Selçuk Üniversitesi Vet. Fak. Dergisi
Cilt: 4, Sayı: 1, (393 — 409), 1988

THE BASIC PRINCIPLES OF INTERMEDIATE-MOISTURE FOODS*

Orta Rutubetli Gıdaların Temel İlkeleri

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Özet: *Orta Rutubetli Gıdalar, hemen yenecek kadar yumuşak (% 20–30 rutubet), fakat uzun süre saklanabilecek kadar kuru gıda olarak tanımlanabilir. En eski gıda muhafaza metodlarından biri olup, son yıllarda yeniden ilgi uyandırmaya başlamıştır. Modern anlamda, Orta Rutubetli Gıdalar, nemlendiricilerin ilavesiyle A_w'nin düşürülmesi; mikostatik ve bakteriyostatik maddelerin katılması ve ayrıca bazı ek kimyasal maddelerin dahil edilmesiyle dayanıklılık ve duyusal özelliklerin yükseltilmesi esasına dayanır. Bu amaçla katılan en önemli kimyasal maddeler gliserol, propilen glikol, K sorbat ve tuzdur. A_w seviyesi düştükçe, gıdalardaki mikroorganizmaların çoğalması da durur, A_w 0.65'ten daha düşük seviyelerde üreme imkansız hale gelir.*

Summary: *Intermediate Moisture Foods (IMF) can be regarded as being moist enough (20–30 % moisture) to be "ready-to-eat" and yet dry enough to be shelf stable. It is one of the oldest preserved foods of man, but recently there occured a revial of interest in them. Modern IMF are based on lowering of water activity through addition of humectants; addition of mycostatic and bacteriostatic agents and incorporation of additional chemicals to improve stability and organoleptic properties. The most outstanding chemicals added for this purpose are glycerol, propylen glycol, K sorbate and salt. As the level of A_w decreases the proliferation of microorganisms in foods suppresses and below A_w 0.65 the growth becomes practically impossible.*

1. *Introduction*

Intermediate moisture food, identified in practice by water activities between 0.6 to 0.9. This level of water activity provides the basis for the preservation of limited number of foods such as jam and jellies, pet foods etc (4,5,16).

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* Presented in Turkish at the seminer of Faculty of Veterinary Medicine in March 9, 1988.

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The requirement for foods of high caloric density per unit volume has stimulated interest in the development of intermediate moisture foods. The intermediate moisture food is considered to be one of the most valuable food sources for military use, small animal needs and space missions due to their small volume and weight, nutritional interchangeability, longterm stability without refrigeration.

The fundementals of intermediate moisture food and relations of water activity to microbiological spoilage and enzymatic changes have been reviewed in detail.

2. *Review of literature*

2.1. The concept of intermediate moisture foods

The expression "intermediate moisture" has crept into our vocabulary relatively recently in connection with a heterogenous group of foods which have a reduced water activity but contain too much water to be regarded as dry. More specifically an intermediate moisture food is a type of food having a water activity between 0.6 and 0.9. Intermediate moisture food can be considered as being moist enough to be "ready-to-eat" and yet "dry" enough to be shelf stable. Jam and jellies, dried fruits, maple syrup, soft candies, fig newtons, marshmallows,a number of baked items such as fruit cake, several species of sausage ,country style ham and salted fish are considered to be typical intermediate moisture foods. The major commercial development of intermediate moisture food in recent years has been soft-moist pet foods (3,17,19,37).

These products fall roughly into the 20 to 30 percent moisture range. All are commercially handled, are shelf-stable without thermal processing or refrigeration and can be eaten without rehydration. When eaten none give a sensation of dryness, although some textural deterioration may occur and they have more familiar mouth feel and flavor than the dehydrated foods.

2.2. The concept of water activity

Water activity is defined as the ratio of the vapor pressure of water in the system to the vapor pressure of pure water at the same temperature. The water activity can be shown by this equation:

$$A_w = \frac{P}{P_0} = \frac{E.R.H.}{100}$$

Where A_w = Water activity

P = Partial pressure of water in food

P_0 = Saturation pressure of water at specified temperature

E.R.H. = Equilibrium relative humidity (%)

The term "moisture activity" or equilibrium relative humidity which most investigators continue to use refers to water activity.

