SEMI-MOIST FOODS

R.G. Hamilton, CSIRO Division of Food Processing, Meat Research Laboratory, P.O. Box 12, Cannon Hill, Queensland, Australia.

INTRODUCTION

The terms "semi-moist food" and intermediate moisture food conjure up different mental pictures to different people. To some these terms may only mean products half way between wet and dry foods, but to a food technologist it means a great deal more.

Semi-moist foods are shelf stable foods and have long been part of the human diet. Aboriginal people dried meat over fires or in the sun, and used the dried product, particularly on long journeys. Without understanding the processes involved, man for centuries has been preserving food from spoiling by reducing its water content in conjunction with the addition of salt and sugar. Production of semi-moist foods obviously therefore pre-dates canning or refrigeration as a food preservation technique and also probably pre-dates pickling.

Long established semi-moist foods include:

- "dried" fruits such as raisins, prunes, dates, figs, apricots and sultanas;
- confectioneries including marshmallows, sweets, marzipan, jams, honey and molasses; and
- bakery products such as fruit cake and some types of biscuits and matured cheese.

Traditional shelf stable meats including salamis and other dry sausage, traditional salted bacon and slow cured ham, prosciutto ham. Coppa, jerky, biltong, pemmican and charqui are also examples of semi-moist foods.

Dried and salted meats have long been used as military, exploration and travel rations, and especially during early sea travel.

A naval captain of the last century, in a letter to his wife, wrote that most of the salted meat on board ship, was over ten years old (makes you wonder if they had date coding way back then). He noted that it was so tough that it had to be grated into the cooking pot to aid in its reconstitution. Other crew members of this ship (perhaps in disgust or to reduce its chance of appearing on the cook's menu) carved models of sailing ships from the dried meat which when polished, he said, looked like the finest mahogany.

As recently as the Second World War, large quantities of dried (salted) meat were produced for troop rations because it was a lightweight, stable meat product which could be reconstituted by the simple addition of water to closely resemble conventionally cooked meat.

Most dehydrated foods are in fact not dried, but have only sufficient moisture removed to guarantee stability at ambient temperatures. Historically, dried meat stability was controlled by its moisture to protein ratio. For example, beef jerky has a moisture to protein requirement of 0.75. At this level of dryness there is a tremendous safety margin.

Our scientific understanding of the shelf stability of semi-moist foods greatly expanded with the work of W.J. Scott in the 1930s. He introduced the term "water activity" to describe one of the variables controlling microbial growth. Control of water activity is essential for the suppression of microbial growth and for maintenance of food wholesomeness, safety and pliable texture in the absence of other factors such as control of temperature and/or gaseous atmosphere.

The purpose of this paper is to outline the basic technology of semi-moist food and to outline the factors which influence the stability of semi-moist food. The most recent work undertaken by the CSIRO, on third generation semi-moist petfood and the generation of accurate organoleptically-balanced semi-moist "dried" meat formulations, will be discussed.

Speculation on consumer perceptions, satisfaction and acceptance of new semi-moist foods into the 1990's will also be presented.

WATER ACTIVITY AND ITS SIGNIFICANCE

Water is essential for microbial growth and germination of spores. If microorganisms are deprived of some or most of the water normally present in food, their growth is reduced, delayed or stopped. The availability of water for growth is determined by its relative vapour pressure (or water activity) rather than its concentration. Reduction of water activity reduces the availability of water in foods and this affects microbial growth even though the total water concentration may remain unchanged.

