and moulds are difficult to remove from food surfaces.

Washing fresh food reduces their numbers only slightly. Peeling root crops, underground stem crops, and tomatoes reduces their numbers greatly. Blanching also helps, but the vital controls are the method of canning and making sure the recommended research-based process times found in the USDA's Complete Guide to Home Canning are used.

The processing times in this book ensure destruction of the largest expected number of heat-resistant microorganisms in home-canned foods. Properly sterilized canned food will be free of spoilage if lids seal and jars are stored below 95°F. Storing jars at 50° to 70°F enhances retention of quality.

FOOD ACIDITY AND PROCESSING METHODS

Whether food should be processed in a pressure canner or boiling-water canner to control botulinum bacteria depends on the acidity of the food. Acidity may be natural, as in most fruits, or added, as in pickled food. Low-acid canned foods are not acidic enough to prevent the growth of these bacteria. Acid foods contain enough acid to block their growth, or destroy them more rapidly when heated.

The term "pH" is a measure of acidity; the lower its value, the more acid the food. The acidity level in foods can be increased by adding lemon juice, citric acid, or vinegar. Low-acid foods have pH values higher than 4.6. They include red meats, seafood, poultry, milk, and all fresh vegetables except for most tomatoes. Most mixtures of low-acid and acid foods also have pH values above 4.6 unless their recipes include enough lemon juice, citric acid, or vinegar to make them acid foods. Acid foods have a pH of 4.6 or lower. They include fruits, pickles, sauerkraut, jams, jellies, marmalades, and fruit butters. Although tomatoes usually are considered an acid food, some are now known to have pH values slightly above 4.6. Figs also have pH values slightly above 4.6.

Therefore, if they are to be canned as acid foods, these products must be acidified to a pH of 4.6 or lower with lemon juice or citric acid. Properly acidified tomatoes and figs are acid foods and can be safely processed in a boiling-water canner.

Botulinum spores are very hard to destroy at boiling-water temperatures; the higher the canner temperature, the more easily they are destroyed. Therefore, all low-acid foods should be sterilized at temperatures of 240° to 250°F, attainable with pressure canners operated at 10 to 15 PSIG.

PSIG means pounds per square inch of pressure as measured by gauge. The more familiar "PSI" designation is used in (the Complete Guide to Home Canning). At temperatures of 240° to 250°F, the time needed to destroy bacteria in low-acid canned food ranges from 20 to 100 minutes. The exact time depends on the kind of food being canned, the way it is packed into jars, and the size of jars. The time needed to safely process low-acid foods in a boiling-water canner ranges from 7 to 11 hours; the time needed to process acid foods in boiling water varies from 5 to 85 minutes.

PROCESS ADJUSTMENTS AT HIGH ALTITUDES

Using the process time for canning food at sea level may result in spoilage if you live at altitudes of 1,000 feet or more. Water boils at lower temperatures as altitude increases. Lower boiling temperatures are less effective for killing bacteria. Increasing the process time or canner pressure compensates for lower boiling temperatures. Therefore, when you use the Complete Guide to Home Canning, select the proper processing time or canner pressure for the altitude where you live.

NUTRITION VALUE

Canning is a way of processing food to extend its shelf life. The idea is to make food available and edible long after the processing time.

Although canned foods are often assumed to be of low-nutritional value (due to heating processes or the addition of preservatives), some canned foods are nutritionally superior-in some ways-to their natural form. For instance, canned tomatoes have a higher available lycopene content.

POTENTIAL HAZARDS

MIGRATION OF CAN COMPONENTS

In canning toxicology, *migration* is the movement of substances from the can itself into the contents. Potential toxic substances that can migrate are lead, causing lead poisoning, or bisphenol A, a potential endocrine disruptor that is commonly use to coat the inner surface of cans.

BOTULISM

Foodborne botulism results from contaminated foodstuffs in which *C. botulinum* spores have been allowed to germinate and produce botulism toxin, and this typically occurs in canned non-acidic food substances. *C. botulinum* prefers low oxygen environments, and can therefore grow in canned foods. Botulism is a rare but serious paralytic illness, leading to paralysis that typically starts with the muscles of the face and then spreads towards the limbs.

In severe forms, it leads to paralysis of the breathing muscles and causes respiratory failure. In view of this life-threatening complication, all suspected cases of botulism are treated as medical emergencies, and public health officials are usually involved to prevent further cases from the same source.

DOUBLE SEAMS

Modern double seams provide an airtight seal to the tin can. This airtight nature is crucial to keeping bacteria out of the can and keeping its contents sealed inside. Thus, double seamed cans are also known as Sanitary Cans.

Developed in 1900 in Europe, this sort of can was made of the traditional cylindrical body made with tin plate. The two ends (lids) were attached using what is now called a double seam.

A can thus sealed is impervious to the contamination by creating two tight continuous folds between the can's cylindrical body and the lids. This eliminated the need for solder and allowed improvements in manufacturing speed, reducing cost.

Double seaming uses rollers to shape the can, lid and the final double seam. To make a sanitary can and lid suitable for double seaming, manufacture begins with a sheet of coated tin plate.

To create the can body, rectangles are cut and curled around a die, and welded together creating a cylinder with a side seam. Rollers are then used to flare out one or both ends of the cylinder to create a quarter circle flange around the circumference.

Precision is required to ensure that the welded sides are perfectly aligned, as any misalignment will cause inconsistent flange shape, compromising its integrity. A circle is then cut from the sheet using a die cutter. The circle is shaped in a stamping press to create a downward countersink to fit snugly in to the can body. The result can be compared to an upside down and very flat top hat. The outer edge is then curled down and around about 140 ° using rollers to create the end curl. The result is a steel tube with a flanged edge, and a countersunk steel disc with a curled edge. A rubber compound is put inside the curl.

Fig. 1: Opened Can

SEAMING

The body and end are brought together in a seamer and held in place by the base plate and chuck, respectively. The base plate provides a sure footing for the can body during the seaming operation and the chuck fits snugly in to the end (lid). The result is the countersink of the end sits inside the top of the can body just below the flange. The end curl protrudes slightly beyond the flange.

FIRST OPERATION

Once brought together in the seamer, the seaming head presses a first operation roller against the end curl. The end curl is pressed against the flange curling it in toward the body and under the flange. The flange is also bent downward, and the end and body are now loosely joined together. The first operation roller is then retracted. At this point five thicknesses of steel exist in the seam. From the outside in they are:

- End
- Flange
- End Curl
- Body
- Countersink.

This is the first seam. All the parts of the seam are now aligned and ready for the final stage.

SECOND OPERATION

The seaming head then engages the second operation roller against the partly formed seam. The second operation presses all five steel components together tightly to form the final seal. The five layers in the final seam are then called:

- End.
- Body Hook.
- Cover Hook.
- Body.
- Countersink.

All sanitary cans require a filling medium within the seam because otherwise the metal-to-metal contact will not maintain a hermetic seal. In most cases, a rubberized compound is placed inside the end curl radius, forming the critical seal between the end and the body.

Probably the most important innovation since the introduction of double seams is the welded side seam. Prior to the welded side seam, the can body was folded and/or soldered together, leaving a relatively thick side seam.

The thick side seam required that the side seam end juncture at the end curl to have more metal to curl around before closing in behind the Body Hook or flange, with a greater opportunity for error.

SEAMER SETUP AND QUALITY ASSURANCE

Many different parts during the seaming process are critical in ensuring that a can is airtight and vacuum sealed. The dangers of a can that is not hermetically sealed are contamination by foreign objects (bacteria or fungicide sprays), or that the can could leak or spoil.

One important part is the seamer setup. This process is usually performed by an experienced technician. Amongst the parts that need setup are seamer rolls and chucks which have to be set in their exact position (using a feeler gauge or a clearance gauge). The lifter pressure and position, roll and chuck designs, tooling wear, and bearing wear all contribute to a good double seam. Incorrect setups can be non-intuitive. For example, due to the springback effect, a seam can appear loose, when in reality it was closed too tight and has opened up like a spring. For this reason, experienced operators and good seamer setup are critical to ensure that double seams are properly closed.