When equilibrium exists between the moisture concentration of a food and the relative humidity of its environment, water activity is directly relatable to the relative humidty as expressed in the moisture sorption isotherm. The relationship between water activity and the moisture of a food depends on the chemical and physical properties of the food solids, temperature, the amount and nature of the soluble material present and possibly on whether equilibrium was established by adsorption or desorption (27,31,32,33).

Water activity can also be expressed as the mole fraction of water, that is, the moles of water divided by the sum of the moles of water and the moles of solute.

There is correlation between water content and relative humidity in the range of moisture contents. At high moisture contens which is above 1 lb water/1 lb solids, water has an activity close to 1.0 (Figure 1). At this level, enzymatic, chemical and microbiological food deterioration is expected.

Below 50 % moisture content water activity falls rapidly because of the various reactions. On Figure 2, the curve related to these changes is called "water sorption isoterm".

The curves show the relative humidities or water activities with which the foods are in equilibrium at various moisture contents. The upper curve represents a dry cereal and the lower one represents a dry gelatine dessert mix. One theory explains the curve by dividing it into three sections. The first section is called "monolayer water region" (region A), which has 50–10 % moisture and represents firmly bound water where the food is microbiologically stable. The second part of the curve, which is flatter and in the middle is called "multi-

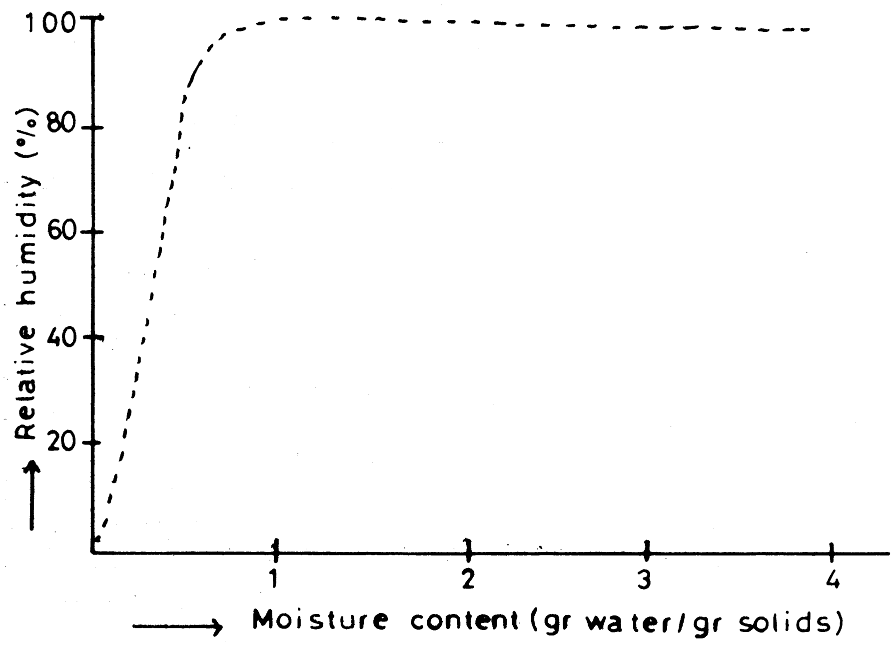

Figure 1– Humidity - moisture relationship of food.