Water activity (a_w) is defined as the ratio of the fugacity of water in a solution to that of pure water. Fugacity may be approximated by partial vapour pressure under the normal conditions of temperature and total atmospheric pressure i.e. water activity is expressed as vapour pressure (P) of water over a solution (or in food) to the vapour pressure of pure water (P_o) at the same temperature, and is written:

$$a_w = P/P_o$$

This equation can also be expressed in terms of relative humidity of an enclosed space above a solution or food. However, Raoult's Law states that the partial pressure of any component of a solution is equal to the product of vapour pressure of the pure component and its mole fraction (X):

$$P = X.P_o$$

Rearranging the equation gives

$$X = P/P_o$$

therefore, for an ideal solution:

$$a_w = X \frac{\text{moles water}}{\text{moles water + moles solute}}$$

This equation only holds true for dilute non-electrolyte solutions and does not cater for multi charges solutions. To all for this it may be expressed -

$$a_w = \gamma \frac{\text{moles water}}{\text{moles water + moles solute}}$$

where γ = activity coefficient (for an ideal solute)

The γ value is a measure of the non-ideality of a dissolved solute. For large molecules like gums, γ is small and thus large molecules decrease a_w much more than ideal solutes such as sugars and salts. However, since their molecular weight is large, the total a_w decrease is small. Electrolytes decrease the a_w more than expected on a molecular basis because they dissociated, increasing the denominator in the above equation.

$$a_w = \frac{(W/18)}{\gamma\,(W/18) + (a/\text{mol wt } A) \times D}$$

where A = weight of solute; D = no. of ions due to dissociation of solute; W = weight of water; γ = activity coefficient.

Further modifications to the above equations have been made to provide for non-ideal, simple and complex solutions and to allow for capillary effect, surface interaction and non-solute components e.g. Gibbs-Duhum equation and the Ross equation.

WATER SORPTION ISOTHERMS

Water sorption isotherms are another useful tool for studying the properties of water in foods. They are curves which relate the water activity (as a function of the partial pressure of water in foods) to the moisture content. The relationship defines the moisture content of the food system in equilibrium with different values of a_w at constant temperature. However, many foods exhibit a "hysterisis effect", that is, their moisture content in adsorption of water is normally lower, at a given water activity, than in desorption.

WATER ACTIVITY AND STABILITY OF FOODS

Water activities and associated moisture contents of semi-moist foods vary widely. They range from 0.65 to 0.9 (a_w) and from 10 to 40% water by weight (Karel 1976).

Most bacterial will not grow below a water activity of 0.9. Those which do, such as *Staphylococcus aureus*, do not produce toxins (Scott 1953) Food-borne pathogens will not grow below a water activity of about 0.85 (Scott 1957). The growth of *Clostridium botulinum* and *Salmonella* are inhibited below a water activity of 0.93 while spores of *Cl.botulinum* and other bacteria do not germinate at water activities of 0.95 or lower. Non-spore forming bacteria which grow at water activities below 0.95 are susceptible to destruction by pasteurisation. Most moulds cease to grow below an a_w of about 0.8. Some xerophilic fungi were reported to be able to grow at an a_w of 0.65, but 0.7 to 0.75 is generally considered their lower limit.

Manipulation of the water activity alone can halt most microbial growth, however other undesirable changes may occur concomitantly and these must be brought under control. This is due to other factors, in addition to water activity, defining the lower limits of chemical activity, and water can act in one or more roles (Karel 1973). Semi-moist foods are susceptible to (1) lipid oxidation and mould growth because water acts as a solvent, and (2) non-enzymic browning because the lack of water concentrates the reaction substrates which promotes browning. Moreover, above a water activity of 0.7, dilution of reactants with water inhibits condensation (malliard type) reactions.

Oxidation of lipids can be minimised by:

- choosing the correct triglyceride (select a fat containing saturated fatty acids);
- decreasing the quantity of fat in food;
- decreasing the oxygen content (by using vacuum or inert gas packaging together with oxygen scavengers);
- applying a mild heat treatment (pasteurisation and blanching will restore stability by deactivating lypolytic enzymes);
- adding approved antioxidants (lecithin, tocopherol, BHA, propyl gallate); and
- avoiding pro-oxidants (e.g. Cu, Fe, Mn, Ni and Zn ions). Chelating agents such as citric acid may be used to complex these elements and prevent oxidation.