Quality control usually involves taking full cans from the line—one per seamer head, at least once or twice per shift, and performing a teardown operation (wrinkle/tightness), mechanical tests (external thickness, seamer length/height and countersink) as well as cutting the seam open with a twin blade saw and measuring with a double seam inspection system. The combination of these measurements will determine the seam's quality.

Use of a Statistical Process Control or [SPC] software in conjunction with a manual double seam monitor, computerized double seam scanner, or even a fully-automatic double seam inspection system makes the laborious process of double seam inspection faster and much more accurate.

Statistically tracking the performance of each head or seaming station of the [can seamer] allows for better prediction of can seamer issues, and may be used to plan maintenance when convenient: rather that to simply react after bad or unsafe cans have been produced.

CANNING FOODS

Canning is a very popular method of preserving food, especially garden produce. It was originally developed in France by a chemist named Nicolas Appert in response to a drive by Napoleon to find a way to get more healthy foods for his army while on the march. He figured out that if he heated foods in jars and then sealed them that the foods would stay relatively fresh until they were opened months and even years later.

Since then advances have been made in canning. Louis Pasteur figured out that it was microorganisms that were spoiling the food. The heat used in the canning process kills the microorganisms. Botulism can still be a problem in food that is improperly canned so before you begin canning, it is wise to use safety precautions.

CANNING SAFETY PRECAUTIONS

Improperly canned food can result in the growth of botulism or other microorganisms. Eating such foods can cause serious illness and even death. For this reason it is important to strictly adhere to canning procedures as well as standards of cleanliness.

Clostridium botulinum spores are everywhere and eating them is not harmful to humans. It is when they grow in astronomical numbers in an ideal environment, such as an improperly canned jar of food, then begin to die off that they become a problem. They actually produce a neuro-toxin. It is this neuro-toxin that causes the effects of botulism.

Yet botulism and moulds, viruses and bacteria that might grow in canned food can be effectively and easily controlled merely by taking simple precautions. Properly heating the jars and the food within them as well as proper sealing is the solution.

Since *Clostridium botulinum* prefers a low acid environment, high acid foods can be canned under less restrictive conditions using a boiling water canner. These foods have a pH of 4.5 or less. They include: apples, apricots, berries, jams, jellies, peaches, pears, pickles, sauerkraut, tomatoes, and more. High pH (meaning low in acid) fruits and vegetables require a special device for canning called the pressure canner. The pressure canner can also be used for canning the high acid foods. Low acid foods include: Asparagus, beans, beets, carrots, corn, mushrooms, peas, potatoes, pumpkin, spinach, squash, most any meat.

It is not generally difficult to detect when a canning job has gone bad (done properly—this will seldom happen). The first sign that a can of food is no good is that the lid will pop up (or bulge), also there might be seeping around the seal. Mould growing on the surface of the food is a sure sign of a problem. Also abnormal colours in the brine of food, cloudiness in the brine, a white coloured film on the surface of the food can all be indications of contaminated food. Do not eat contaminated food. It invariably will cause harm. Reheating the food, even boiling it for long periods is not a solution as botulism is not the living part of the *Clostridium botulinum*, but a byproduct of its life-cycle. Some traditional methods are *not* recommended such as open kettle canning, paraffin wax sealing, oven or microwave canning.

A final helpful hint regarding safety—it is best to store canned foods at relatively low temperatures as this helps to prevent any activity by microorganisms that might have survived the heating process. Keeping cans in dark, cool places also helps to preserve vitamins and taste.

CANNING STEPS

- *Have All Your Equipment Ready to Use*: Wash jars and lids with hot, soapy water. Thoroughly rinse and air dry. Check glass jar rims for even minute chips or cracks as these will not seal. Rinse new caps with hot water before using them.
- *Prepare the Food*: Always start with fruit at the peak of freshness. Fruit and vegetables should be washed, peeled and prepared according to your recipes for preserves, pickles, salsa, spaghetti sauce, etc. For fruit, we recommend using a product such as "Fruit Fresh" to prevent discoloration. Follow the package

directions for the desired amounts of sugar and water for a light, medium or heavy syrup. Prepare jams and jellies according to the directions for the brand of pectin you're using or follow a trusted recipe.

- Pack prepared food into hot jars, leaving a head space... usually 1/2" to 1" below the top of the jar rim or the amount stated in the recipe you followed.
- Carefully run a wooden or other non-metallic spatula or knife down through the ingredients to release any trapped air bubbles.
- Wipe the jar rims with a clean, damp cloth to remove all traces of food on the rims.
- Place a cap on each jar, making sure it's centered and seated with the rubber edge directly over the rim.
- Screw the lid band onto the jar, but do not over tighten.
- Fill the canner with hot water—the amount depends on the size of the jars you are using. Most canners have pre-marked guides to give you a general idea.
- Place the jars on the rack in the canner or stock pot, adding more water if necessary to cover the jars by 1 to 2 inches.
- Cover with lid and bring the water to a full rolling boil. Continue to boil for the time stated in your recipe. A rough guide is about 5 to 10 minutes for pickles, 10 minutes for jam, about 20 to 30 minutes for fruit, fruit pie fillings, and applesauce, and 30 to 45 minutes or more for tomatoes. (Begin timing after the water begins to boil.)

- Turn off heat, carefully lift the lid away from you to prevent burning by steam. Using a jar tongs, remove jars from water. Place jars on a dish towel or absorbent mat. Allow to cool several hours or overnight.
- *Check Seals*: Lids should be lowered in the middle and not move up or down when you lightly press or tap them. Remove bands wash them and dry them thoroughly. Some sources suggest taking them off for storage. This is important if they will be in a damp area such as a basement where the rims could become rusty. For storage in a dry pantry, prefer to store them with the bands in place. If you do store them without the bands, leave a few bands in a convenient spot, to use on jars to hold caps in place after they have been opened for use.
- Label and date the jars, then store them in a dark, cool, dry area where there's no danger of freezing.

UNSUCCESSFUL CANNING

If any jars did not seal, the centre of the cap will be raised, not lowered. Refrigerate the unsealed jar and use the contents within a few days. Unsealed jars may also be reprocessed. Remove their bands and caps; wipe the rims. Carefully check the rim for any small chips. If the jar rim is okay, add new caps and clean bands. If damaged, replace the jar too, then reprocess in a boiling water bath. Most foods can also be frozen instead being reprocessed.

Before using, always examine jars for signs of spoilage - a bulging lid or leaking. To open—remove the band if it was left in place. Use a lift type can opener and gently pry the cap to break the vacuum seal. If the food spurts out when opened; if liquids are cloudy or frothy; if food is slimy or mouldy, or if it smells bad, do not use. Never taste the contents of a jar of food with a broken seal or food with even the slightest sign of spoilage. As with any spoiled food, discard it where it is completely out of reach of animals.

HOME CANNING FOOD PRESERVATION

THE BENEFITS OF HOME CANNING

Canning food in your own home is a safe and rewarding process that is becoming popular again as food prices soar and people realise they need to pay attention to securing their food supplies. Preserving food with home canning is an excellent way to increase your consumption of local food. Eating locally requires eating foods when they are in season, and canning allows you to capture the bounty of any particular crop in season and extend its availability throughout the year.

You can approach home canning as a hobbyist or a full-time enthusiast who stocks a sizeable percentage of his or her food supply with home preserved food. Whether you want to enjoy a couple fun weekend projects putting up jam or seriously supplement your diet, you will enjoy many personal benefits while being a good steward to the environment and supporting your local economy. And the way things are going with the global food market, you will likely save money as well, especially as time goes on.

HOW PRESERVING FOOD AT HOME HELPS US

- *Excellent Quality and Taste*: When you use quality produce and perform the canning process correctly, you will create superior products to those for sale at the supermarket. Many recipes for home canned food are delicious and literally the quality is something that money can't buy. You have to make these luscious foods yourself.