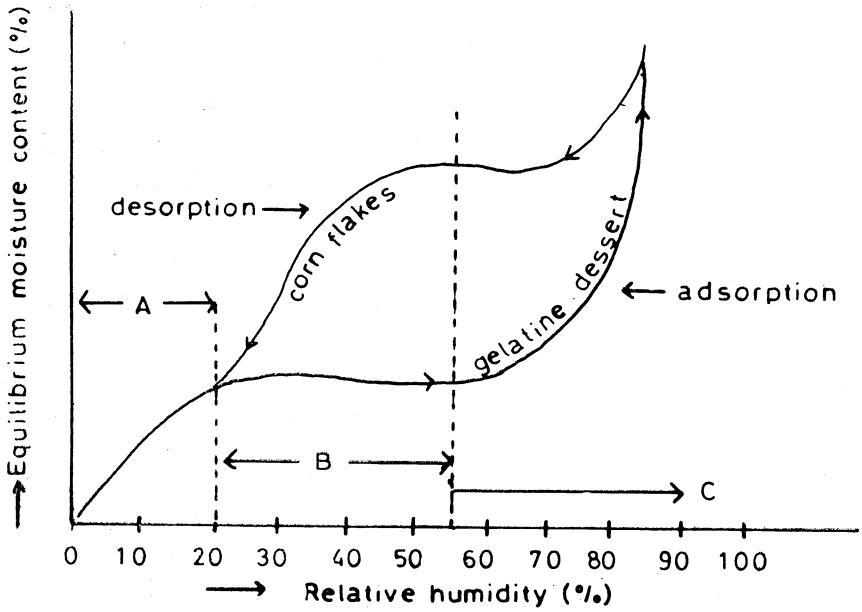

Figure 2– Water sorption isotherm.

layer region" (region B) where water is not bound as tightly, and toward the higher end the food may support mold and yeast growth. This area is a representative section of intermediate moisture foods. The final section of the curve is called "capillary condensation region" (region C) and represents the food containing free water, where it is subject to microbiological spoilage (2,9).

The control of water activity is achieved either by adding solutes such as sucrose, salt, calcium chloride, potassium chloride or by removing water. Solutes have "buffer" action to stabilize water activity. Sulfuric acid has been widely used to produce an equilibrium relative humidity.

The effectiveness of non-dissociated additives such as sucrose, glucose and glycerol is not in the equal range. Lesser amount of glycerol, comparing to other solutes, is more effective in terms of the reduction of water activity (Figure 3).

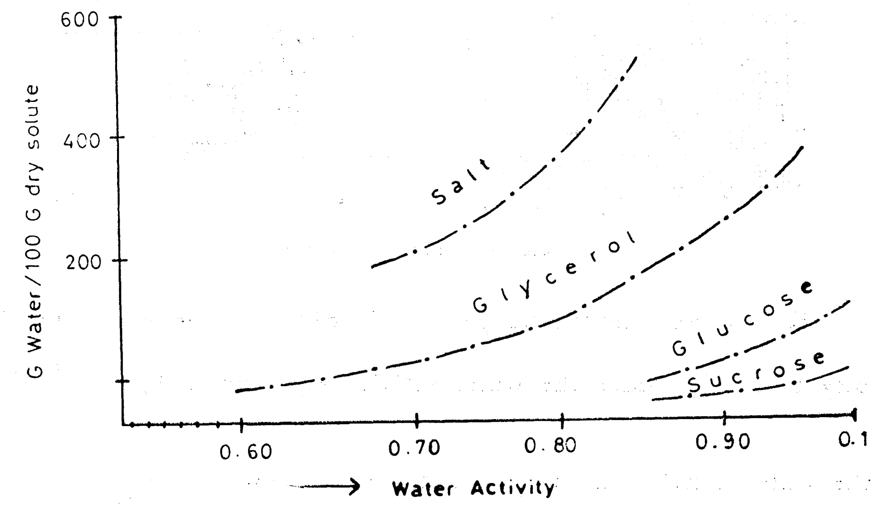

Figure 3– Solute dilution and water activity.

2.3. Determination of Water Activity

For the determination of water activity of a product on Electric Hygrometer Indicator, Type 15–3001, which is available at Food

Technology Department is used. A temperature-humidity sensing element is fitted into an air-tight jar, through the lid, containing the sample. After an equilibrium between the product and surrounding atmosphere is reached, the temperature and humidity readings are obtained through the indicator. Water activity can be found by figuring out the values on the specific chart supplied by the company (Figure 4).