The growth of yeasts and mould can be controlled by:

- vacuum packaging (in oxygen impermeable plastic films);
- packaging in inert gases (in oxygen impermeable plastic films in conjunction with oxygen scavengers); and
- adding anti-mycotics, such as potassium sorbate.

Non-enzymic browning can be controlled by keeping the water activity above 0.7 (Lea 1945). This is particularly important for foods that are prepared without the addition of sulphite. This may occur with greater frequency due to the increased consumer interest in additive-free foods.

MANIPULATION OF WATER ACTIVITY

In practice, the manipulation of water activity is achieved by either:

- removing water - drying (desorption);
- incorporating solutes (desorption);
- combining water removal and addition of solutes (desorption); or
- blending moist and dry ingredients in combination with the addition of additives.

Note:- absorption and desorption occur simultaneously when wet and dry components are blended and heated together as in the manufacture of semi-moist petfoods (Ledward 1985).

Of the above methods these which involve desorption are less expensive, but water activity may be higher during water adsorption than during desorption (Labusa 1972).

THE TECHNOLOGY OF SEMI-MOIST PRODUCTS

The lower limit for water activity in semi-moist foods is arbitrarily set at a_w 0.65. The upper limit, however, is dependant upon the composition of the product, the methods used to process and package the product and the conditions during storage.

For example, the a_w of semi-moist meat products such as beef jerky has traditionally been between 0.7 and 0.8 (usually around 0.76) to minimise microbial growth. The reduced yield and tough texture of intact meat at this a_w reduces profitability and the consumer acceptance of such products. Achieving the same a_w at higher moisture levels certainly increases the yield and improves the organoleptic acceptability of the product, but necessitates the inclusion of high concentrations of humectants (solutes) to reach the desired a_w. Vacuum packaging has enabled the a_w to be lifted to between 0.80 to 0.83, but the improvement in yield and taste is marginal.

Semi-moist petfoods which are normally protected against mould growth with antimycotics have water activities in the range 0.8 to 0.85 with moisture contents of about 23 - 27%.

Combining the effect of water activity with the manipulation of other factors or parameters such as pH, redox potential, temperature, citrates, competitive flora and preservatives, greater flexibility in microbiologically-safe water activities is achievable together with the possibilities of optimising other food characteristics (Leistner 1985).

SOLUTE EFFECT AND SELECTION CRITERIA

The effect of solutes or humectants on water activity, their selection and levels of use are equally as important as Leistner's "hurdle technology". The ideal humectant should have no odour of flavour and should not otherwise alter the organoleptic quality of the food. It should also be highly soluble, of low calorific value, non-toxic, naturally-occurring, have the power to lower water activity at low usage levels, and of course, be cheap. In seeking this mythical substance, we should be looking for an organic material which has a high osmotic pressure, a low molecular weight and which dissociates in water.

All humectants in use and of potential use in semi-moist meat products fall short of these ideal requirements. Basically there are three general classes of humectant in food use at present. The are salts, polyhydric alcohols (polyols) and sugar.

SALTS

NaCl and KCl are the most effective substances for depressing aw. However, they are too strongly flavoured to be used alone in semi-moist food formulations. Use of NaCl as single humectant would result in such a high intake of NaCl as to discourage this practice.

POLYOLS

The next most effective humectants are polyols. These have a low molecular weight, and some are liquid, which has the effect of enhancing juiciness. Many of these compounds produce a significant depression of water activity only at concentrations above their flavour threshold, which restricts their usefulness in foods. Although not as sweet as sugar, they produce a "hot", "spicy" sensation in the mouth. On the basis of lowering water activity, glycerol is the most effective polyol.

SUGARS

Sorbitol although not strictly a sugar, is second only to fructose in its potential to lower water activity. Sucrose is less effective than fructose, but after modification to invert sugar (fructose/glucose) has useful water activity lowering potential. Lactose, which is readily available as a byproduct of the dairy industry, is not effective in lowering water activity. However, this is improved dramatically if it is converted to lactic acid or lactates (normally by fermentation).