- *Control over the Ingredients*: With home canning, you will know exactly where your food is coming from. Ideal sources of produce are your own garden and fruit trees, local organic farms, and any local farm. From any of these sources you will be able to hand select your produce at the peak of ripeness. With home canning you will also reduce your exposure to Bisphenol A that lines the cans of many mass produced food products. Bisphenol A is an endocrine disruptor and people are becoming increasingly aware of its potential harm to humans.
- *Support of the Local Economy*: By directly buying produce from local growers, you are putting money into the hands of local people. Local growers love selling from their own farms or market stands because they are not at the mercy of the big commodity buyers who set prices. This also allows local growers, especially small ones, to remain profitable, which is good for the local economy.
- *Lower Your Carbon Dioxide Footprint*: Great amounts of energy are used to produce and transport the food eaten by society. Highly industrialized agriculture also relies on pesticides, herbicides, and petrochemical fertilizers. All of these things are bad for the environment and degrade the ability of soils to produce food in the future, which means greater

scarcity, lower quality, and higher commodity prices. When you buy local food and can it at home, you are eliminating a huge percentage of the transport costs from burned fuel associated with shipping food across continents. Yes, home canning requires an energy input, but it does not compare to food being trucked halfway across the country to stock a shelf in a store. Reducing the amount of food you eat from distant places reduces the amount of fuel you are causing to be burned. Also when buying local food, try to focus on those growers who use sustainable growing practices that do not poison the environment.

- *Sense of Accomplishment*: Once you begin canning food, you will be thrilled with yourself. You will feel like you did something very meaningful to your existence because you did! For most of human history most people focused a great deal of time and energy on securing their food supplies. We are not suggesting we all go back to digging for roots in the field, but people in general have a deep need to participate in the gathering and preparation of food. Sitting in an SUV for drive-through fast food does not satisfy. It only promotes outrageous energy consumption for low quality products.

Now that you are ready to do some work in the kitchen and participate in food preservation, you need to understand the basics of home canning. The process is a little intimidating at first, but after a couple canning projects, you will feel much more comfortable doing it.

There are safety considerations with home canning, but these are all satisfied by following the directions associated with any particular home canning project. The manufacturers of Mason jars (which are the essential product needed for safe home canning) offer great information on how to can food at home, and many university agriculture departments and the USDA offer very reliable information on this subject as well.

FOOD PRESERVATION WITH HOME CANNING HALTS SPOILAGE

Food preservation in canning jars is accomplished by killing spoilage causing agents with heat, removing air from the food products, and sealing the jars so that air and yeasts, moulds, and bacteria cannot be reintroduced to the food.

FOUR CAUSES OF FOOD SPOILAGE

- Enzymes – Destroyed at 140°F.
- Moulds – Destroyed at 140°F to 190°F.
- Yeasts – Destroyed at 140°F to 190°F.
- Bacteria – Many types of bacteria exist. The toxins produced by some bacteria are also a hazard. Bacteria and associated toxins are destroyed in heat ranges from 190°F to 240°F.

Some bacteria are very tough and resist death even at high temperatures. The toughest bacterium is *Clostridium botulinum*, whose spores cause the deadly botulism. This bacterium is killed at 190°F and its toxic spores are destroyed at 240°F.

This bacterium thrives in low-acid or nonacid foods in the absence of air. Foods in this category include corn, beans, peppers, poultry, fish, and meat. This is the main reason that these types of foods require the higher temperatures achieved during pressure canning.

Boiling canned low-acid or nonacid foods for 10 to 20 minutes before eating them will destroy potential lingering toxins. This added step will give you one more reason to feel safe about eating home canned low-acid or nonacid foods.

WATER BATH CANNER

- *Equipment*: A large metal enamel kettle with lid and jar rack with the capacity to hold up to 7, quart-sized Mason jars. Widely available at discount stores and hardware stores. Cost: $20 to $25.
- *Uses*: The water bath canner is used to process Mason jars for home preservation of jams, fruits, fruit juices, and pickled vegetables.
- *Safety Considerations*: It is a large kettle of boiling water so be careful to avoid steam burns and splashing hot water.

Tested recipes are widely available from the USDA, numerous University agriculture departments, Mason jar manufacturers, fruit pectin manufacturers, and from friends and family who have recipes that are known to be safe. As you familiarize yourself with the principles of safe home canning, you will be able to judge all recipes for safety and even develop your own.

HOW TO USE WATER BATH CAN

Please always review the manufacturer's directions for the Mason jars that you are using and pay close attention to the head space and processing times specified by recipes.

- Pick a recipe for the produce that you wish to can. Select only quality produce at or near the peak of ripeness. Prepare the recipe.
- While preparing the food, you will also need to get the Mason jars ready. Wash the jars, bands, and lids in hot soapy water. Only use new lids. Never re-use lids. Jars and bands can be re-used.
- Fill the water bath canner and start to heat it in order to sterilize your jars and lids. Use a large thermometer (a candy thermometer works well) to monitor the temperature. When the water is at least 180°F but less than boiling (212°F) add the jars and lids to the water. Sterilizing bands in unnecessary. Kerr and Ball lids specify that they should not be boiled, so make sure that the water stays just below the boiling point.
- Remove the jars and lids from hot water when the food is ready to be packed in jars.
- Add prepared food to jars. Use the handle of a wooden spoon along the insides of the jars to work out any air bubbles. Leave the specified head space, usually ¼ inch or ½ inch.
- Wipe the edges of jar mouths very carefully. They need to be completely clean. Any food particles or other debris on the mouth edge will interfere with the sealing of the lids.
- Place lids on jars and screw on the bands. Only screw them on hand tight. You don't need to twist hard.
- With a jar lifter, place the Mason jars into the hot water. Make sure that jars are not touching each other or the side of the kettle.

- Bring the water to a boil. Once the water is boiling, you can begin the timer for the processing time specified by the recipe. Adjust the heat source as necessary to keep the water boiling but to prevent it from boiling over.
- Once processing time is complete, shut off heat source, and use a jar lifter to remove jars from the canner. Set the jars on a cloth in a location free of drafts. Do not disturb the jars for 12 to 24 hours. You will likely hear the lids “pop” or “snap” down not long after removal, but the jars need to cool completely to make sure the seal is complete. (Processing times change with your land elevation. Consult charts that come with recipes and/or equipment.)

PRESSURE CANNER FOR HOME CANNING

- *Equipment*: A pressure canner that has a sealed lid and a gauge that measures the pressure created by boiling water and steam. Under pressure, the steam will achieve temperatures of 240 to 250°F. Such high temperatures are necessary to destroy the bacterium *Clostridium botulinum*. Canners for home use typically cost between $80 and $130. Major brand is Presto.
- *Uses*: To process canning jars of fruit, vegetables, meat, fish, and poultry for purposes of preservation. Pressure canning is the only safe method for preserving low-acid vegetables and meats. Note, the pressure canner can also be used like a pressure cooker to prepare meals.

- *Safety Considerations*: Proper use of a pressure canner requires diligent monitoring of the pressure gauge during operation and maintenance of the plugs, gaskets, and metal parts. An actual explosion of the equipment would only occur if the heat was left on and the pressure climbed into the danger zone.

Even so, the plug in the safety valve should blow out before a catastrophic failure of the pressure canner happened. Note that the danger zone for the equipment is several pounds of pressure beyond the pressures necessary for processing foods. To avoid problems, keep the pressure within the safe zone by watching the gauge and adjusting the heat source. In case of emergency, rapid cooling of the canner can be initiated by running it under cold water.

HOW TO USE PRESSURE CAN

Please follow the manufacturer's directions that accompany your specific pressure canner model. In general:

- The pressure canner will be filled with approximately 3 quarts of water (this amount would vary depending on size of canner).
- The water is brought to a boil and the prepared Mason jars are placed in the canner.
- The lid is placed on the canner, sealed, and locked, but the pressure regulator is *not* put in place yet.
- Once a free flow of steam is initiated through the vent, it will be allowed to vent for 10 minutes. (Time may vary depending on size of canner.) Venting steam exhausts air from the pressure chamber.