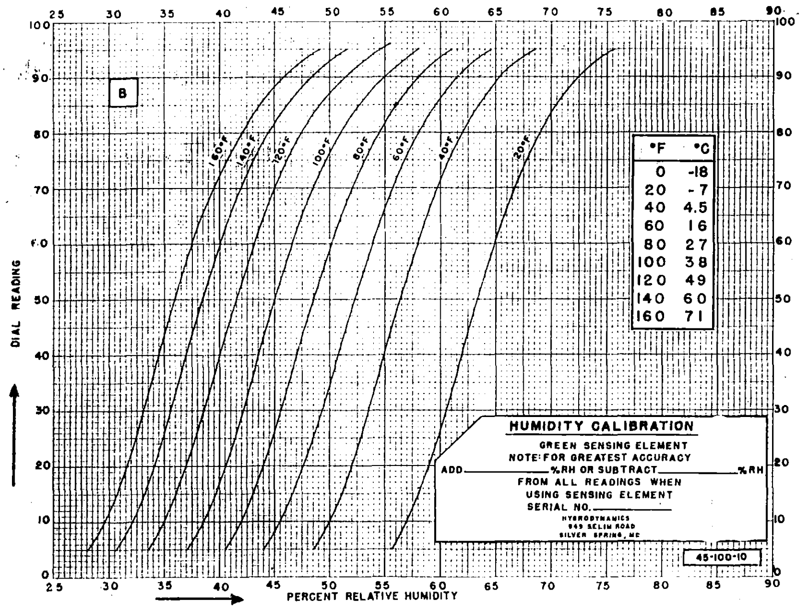

Figure 4– Calibration curve

For example, let the temperature be 84°F and the relative humidity be 87 %. Since the water activity equation is $A_w = \frac{R.H.}{100}$ the water activity can be calculated easily. $Aw = \frac{87}{100} = 0.87$

2.4. Microbiological Reactions in Intermediate Moisture Foods

Microorganisms require an aqueous environment in which to carry on the solute exchanges accompanying growth and reproduction. It is a matter of common observation that fluid aqueous solutions containing only innocuous components resist spoilage if they are sufficiently concentrated. Evidently the presence of a continuous liquid medium containing a substantial proportion of water molecules is not sufficient in itself to allow detectable growth of microorganisms (24,25).

The necessary interactions with the environment can occur in media which appear to be solid, but it is essential that there exist some continuous network of water molecules having a form permitting the solution and diffusion of metabolites. It is evident that immobilization of the water molecules to a degree which will prevent such interactions will occur at different moisture contents in different substances.

Moisture content thus seems to be an inexact indication of the susceptibility of a product to microbial spoilage. A factor which appears to be more closely related to conditions leading to the onset of microbial growth is the water activity of the system. Indeed, water activity is a significant factor in the growth and reproduction of the spoilage microorganisms (26,29).

Each species of microrganisms seems to have an optimum water activity at which it can grow, which usually lies between 1.0 and 0.9 (Figure 5).

Microbial growth can occur at water activity levels ranging from 1.0 to 0.65. As the water activity is increased above the optimum, the rate of growth falls sharply; as it is reduced below the optimum, the decrease in growth rate is usually less abrupt. Reduction in water activity leads also to an increase in the lag phase and for spores it leads to an increase in the time required for germination.

Molds are most resistant to lowered water activity. Most of the molds can germinate and grow only above a water activity of 0.8, but some species exhibit extremely low water requirements and grow, but slowly, at a water activity of below 0.65. Certainly this is a broad generalization and it should be noted that there are individual variations in resistance.

Several yeast can grow, at least slowly, at relative humidity levels of 85 to 92 %. Debaryomyces species have the greatest salt tolerance and could be induced to grow in 24 % salt brine, corresponding to a water activity of about 0.85. Von Schelohorn has noted the growth of some of the osmophilic yeasts at A_W 0.62.