The function of humectants is to make water unavailable for microbial growth and therefore quantification of this ability is desirable if not paramount in the selection and use of these substances. A correlation of their water-binding capacity and organoleptic threshold concentrations (for taste) would also be useful for the formulation of semi-moist products if presented in a directly usable form. We have done this for a limited number of well-known and reputedly safe substances, so that we can incorporate them, using computer technology, in a new semi-moist petfood we have recently developed.

SEMI-MOIST PETFOOD

The petfood developed by the CSIRO is characterised by a high level of moist meat by-products (60%) and a low level and short list of humectants, viz. salt below 2% and sugar below 9%. It thus utilises hurdle technology. No polyhydric alcohols are used because of the possibility that the one preferred, propylene glycol, might be removed from the list of approved ingredients in the future. Propylene glycol is also expensive.

Semi-moist petfoods have been around now for almost 20 years and in this country, until recently, have been declining in sales, presumably due to a long term lack of acceptance by the animals fed. Sugar levels in some were found to be higher than 30% and although one could not question their nutritional soundness, animals appeared to tire of the products when they were served as a staple diet. Sugar is also know to be less effective in controlling bacteria than other humectants used at the same water activity.

Semi-moist petfoods which contained polyhydric alcohols such as glycerol were reported to have caused explosive diarrhoea in some animals - not much fun if you happen to live with "Fido" in a small inner-city flat. Above all, the raw material and processing costs of the CSIRO petfood are on the same levels as canned and dry petfood and its continued acceptance by animals on a par with the best existing products.

TRADITIONAL MEAT PRODUCTS

Our work on semi-moist food for human consumption has, to date, been limited to traditional meat products such as jerky. The reasons for our interest in processed meats which are shelf-stable without the need for refrigeration or expensive packaging should be obvious to this audience especially for export markets.

Armed with our newfound ability to predict accurately the water activity and therefore the shelf stability of a computer-based, least cost petfood formulation, the possibility of applying this to achieve improved jerky formulation with particular emphasis on taste was investigated. As a result of this work, a commercially available jerky product with salt levels as low as 3% (whereas 6.5% salt is not uncommon in other formulations on the market) is now available for export to countries sensitive to salty products, whilst maintaining safe microbiological status.

By utilising the latest in packaging technology e.g. retortable plastic pouches and sausage casings; hurdle technology i.e. integration of critical conditions; simple, sale consumer comfortable humectants, mild refrigeration and an understanding and prevention of undesirable chemical reactions, traditional "ready to eat" and reconstitutable "convenience foods" are within our technical grasp.

DEVELOPMENT OF NEW STYLES OF TRADITIONAL SEMI-MOIST FOODS

There is an increasing consumer interest in wholesome, natural foods without so called artificial, chemical additives. Food science must recognise this and be aware of the demand for quality in processed foods. Additives such as humectants, emulsifiers, stabilisers and antioxidants are criticised and regarded as artificial preservatives and as such, are viewed with suspicion by the consumer. As food scientists we must heed the warnings and find naturally occurring alternatives to these substances such as fermented cheese whey (high in lactates), or develop the kind of food additives that are effective in small quantities and without side effects.

Tomorrow's consumer will demand processed foods such as semi-moist foods that are:

- wholesome and not lacking in nutrients as a result of processing;
- low in unnatural additives;
- convenient, but not at the expense of quality.

The challenge is to supply them!

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Wt of water bound per unit "x" solution

	a_w			
Solute	0.80	0.85	0.90	organolep-tic/threshold (rating only)
NaCl	0.70	1	2.0	++++
KCl	0.25	0.6	1.1	++++
P.Glycol	0.20	0.3	0.5	+
Glycerol	0.20	0.25	0.4	+++
Fructose	0.10	0.20	0.3	++
Sorbitol	0.12	0.18	0.25	+
Glucose	0.11	0.15	0.20	+
Sucrose	0.10	0.11	0.14	++
Lactose	-	-	-	+