- After 10 minutes, the pressure regulator is put over the vent and pressure begins to build inside. When the interior becomes pressurized, the air vent/cover lock will rise and completely seal the chamber. Then pounds of pressure will start to accumulate and register on the gauge.
- Bring the canner to the pressure specified by the canning recipe and then maintain that pressure by adjusting heat source as necessary. You will find that once pressure has been achieved, the stove burner no longer needs to be on a high setting. Monitor the pressure closely to make sure it does not rise too far beyond desired pressure. Also, do not let the pressure fall below the pressure required by the recipe. It is important for the food within to be kept at the necessary pressure/temperature for the required amount of time.
- Once the food has processed at the required amount of time at the necessary pressure, turn off the heat source. Do not rapid cool the canner because this would cause jars within to break. (Processing times change with your land elevation. Consult charts that come with recipes and/or equipment.)
- Allow canner to cool until air vent/cover lock drops on its own. Then remove pressure regulator and allow canner to set for 10 more minutes.
- At this point you may unlock the lid and open it. Be careful of the steam that comes out because it will be scalding hot.
- With a jar lifter, remove Mason jars and set them on a cloth in a location free of drafts.

- Do not disturb jars for 12 to 24 hours after removal. They will be exceedingly hot. The contents will continue to boil after removal from the canner. As the jars cool, the lids will seal.

GENERAL TIPS FOR HOME CANNING

You will have to attend to many details while preserving food at home, but it gets easier as you become familiar with the process. The following tips will help you successfully complete your home canning project with great results: sealing impossible.

- Always use new lids. Packages of just lids are widely available for this purpose. Jars and bands may be re-used.
- Always wipe completely clean the jar mouth edges before applying the lid. Particles of food on the jar mouth could interfere with sealing.
- Follow canning guidelines. Don't compromise, substitute, or declare something good enough. Follow the directions and your food will be safe and good.
- When pickling foods, make sure to use vinegar with 5% acidity. Some vinegars only have 4% acidity, but don't use them.
- Allow jars to cool undisturbed for 12 to 24 hours after removing them from the water bath or pressure canner.
- Remove the jar bands and wipe clean the jars and lids before storing. Little bits of food often leak out during processing and you would not want to store the jars with food bits stuck to them. You can put clean jar bands back on for storage if you want to.

- Home canned products have a shelf life of up to 12 months. Label and date your jars as you produce the food. Do not eat food more than 12 months old.
- Select high quality produce at or near the peak of ripeness. You can cut out small blemishes if necessary, but don't use overly damaged foods.

7

Water Activity for Food Safety

The single most important property of water in food systems is the water activity (a_w) of food. Throughout history the importance of controlling water in food by drying, freezing or addition of sugar or salt was recognized for preserving and controlling food quality. Water activity is the ratio of the vapour pressure of water in equilibrium with a food to the saturation vapour pressure of water at the same temperature. The water activity of a food describes the degree to which the water is "bound" in the food and hence its availability to act as a solvent and participate in chemical/biochemical reactions and growth of microorganisms.

It is an important property that can be used to predict the stability and safety of food with respect to microbial growth, rates of deteriorative reactions and chemical/physical properties. The water activity principle has been incorporated by various regulatory agencies in definitions of safety regulations regarding the growth and proliferation of undesirable microorganisms, standards of several preserved foods, and packaging requirements. New instrumentation has improved the speed, accuracy and reliability of water activity measurements and is definitely a needed tool for food safety. The AquaLab, a chilled mirror dew point instrument, measures water activity values between 0.030 and 1.000 a_w in less than five minutes. It attains a resolution and precision of ±0.001 a_w with an accuracy of ±0.003 aw. There are two basic types of water analysis. The first, water content, is a quantitative or volumetric analysis to determine the total amount of water present in a food. The second type measures the water activity, aw. It indicates how tightly water is bound, structurally or chemically, in food products. Water activity is the relative humidity of air in equilibrium with a sample in a sealed measurement chamber. It is therefore the ratio of the water vapour pressure (p) over a food to that over pure water (po) at a given temperature. Multiplication of the a_w by 100 gives the per cent equilibrium relative humidity (ERH) of the atmosphere in equilibrium with the food.

$$a_w = \frac{p}{po} = \frac{\%ERH}{100}$$

The single most important property of water in a food is the water activity. The water activity of a food describes the energy status of water in a food and hence its availability to act as a solvent and participate in chemical or biochemical reactions. Fig. 3 is a global stability map of foods, showing stability as a function of a_w. Water's ability to act as a solvent, medium and reactant increases with increasing water activity. The concept of water activity (a_w) is an important property for food safety.

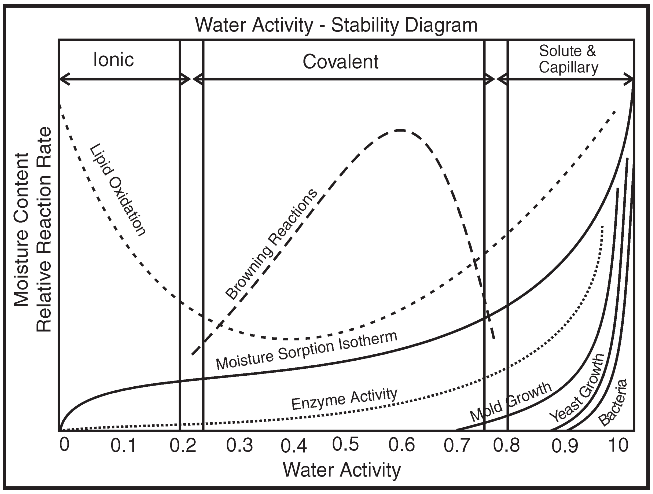

Fig. 3: Water Activity—Stability Map

It predicts food safety and stability with respect to microbial growth, chemical/biochemical reaction rates, and physical properties. By measuring the water activity of foodstuffs, it is possible to predict which microorganisms will be potential sources of spoilage and infection. Controlling water activity is an important way to maintain the chemical stability of foods. Non-enzymatic browning reactions and spontaneous autocatalytic lipid oxidation reactions are strongly influenced by water activity. Water activity can play a significant role in determining the activity of enzymes and vitamins in food. Finally, a_w plays a significant role in the physical properties such as texture and shelf-life of foods.

MICROBIAL SAFETY

One purpose of food safety is to prevent growth and toxin production from harmful microorganisms. According to the trends in the United States survey, American consumers' confidence in the safety of the food supply has increased. In fact, 77% of shoppers are now completely or mostly satisfied that supermarket foods are safe.

The top concerns regarding the food supply are spoilage and bacterial contamination. Incidentally, 77% of all traceable foodborne illness outbreaks result from improper handling in foodservice establishments, 20% from improper handling in the home, and only 3% from manufacturing errors. Scott showed that micro-organisms have a limiting water activity level below which they will not grow. Water activity, not water content, determines the lower limit of available water for microbial growth.

The lowest a_w at which the vast majority of food spoilage bacteria will grow is about 0.90. *Staphylococcus aureus* under anaerobic conditions is inhibited at an a_w of 0.91, but aerobically the a_w level is 0.86. The a_w for moulds and yeasts growth is about 0.61 with the lower limit for growth of mycotoxigenic moulds at 0.78 a_w. In addition to the relationship between microbial growth and water activity, a number of other aspects of food microbiology are influenced by water activity.

The effect of a_w on sporulation, germination, and mycotoxin production of microorganisms is complex. Generally for yeast, a higher a_w is required for sporulation than spore germination. The minimum a_w for toxin production are generally higher than the minimum a_w growth level.

CHEMICAL/BIOCHEMICAL REACTIVITY

Water activity influences not only microbial spoilage but also chemical and enzymatic reactivity. Water may influence chemical reactivity in different ways. It may act as a solvent, reactant or change the mobility of the reactants by affecting the viscosity of the food system. Water activity influences non-enzymatic browning, lipid oxidation, degradation of vitamins, enzymatic reactions, protein denaturation, starch gelatiniza-tion, and starch retrogradation. The likelihood of non-enzymatic browning increases with increasing a_w , reaching a maximum at a_w in the range of 0.6 to 0.7.

Generally, further increases in water activity will hinder browning reactions. Lipid oxidation has a minimum in the intermediate a_w range and increases at both high and low a_w values, although due to different mechanisms. This type of food spoilage results in the formation of highly objectionable flavours and odours. Water soluble vitamin degradation in food systems increases with increasing a_w values. Enzyme and protein stability is influenced significantly by water activity due to their relatively fragile nature.