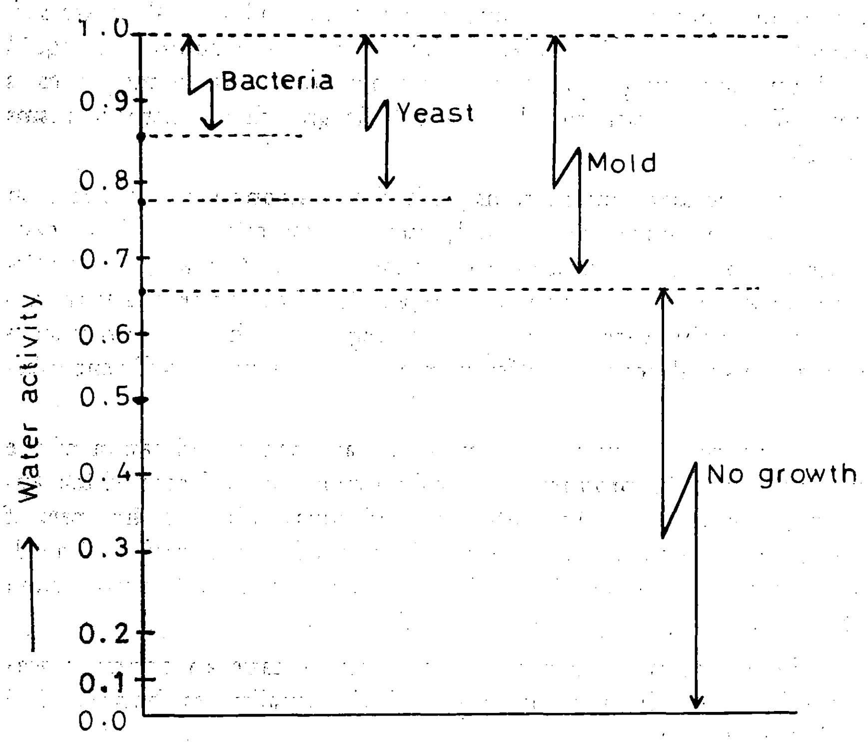

Figure 5– The level of water activity at which bacteria, yeast and mold grow.

Bacteria may be divided into halophilic and non-halophilic strains. Many species of bacteria don't grow below 0.95–0.96. But there are some that grow at a water activity as low as 0.86, in other words, bacterial growth can be prevented below this level of water activity. According to Scott (38), the lowest level at which bacterial growth has been observed is A_w 0.75, the water activity of a saturated sodium chloride solution.

Salmonella, E. coli, Staphylococcus aureus and Cl. perfringens don't grow at an A_w of 0.86. This is the minimum level of water activity for them.

Clostridium botulinum has been reported to grow only at an activity of water above 0.94.

As a whole, water activity must be lowered to at least 0.65 to prevent mold and yeast growth. To reduce the water activity to this level, a very high concentration of glycerol would be required. Such high concentrations of glycerol would have an undesirable influence on flavor. However, if an antimycotic and propylen glycol were added to the solution, less glycerol would be consumed, yet the growth of mold and yeast is suppressed.

20 % glycerol produces an A_w of 0.94. If the percentage of glycerol is increased to 60%, water activity of 0.79 is obtained.

2.5. Textural properties of intermediate moisture foods

One of most complex problems that arises with intermediate moisture foods is the deterioration in texture. Brittleness, dryness or excessive hardness are of the unwelcome textural changes that may occur. A related problem is the fragmentation and pulverization of leafy or fibrous dried foods which occur during storage and transportation (17,18).

The textural properties of dehydrated foods in intermediate moisture range are greatly affected by the hygroscopic equilibrium in terms of the water activity and residual moisture.

There is a relationship between the sorption of water and the textural properties. The adsorption of water vapor by the food is an exothermic proccess and heat is released. This heat produces a mouth-drying sensation when the food is mixed with the saliva during chewing.

The textural properties of the food at different water activities can be determined by three instruments, which are Kramer Shear Press (cutting test), Instron Universal Testing Apparatus (compression test) and Masticometer (penetration test) (Figure 6).