Most enzymes and proteins must maintain conformation to remain active. Maintaining critical a_w levels to prevent or entice conformational changes is important to food quality. Most enzymatic reactions are slowed down at water activities below 0.8, but some reactions occur even at very low a_w values. Water activity influences the gelatinization temperature and retrogradation rate of starch.

WATER ACTIVITY AND pH

Water activity and pH can be directly controlled in foods. Inhibitors to growth can be created by adding chemicals—additives or substances such as salt. In addition, one can adjust the atmosphere using special packaging techniques. Very often food processors use a combination of controls, rather than relying on only one. This is because a one-control system carried to the extreme, can be harsh, making food unacceptable to consumers. The use of multiple controls is called the hurdle concept.

PH CONTROL

Every micro-organism has a minimum, optimum, and maximum pH for growth. Yeasts and moulds can grow at low pH, but 4.6 is generally considered the level that will prevent the growth and toxin production for pathogens. Some pathogens, in particular *E. coli*, can survive acidic conditions for extended periods of time, even if their growth is inhibited. pH is considered primarily a means of growth inhibition and not a method for destruction of existing pathogens. However, at low pH values many micro-organisms will be destroyed if held at that pH for significant time.

A pH 4.6 is used as a divider between high-acid and low-acid foods. Some foods that are naturally low-acid are processed in a way that makes them a high-acid food. This is called acidification. Naturally high-acid foods include peaches (pH 4.0), orange juice (pH 3.5), and apples (pH 3.5). In general, most fruits are high-acid. However, some tropical fruits including pineapple, might fall in the pH range above 4.6 depending upon growing conditions. Examples of low-acid foods (pH above 4.6) are: fresh fish (pH 6.3), canned green beans (pH 5.0), bread (pH 5.5), and fresh ham (pH 6.2). Low-acid foods include protein foods, most vegetables, starch-based foods, and a variety of others.

Examples of foods that are processed to make them high-acid include pickled fish and pickled peppers that use vinegar (acetic acid) to lower the pH (a process called acidification); and olives and sauerkraut that use a fermentation process to produce lactic acid that reduces pH. Acidification is the direct addition of acid to a low-acid food. The target is usually a pH of 4.6 or lower. These foods are called acidified foods and are covered under 21 CFR Part 114. There are instances where the target pH is higher than 4.6 and the food requires multiple barriers, such as refrigeration. These foods are not covered by the acidified food regulation.

Fermentation is a process where certain non-pathogenic microorganisms are used to promote chemical changes in the food. The action of these microorganisms result in the production of acid or alcohol. Bacteria typically produce acetic or lactic acid. Yeast typically produce alcohol. The production of acid or alcohol through fermentation serves two purposes. One is to impart certain qualities to the food to produce a desired taste or even texture. An example of this is yogurt. Its unique flavour and texture is due to the fermentation process. The other purpose is to preserve the food, such as with pickled products. These foods are not regulated by the acidified food regulations. However, the food must be fermented to a pH of 4.6 or below to be considered safe at non-refrigerated storage temperatures.

ACIDIFICATION

Acidification is the direct addition of acid to a low-acid food. There are a variety of organic acids that are used—acetic, lactic, and citric. Which one is selected, is dependent on the desired attributes of the finished product. Other examples of acidified foods are: pickled pig's feet, pickled onions, pickled asparagus, and fresh pack cucumber pickles that are acidified rather than fermented to get the desired pH. Rather than using acids to acidify foods, naturally acid foods, such as tomatoes, can be added to acidify low-acid ingredients. An example is the use of tomatoes in spaghetti sauce containing whole vegetables like celery, onions, or peppers. Canned tomatoes generally have a pH of about 4.2, while the other vegetables are low-acid. The finished food would be below pH 4.6.

A food is considered to be acidified, and covered by the FDA regulations, if the pH of the finished food differs from the pH of the acid raw material. For example, the raw material tomatoes has a pH 4.2. If the finished product pH is 4.5 then the food would be acidified, because acid from the tomatoes was used to acidify the vegetables.

On the other hand, if the finished product pH was still 4.2, then no significant amount of acid from the tomatoes was used to acidify the vegetables. In this case the product might not be covered under the acidified food regulations and might not be considered an acid food by formulation. Some of these foods are mustard, catsup, salad dressing, and other condiments—all of which are shelf stable. Processors of acidified foods are required to register and file a scheduled process with FDA. The process needs to be scientifically established to ensure that the final pH is always below 4.6. Processors need to test each lot of finished product for equilibrium pH. That means a natural pH balance has been reached by all ingredients—which can take as long as 10 days in foods with very large particulates.

Foods that require several days to reach equilibrium pH might need to be refrigerated during that time to prevent the growth of *C. botulinum* or other pathogens. In order to speed up the testing process, the product can be blended to a uniform paste. When a food that contains oil is blended, the oil should be removed before blending. Another way to do this is to measure the pH before the oil is added to the product because the oil does not affect the final pH.

MEASURING PH

If a processor is using acidification, they must measure pH. A pH meter is what most food processors use. Food processors can also use indicator solutions, indicator paper, or titration as long as the finished pH is below 4.0. If a pH meter is used, it must be calibrated properly.

The pH meter can be a two electrode or a single combination electrode, where both functions are combined into one electrode system. One is the reference electrode and one is the measuring electrode. When not in use, the electrodes are stored submerged in distilled water or other solutions as recommended by the manufacturer.

The instrument must be checked each day of use with two different buffer solutions—one on either side of the expected equilibrium pH. After calibration, the electrodes should be rinsed off with distilled water and then they can be used for testing. The operation and calibration of the pH meter must follow the meter manufacturer's instructions.

DIRECT ACIDIFICATION AND BATH ACIDIFICATION

There are several different methods of adding the acid to the product. One is direct acidification, where predetermined amounts of acid are added to individual finished product containers during production (adding vinegar to home canned tomatoes is an example of this). With this method, one must control the acid to food ratio. This is probably the most common method used for acidified vegetables. Another method of acidification is batch acidification. Acid and food are combined in large batches and allowed to equilibrate. The acidified food is then packaged.

The necessary frequency of monitoring the finished product for pH would be less for batch acidification than for direct acidification. This is because there is variability from jar to jar with direct acidification that one does not have with batch acidification.

Acidified foods and acid foods by formulation must be heat treated sufficiently to inactive spoilage microorganisms and vegetative pathogens. There are two reasons for this:

- To prevent spoilage triggering economic loss.
- The action of the spoilage microorganisms can raise the pH, compromising the safety of the product.

FERMENTATION

In wine and beer production, yeast is used to ferment the product to alcohol. The alcohol preserves the product. In the production of sauerkraut, fermented sausages, cheese, sweet pickles, olives, and buttermilk, lactic acid is produced by bacteria during fermentation. Moulds are used to ferment some foods, such as soy sauce, tamari sauce, and other oriental foods, mainly for taste and to achieve other desirable characteristics.

In practice, fermentation is an art. One needs to encourage growth of the right microorganisms and discourage the growth of the wrong microorganisms that cause spoilage.

This is usually accomplished by adding salt or a starter culture to the food, or in some cases slightly acidifying it. A starter culture can be either yeast or bacteria. In many fermented foods, there is no process to eliminate acid-producing bacteria. That is common for many but not all fermented foods. It is the reason why most fermented foods must be refrigerated—so culture bacteria do not spoil the product.

WATER ACTIVITY CONTROL

Like pH, every micro-organism has a minimum, optimum, and maximum water activity for growth. Yeasts and moulds can grow at a low water activity, however 0.85 is considered the safe cutoff level for pathogen growth. A water activity of 0.85 is based on the minimum water activity needed for *S. aureus* toxin production.

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Dehydration Preserves Foods

Foods can be spoiled by food microorganisms or through enzymatic reactions within the food. Bacteria, yeast, and molds must have a sufficient amount of moisture around them to grow and cause spoilage. Reducing the moisture content of food prevents the growth of these spoilage-causing microorganisms and slows down enzymatic reactions that take place within food. The combination of these events helps to prevent spoilage in dried food.

THE BASICS OF FOOD DEHYDRATION

Three things are needed to successfully dry food at home:

- Heat — hot enough to force out moisture (140°F), but not hot enough to cook the food;
- Dry air — to absorb the released moisture;
- Air movement — to carry the moisture away.

Foods can be dried using three methods:

- In the sun— requires warm days of 85°F or higher, low humidity, and insect control; recommended for dehydrating fruits only;
- In the oven;
- Using a food dehydrator — electric dehydrators take less time to dry foods and are more cost efficient than an oven.

PREPARING FRUITS AND VEGETABLES FOR DRYING

Many fruits and vegetables can be dried. Use ripe foods only. Rinse fruits and vegetables under cold running water and cut away bruised and fibrous portions. Remove seeds, stems, and/or pits.

STEPS FOR STEAM BLANCHING (FRUIT AND VEGETABLES)

- Use a steamer or a deep pot with a tight-fitting lid that contains a wire basket or could fit a colander or sieve so steam can circulate around the vegetables.
- Add several inches of water to the steamer or pot and bring to a rolling boil.
- Loosely place fruits/vegetables into the basket, no more than 2 inches deep.
- Place basket into pot (fruits/vegetables should not make contact with water).
- Cover and steam until fruits/vegetables are heated for the recommended time.

- Remove basket or colander and place in cold water to stop cooking.
- Drain and place fruits/vegetables on drying tray.

STEPS FOR WATER BLANCHING (VEGETABLES ONLY)

- Use a blancher or a deep pot with a tight-fitting lid.
- Fill the pot two-thirds full with water, cover, and bring to a rolling boil.
- Place vegetables into a wire basket and submerge them into the boiling water for the recommended time.
- Remove vegetables and place in cold water to stop cooking.
- Drain and place vegetables on drying tray.

STEPS FOR SYRUP BLANCHING (FRUITS ONLY)

- Combine 1 cup sugar, 1 cup light corn syrup, and 2 cups water in a pot.
- Add 1 pound of fruit.
- Simmer 10 minutes.
- Remove from heat and keep fruit in syrup for 30 minutes.
- Remove fruit from syrup, rinse, drain, and continue with dehydration step.

Dipping is a pretreatment used to prevent fruits such as apples, bananas, peaches, and pears from turning brown. Ascorbic acid, fruit juices high in vitamin C (lemon, orange, pineapple, grape, etc.), or commercial products containing ascorbic or citric acid may be used for dipping. For example, dipping sliced fruit pieces in a mixture of ascorbic acid crystals and water (1 teaspoon ascorbic acid crystals per 1 cup of water), or dipping directly in fruit juice for 3 to 5 minutes will prevent browning. Fruits may also be blanched as a means of treatment.

DRYING FRUITS AND VEGETABLES

NATURAL SUN DRYING

Sun drying is recommended for drying fruit only. Sun drying is not recommended in cloudy or humid weather. The temperature should reach 85°F by noon, and the humidity should be less than 60 percent.

Outdoor dehydration can be difficult in Virginia and other southern states due to high humidity. All food that is dried outdoors must be pasteurized.

- Dry in the sun by placing slices of food on clean racks or screens and covering with cheesecloth, fine netting, or another screen. Food will dry faster if racks are placed on blocks and the rack is not sitting on the ground.
- If possible, place a small fan near the drying tray to promote air circulation.
- Drying times will vary.
- Turn food once a day. Dry until the food has lost most of its moisture (fruits will be chewy).
- Fruits should be covered or brought in at night to prevent moisture being added back into the food.

DRYING WITH A FOOD DEHYDRATOR

- Place food dehydrator in a dry, well-ventilated, indoor room.

- Arrange fruits or vegetables in a single layer on each tray so that no pieces are touching or overlapping.
- Dehydrate at 140°F. Check food often and turn pieces every few hours to dry more evenly.

OVEN DRYING

- Dry food in an oven that can be maintained at 140°F. Leave door 2 inches to 3 inches ajar. Place a fan in front of the oven to blow air across the open door.
- Spread the food in a single layer on racks or cookie sheets. Check food often and turn pieces every few hours to dry more evenly.
- Drying time will vary. Do not leave oven on when no one is in the house.
- Oven drying is not recommended in households where children are present.

When food is dehydrated, 80 percent of the moisture is removed from fruits and up to 90 percent of the moisture is removed from vegetables, making the dried weight of foods much less than the fresh weight.

PASTEURIZING SUN-DRIED FRUITS

All sun-dried fruits must be pasteurized to destroy any insects and their eggs. This can be done with heat or cold. To pasteurize with heat, place dried food evenly in shallow trays no more than 1 inch in depth. Fruits should be heated at 160°F for 30 minutes. To pasteurize with cold, fruits can be placed in the freezer at 0°F for 48 hours.

CONDITIONING DRIED FRUITS

Dried fruits must be conditioned prior to storage. Conditioning is the process of evenly distributing moisture present in the dried fruit to prevent mold growth. Condition dried fruit by placing it in a plastic or glass container, sealing, and storing for 7 days to 10 days. Shake containers daily to distribute moisture. If condensation occurs, place fruit in the oven or dehydrator for more drying and repeat the conditioning process.

STORING DRIED FRUITS AND VEGETABLES

Cool-dried food should be placed in a closed container that has been washed and dried before storing. Home-canning jars are good containers for storing dried foods. Store in a cool, dry, and dark place. Dried foods can maintain quality for up to a year depending on the storage temperature. The cooler the storage temperature, the longer dehydrated foods will last.

RECONSTITUTING DRIED FRUITS AND VEGETABLES

Dried fruits and vegetables may be reconstituted (restoring moisture) by soaking the food in water. Time for reconstituting will depend on the size and shape of the food and the food itself. Most dried fruits can be reconstituted within 8 hours, whereas most dried vegetables take only 2 hours. To prevent growth of microorganisms, dried fruits and vegetables should be reconstituted in the refrigerator. One cup of dried fruit will yield approximately 1½ cups of reconstituted fruit. One cup of dried vegetable will yield approximately 2 cups of reconstituted vegetable. Reconstituted fruits and vegetables should be cooked in the water in which they were soaking.

MAKING SAFE JERKY

Jerky can be made from almost any lean meat, including pork, venison, and smoked turkey. Jerky made from meat is of particular concern because dehydrators rarely reach temperatures beyond 140°F. This temperature is not high enough to kill harmful microorganisms that may be present on meat. Before dehydration, precook meat to 160°F, and precook poultry to 165°F. For best results, precook meat by roasting in marinade.

MEAT PREPARATION

To prepare meat for jerky, make sure that safe meat handling procedures are followed.

- Clean: Wash hands with soap and running water for at least 20 seconds before and after handling raw meat. Use clean utensils.
- Chill: Store meat or poultry refrigerated at 40°F or below prior to use. It is important to thaw frozen meat in the refrigerator. Never thaw meat on counter tops.

Slice partially frozen meat into strips no thicker than ¼ inch. Trim and discard any fat. Meat can be marinated for flavor and tenderness. Many marinade recipes can be used, including this recipe taken from Andress and Harrison, 2006.

SIMPLE MEAT MARINADE RECIPE

- 1½ – 2 lbs lean meat
- ¼ cup soy sauce
- 1 tbsp Worcestershire sauce

- ¼ tsp black pepper
- ¼ tsp garlic powder
- 1 tsp hickory-smoke flavored salt

Combine all ingredients. Place strips of meat in a shallow pan and cover with marinade. Cover and refrigerate 1 hour to 2 hours or overnight. Heating meat to reduce chances of food-borne illness should be done at the end of marinating. Bringing strips and marinade to a boil for about 5 minutes will accomplish this. Drain.

DRYING MEATS

Drain strips on a clean, absorbent towel. Place strips in a single layer, making sure they don't touch or overlap. Dehydrate at 140°F until a test piece will crack, but not snap, when bent. Remove dried strips from rack and cool. If the meat strips were not heated to 160°F in marinade prior to drying, you may want to do this in an oven after drying. Place the dried strips on a baking sheet and cook at for 275°F, or until meat reaches 160°F. This process adds an additional safety step to the process.

STORING MEAT JERKY

Meat strips should be packaged in glass jars or heavy plastic storage bags. Jerky can be stored at room temperature for 2 weeks in a sealed container. For the longest shelf life, flavor, and quality jerky, store in the refrigerator or freezer.