The curve obtained with the dry sandwich indicates the heterogenety of the food, as the punch of the instrument penetrates the first bread with a sharp increase in force, enters the softer meat layer with an intermediate drop of force and it continues through the second bread with an increase again of force. In all cases the force or hardness is different at different depths (11,22).

There is a general tendency of the meat to toughen as the relative humidity increases.

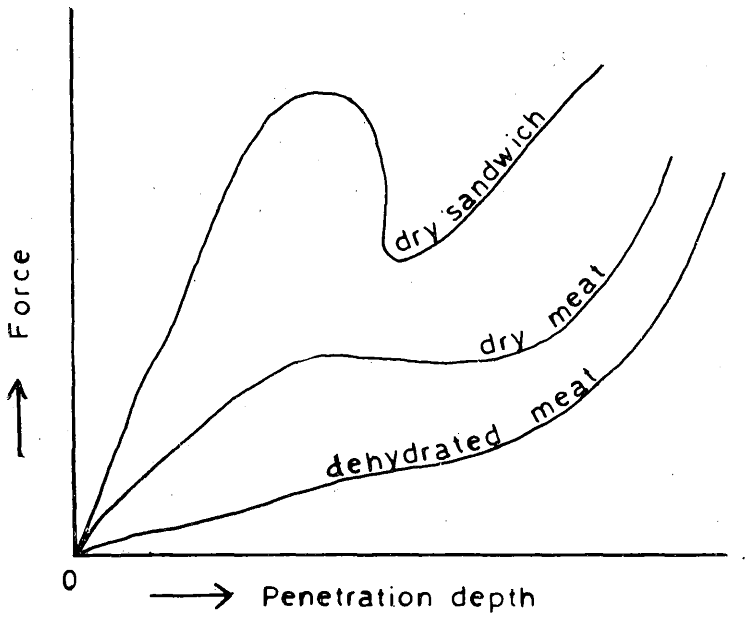

Figure 6– Typical masticometer curves.

2.6. Stability of intermediate moisture foods

Food is a complex substance consisting of lipids, carbonhydrates, protein and water. The various reactions of these compounds effect the extent of storage stability of intermediate moisture foods.

Lipid oxidation, non-enzymatic browning and the growth of microorganisms are the major limitation factors to the stability.

If the intermediate moisture foods can be held to the level of water activity above the point of maximum browning without microbiological deterioration, the storage life could be extended. One can certainly say that it is best to have moisture as low as possible, but the moisture content of many foods can not be lowered without damage; in other words, the results do not warrant the cost. On the other hand, oxidation of the lipids is to be feared at a low moisture content. Increasing moisture levels exert the protective in the lipid oxidation. Lipid oxidation leading to rancidity is most rapid at low moisture contents and its rate decreases as the humidity is increased. At still higher humidities it again increases. It should therefore be possible to find the moisture level at which these spoilage reactions occur not at all, or only very slowly. Lipid oxidation results in the production of carbony compounds that react with the pigments. Randicity in freezedried foods may occur due to the free radical reaction between unsaturated lipid and oxygen.

The other limitation to stability of intermediate moisture food is the growth of spoilage microorganisms. As the water activity increases the growth of spoilage microorganisms increases. To extend the storage life, aqueous solution of glycerol, salt, antimycotic and other FDA approved chemicals should be added.

The storage life of products whose spoilage reactions are triggered by enzymes might be judged on the basis of the sorption isotherm since they have found so far that the enzymatic reaction occur at a noticable rate only above the inflection point of the sorption isotherm. There is a remarkable dependence of enzymatic reaction on moisture content and the fact that if the enzymes are not inactive, they can play an important role in the deterioration of intermediate moisture food. This dependence of enzymatic reaction on moisture content can not be explained by the law of mass action but can be understood in relation to sorption isotherm of corresponding food.