DRYING FOOD PRESERVATION METHOD

Drying is the simple process of dehydrating foods until there is not enough moisture to support microbial activity.

Drying removes the water needed by bacteria, yeasts, and molds need to grow. If adequately dried and properly stored, dehydrated foods are shelf stable (safe for storage at room temperature). The drying food preservation method is easy to do, very safe, and can be used for most types of foods (meats, fruits, and vegetables).

There are several methods for drying foods. Two of the easiest and most common that can be used in any climate are oven drying and drying with an electric dehydrator appliance; these methods are described below. The other methods are air drying (in the shade during warm weather), sun drying (limited to desert climates), solar drying (requires specially built dryer), and pit oven drying (useful when other methods are impractical). Find these other food drying methods describe in The Home Preserving Bible by Carole Cancler.

HOW TO DRY FOOD IN A CONVENTIONAL OVEN

Oven drying is a good choice if you have never dried foods before, or plan to do only occasional drying. It tends to be slower than an electric dehydrator, but there is little or no investment in equipment and you don't have to depend on the weather as with other methods. Foods that are well-suited to oven drying are meats; seafood; fruit leather; low-moisture foods such as herbs, potatoes, bread cubes, berries, and meaty tomatoes (roma or paste-type); and excess produce you might otherwise throw out, such as onions, celery, and bananas. If you are new to drying, start with a few of the easiest foods to dry: berries, banana slices, tomato slices, chopped onions, oven jerky, and smoked salmon.

Here are the basic steps for oven drying foods:

1. Prepare suitable trays for drying foods.
2. Prepare food for drying. Preparation methods vary depending on the food you want to dry. For fruits and vegetables, you wash and then usually halve, quarter, or slice the produce. For light colored fruits and all vegetables, you also steam-blanch to deactivate enzymes or prevent browning in light colored foods, and then pat dry. Find more detailed instructions in this article: Methods for dried fruits, dried vegetables, and dried tomatoes. Meat or fish jerky is often marinated and may also be cooked before drying. Find more information in this article: How to decide whether to precook meat when making dried beef jerky.
3. Preheat (a gas or electric) oven to the lowest temperature setting. Maintain an oven temperature between 125°F and 145°F. Check the oven temperature with an accurate thermometer.
4. Decrease the temperature by propping open the oven door with a wooden spoon or folded towel. Caution: the oven-drying method is not safe in a home with small children.
5. Maximize air circulation to speed drying. Place a fan on a chair near the propped-open oven door so that it blows away the hot, escaping air. Open nearby doors and windows to promote more airflow.
6. Dry until pliable or crisp: The extent of dryness is somewhat a matter of preference. Therefore, the length of drying time can fluctuate widely (from a few hours

to more than 24). Drying time also depends on several factors: the type of food (meat, fruit, vegetables, etc.), the size of the portions to be dried (thick or thin), the drying method used (sun, air, oven), and the weather (especially humidity, which greatly increases drying time).

7. Tips for successful drying include drying foods only on days when the humidity is not high, space the food about an inch apart, and fill only half of the oven racks with food.

SUITABLE TRAYS FOR OVEN-DRYING FOODS

Trays used for drying foods in an oven (or other methods than a food dehydrator) need to be of a food-safe screen material such as plastic (preferably polypropylene), stainless steel, Teflon or Teflon coated fiberglass, or wood. An economical solution is to stretch cheesecloth or natural muslin over an oven or cake rack or a wood frame, and attach it with masking tape, paper clips, or clothespins. For a more permanent, but more costly option, have (window) screens made at a hardware store and use them for drying.

Avoid materials which can leach harmful chemicals, darken the food, or melt at drying temperatures. These materials include:

- Do not use uncoated fiberglass and vinyl.
- Do not use metals other than stainless steel (such as aluminum, galvanized steel, and copper); they can transfer a metallic flavor to food, rendering it inedible. Covering metal with cheesecloth or muslin is another

option, especially if you are re-purposing material and are unsure of the type of metal.

- Do not use green wood, pine, cedar, oak, and redwood.

After oven drying a few foods, if you want to continue to use the drying method, consider investing in an electric food dehydrator.

ELECTRIC FOOD DEHYDRATOR APPLIANCES

A food-dehydrating appliance has few weather dependencies, can consistently produce a quality product, and is less prone to inconsistency or other problems when drying foods. This makes it easier than most other methods. A good food dehydrator provides variable temperature control and good air circulation. A temperature control with a range of 85°F to 180°F provides full flexibility for drying all types of foods, from delicate herbs and firm fruits to meat jerkies. A temperature control with a maximum of 160°F will limit your ability to dry meats and fish.

You can purchase a basic food dehydrator model for under $100, which is a good choice for first-time users or those who want to dry foods occasionally and in small amounts. Basic models have limited temperature ranges, vertical airflow, single-wall construction, and limited drying capacities. More deluxe food dehydrator models cost $200 or more, and offer more temperature range, efficient horizontal airflow, double-wall construction, and larger drying capacities. With a food dehydrator, you simply prepare the food and place it on the appliance trays, preheat the dehydrator to 125°F to 135°F, and the appliance does the rest.

HOW TO USE DRIED FOODS

You can used dried foods in a variety of ways:

- eat dried foods as is (such as snacking on dried beef jerky and dried fruits)
- rehydrate dried foods water (such as adding vegetables to a meat stew)
- grind dried foods into a powder (for example, grind tomatoes to a powder that you can reconstitute with water to make tomato sauce).

Therefore, you may dry foods until pliable, especially if you want to use them as a snack food. If you want to store dried food longer or use it to grind to a powder (such as tomatoes to make sauce), then you want them to be crisp and brittle. Less-dry products have considerably shorter shelf life—from 2 weeks to 2 months. Very dry foods, if properly stored, may last several months. Whether pliable or crisp, condition all foods at the end of the drying process. Alternatively, you may store partially dried or unconditioned foods in the freezer.

HOW TO CONDITION AND STORE FOODS AFTER DRYING

Individual pieces of food dry at different rates; some pieces will have more moisture than others. If there is too much moisture left in a few pieces, they can grow mold and contaminate the entire batch. To guard against mold growth, you need to condition dried foods before you store them. During conditioning, the moisture will equalize—that is, excess moisture will transfer to drier pieces, until it is evenly distributed throughout the batch.

To condition dried foods, place them in a tightly closed container at room temperature. Stir or shake the contents every day for a week. If you open the container to stir the contents, be sure to close it again tightly. During conditioning, if moisture forms on the inside of the container, the food is not sufficiently dry and you need to return it to the dryer.

To store dried foods after conditioning, seal dried food in airtight containers that hold only enough food to be used at one time. This reduces the number of times a package is reopened. You can also limit air by taping over jar enclosures or using a desiccant to absorb oxygen. Ideally, you want to store dried foods at a constant temperature between 40°F and 70°F. Be sure to store foods in a closed cupboard or dark room, away from light. If you live in a dry climate, your dehydrated foods will tend to stay fresh longer. However, if you live in a humid area, moisture can get in and shorten storage life considerably. In high-humidity locations, put dried food in zipper-lock plastic bags that allow you to push out excess air.

You can store properly packaged, well-dried foods at room temperature for up to 1 year. Less dry, pliable products have a shelf life of a few weeks to several months. Storage life decreases with packaging that is not airtight, reopening packages, and fluctuating temperatures. You can vacuum-seal, refrigerate, or freeze any dried food for longer storage.

Check dried foods monthly for spoilage—usually mold. Use dried foods before other types of preserved foods, such as frozen or canned. Most importantly, enjoy eating your dried foods and be sure to experiment with different ways of using your stored treasures.

Hints for successfully storing dried foods

- Always store dried foods in airtight containers in a cool, dry place.
- Reduce the number of times a package is reopened by using containers that hold only enough food to be used at one time.
- Limit air, light, and heat. Put masking tape over jar enclosures or use a food-safe desiccant in the jar to absorb excess oxygen. Be sure to store foods in a closed cupboard or dark room, away from light. Ideally, you want to store dried foods at a constant temperature between 40°F and 70°F.
- In humid locations, put dried food in zipper-lock plastic bags that allow you to push out excess air. This helps to prevent moisture from re-entering the food, shortening the storage life considerably.
- To increase storage life, vacuum-seal, refrigerate, or freeze dried foods.

DRYING FOODS METHODS

Food drying is one of the oldest methods of preserving food for later use. It can either be an alternative to canning and freezing or compliment these methods. Drying food is simple, safe and easy to learn. With modern food dehydrators fruit leathers, banana chips, pumpkin seeds and beef jerky can all be dried year-round at home. Dried foods are ideal for backpacking and camping. They are lightweight, take up little space and do not require refrigeration.

HOW DRYING PRESERVES FOOD

Drying removes the moisture from the food so that bacteria, yeasts and molds cannot grow and spoil the food. It also slows down the action of enzymes but does not inactivate them. When the food is ready for use, the water is added back and the food returns to its original shape. Foods can be dried in the sun, in an oven or in a food dehydrator by using the right combination of warm temperatures, low humidity and air current. The optimum temperature for drying food is 140 °F. If higher temperatures are used, the food will cook instead of drying. When the food cooks on the outside and the moisture cannot escape, "case hardening" can occur. The food will eventually mold. Thus, the drying process should never be hurried by raising the drying temperature. Low humidity aids the drying process. Food contains a lot of water. To dry food, the water must move from the food to the surrounding air. If the surrounding air is humid, then drying will be slowed down. Increasing the air current speeds up drying by moving the surrounding moist air away from the food. To speed the drying time, increase the air flow. Most foods can be dried indoors using modern food dehydrators, counter-top convection ovens or conventional ovens. Microwave ovens are recommended only for drying herbs, because there is no way to create enough air flow to dry denser foods.

SUN DRYING

Vegetables and meats are not recommended for out-of-doors drying. Vegetables are low in sugar and acid, which increases the risks for food spoilage. Meats are high in protein, making them ideal for microbial growth when heat and humidity can't be controlled. It is best to dry meats and vegetables indoors using controlled conditions of an oven or food dehydrator. The high sugar and acid content of fruits make them safe to dry out-of-doors when conditions are favourable for drying. It takes several days to dry foods out-of-doors, and because the weather is uncontrollable, this method can be risky. Hot, breezy days with humidity below 60 per cent are best, but usually these ideal conditions are not available in South Carolina when the fruit ripens, so that alternative methods are needed. A minimum temperature of 85 °F is needed with higher temperatures being better. Fruits dried out-of-doors must be covered or brought under shelter at night. The cool night air condenses and could add moisture back to the food, thus slowing down the drying process.

EQUIPMENT

Racks or screens placed on blocks allow for better air movement around the food. Because the ground may be moist, it is best to place the racks or screens on a concrete driveway or if possible over a sheet of aluminum or tin. The reflection of the sun on the metal increases the drying temperature. Screens need to be safe for contact with food. The best screens are stainless steel, teflon-coated fibreglass and plastic. Avoid screens made from "hardware cloth." This is galvanized metal cloth that is coated with cadmium or zinc. These metals can oxidize, leaving harmful residues on the food. Also avoid copper and aluminum screening. Copper destroys vitamin C and increases oxidation. Aluminum tends to discolour and corrode. Because birds and insects are attracted to dried fruits, two screens are best for drying food. One screen acts as a shelf and the other as a protective cover. Cheesecloth could also be used to cover the food.

SOLAR DRYING

Recent efforts to improve sun drying have led to solar drying. Solar drying uses the sun as the heat source, but a specially designed dehydrator increases the temperature and air current to speed up the drying time. Shorter drying times reduce the risk of food spoilage or molding.

VINE DRYING

Another method of drying outdoors is vine drying. To dry beans leave bean pods on the vine in the garden until the beans inside rattle. When the vines and pods are dry and shriveled, pick the beans and shell them. No pretreatment is necessary. If beans are still moist, the drying process is not complete and the beans will mold if not more thoroughly dried. *If needed, drying can be completed in the sun, oven or a dehydrator:*

- *Pasteurization*: Sun-dried fruits and vine-dried beans need treatment to kill insects and their eggs.
- *Freezer Method:* Seal the food in freezer-type plastic bags. Place the bags in a freezer set at 0 °F or below and leave them at least 48 hours.
- *Oven Method:* Place the food in a single layer on a tray or in a shallow pan. Place in an oven preheated to 160 °F for 30 minutes.

FOOD DEHYDRATORS

A food dehydrator is a small electrical appliance for drying foods indoors. A food dehydrator has an electric element for heat and a fan and vents for air circulation. Dehydrators are efficiently designed to dry foods quickly at 140 °F. Food dehydrators are available from department stores, mail-order catalogs, natural food stores, and seed or garden supply catalogs. Costs vary from $50 to $350 or above depending on features. Some models are expandable and additional trays can be purchased later. Twelve square feet of drying space dries about a half-bushel of produce. The major disadvantage of a dehydrator is its limited capacity.

Dehydrator features to look for:

- Double wall construction of metal or high-grade plastic. Wood is not recommended, because it is a fire hazard and is difficult to clean.
- Enclosed heating elements.
- Counter-top design.
- An enclosed thermostat from 85 to 160 °F and a dial for regulating temperature.
- A fan or blower.
- Four to 10 open mesh trays made of sturdy lightweight plastic for easy washing.
- A timer to turn the dehydrator off and prevent scorching if the drying time is completed during the night.
- UL seal of approval, a one-year guarantee and convenient service.

TYPES OF DEHYDRATORS

There are two basic designs for dehydrators. In horizontal air flow units, the heating element and fan are located on the side, whereas the vertical air flow dehydrators have the heating element and fan located at the base.

The major advantages of horizontal flow are:

- It reduces flavour mixture so several different foods can be dried at one time; all trays receive equal heat penetration;
- Juices or liquids do not drip down into the heating element.

OVEN DRYING

Everyone who has an oven has a food dehydrator. By combining the factors of heat, low humidity and air current, an oven can be used as a dehydrator. An oven is ideal for occasional drying of meat jerkies, fruit leathers, banana chips or for preserving excess produce like celery or mushrooms. Because the oven may also be needed for everyday cooking, it may not be satisfactory for preserving abundant garden produce. Oven drying is slower than dehydrators because it does not have a built-in fan for the air movement. It takes twice as long to dry food in an oven than in a dehydrator, and it uses more energy.

TO USE YOUR OVEN

First, check your dial and see if it has a reading as low as 140 °F. If your oven does not go this low, then your food will cook instead of dry. For air circulation, leave the oven door propped open 2 to 6 inches. Circulation can be improved by placing a fan outside the oven near the door.

CAUTION: This is not a safe practice for a home with small children. Because the door is left open, the temperature will vary. An oven thermometer placed near the food gives an accurate reading. Adjust the temperature dial to achieve the needed 140 °F. Trays should be narrow enough to clear the sides of the oven and should be 3 to 4 inches shorter than the oven from front to back. Cake cooling racks placed on top of cookie sheets work well for some foods. The oven racks, holding the trays, should be 2 to 3 inches apart for air circulation.

ROOM DRYING

This method of drying differs from sun drying since it takes place indoors in a well-ventilated attic, room, car, camper or screened-in-porch. Herbs, hot peppers, nuts in the shell and partially sun-dried fruits are the most common air-dried items. Herbs and peppers can be strung on a string or tied in bundles and suspended from overhead racks in the air until dry.

Enclosing them in paper bags, with openings for air circulation, protects them from dust, loose insulation and other pollutants. Nuts are spread on papers, a single layer thick. Partially sundried fruits should be left on their drying trays.

DEHYDROFREEZING

Dehydrofreezing is a new method of food preservation that combines the techniques of drying and freezing. Fruits dried at home normally have had 80 per cent of their moisture removed; vegetables, 90 per cent. However, by removing only 70 per cent of the moisture and storing the fruit or vegetable in the freezer, a tastier product results.

The low temperature of the freezer inhibits microbial growth. Also, the food takes up less room in the freezer. Dehydrofrozen fruits and vegetables have good flavour and colour. They reconstitute in about one-half the time it takes for traditionally dried foods. Dehydrofreezing is not freeze-drying. Freeze-drying is a commercial technique that forms a vacuum while the food is freezing. Freeze-drying is a costly process that can't be done in the home.