Even at low water activity sucrose may be hydrolized to reducing sugars which have a potential for browning. The water has a dominant influance on the rate of browning on all carbonyl containing systems. For example, even 1 % moisture level, on a dry basis is not low enough to completely eliminate browning and ascorbic acid destruction on dehydrated orange crystals. For complete inhibition of these types of reactions a complete absence of water is essential. Non-enzymatic browning, which involves the reaction between carbonyl and amino compounds, increases as humidity increases up to a maximum in the intermediate moisture range then decreases again.

The peroxidase production, which is also a factor in the deterioration of intermediate moisture food, decreases as weter activity increases above the monolayer of water content.

2.7. Preparation of intermediate moisture foods

Foods of a high solute content can be brought into the intermediate moisture range by partial dehydration. This dehydration may be attained through equilibrium of water and solute between external and internal aqueous phases. Most of the intermediate moisture products have been prepared by equilibration with a glycerol solution to get a desirable level of water activity.

First, foods are dehydrated by sun drying, microwave, dielectric and freeze-drying etc. and infused with an aqueous solution containing additives required for preservation and palatability.

According to the methods of Brockmann (4,5) and Kaplow (16), the intermediate moisture food can de prepared by holding food in an "infusion solution" until the proper water activity is achieved. Brockmann (5) has formulated a special infusion solutions for chicken, pork and beef (Table 1).

Table 1. Preparation of intermediate moisture foods (meats).

	Chicken	Beef	Pork
Raw meat	1928 G	3600 G	130.6 G
Moisture	73.7 %	65 %	72.5 %
Immersion solution	3865 G	6660 G	
Water	45.0 %	45.9 %	
Glycerol	39.7 %	34.4 %	
Soup base	10.1 %	13.5 %	
NaCl	4.5 %	5.4 %	
K Sorbate	0.7 %	0.8 %	
Intermediate moisture (A_w)	0.84	0.83	0.82
Moisture	42.6 %	42.3 %	46.6 %

During the evaporation of water from the food containing a high solute content must be carfully controlled to avoid accumulation of solutes at the surface.

In general, meat items with water activity above 0.80 are soft, moist and tender but retain fibrous structure normal to the orginal meat. Odor of all meats is uniformly normal. Taste is somewhat sweeter than normal, but recognizable as cooked pork, beef, chicken, etc. Flavor is improved by addition of gray base material to the immersion solution. It is belived that intermediate moisture meat would be acceptable for casseroles and communation dishes. The equilibrium process is reversible. Immersion of intermediate moisture meat in a 2 % salt solution followed by a brief heating, eliminates the taste imparted by the glycerol.

If we could lower the water activity to 0.6, we would probably have a shelf stable food. To obtain a water activity of 0.6 requires 21.6 % salt as a solute in a mixture at 20 % moisture. Since this level of salt makes the food unpalatable, we can replace some of the salt with sugars or other food ingredients. To get a water activity of 0.8, 8.4 % salt is required.

Intermediate moisture foods prepared with glycerol, salt and antimycotic solution have been stored for three months at 38°C without significant changes in chemical, physical or sensory properties and without evidence of microbiological growth. Standard plate counts are generally reported as less than 10 per gram.

Outside of the meat industry the development of new intermediate moisture produtcs has been stimulated by the availability of antimycotic agents, such as potassium sorbate, which are effective at concentrations permitted for consumption. Most of the development has been directed to pet foods. They contain about 25 % moisture which eliminates the sensation of dryness. They are somewhat plastic, easily masticated, nutritionally balanced. To prepare this intermediate moisture product, 32 parts of ground meat by-products (e.g.beef tripe, gullets, udders) are cooked at 82–100°C with small amounts of sorbitol, propylene glycol, mono- and diglycerides, fat, salt, mineral supplement and potassium sorbate. The cooked components are mixed with 32 parts of soy flakes, 3 parts of milk powder, flavorings, vitamin concentrates and coloring materials and extruted in a desired configuration into an inexpensive plastic pouch which is subsequently sealed. The milk may serve as the ration-balancing protein supplement to the soy flakes, supplying the amino acids lacking in the soy flakes. Pet food prepared in this manner is distributed through normal market channels without refrigeration. These foods have proved virtually immune to microbiological deterioration. A sample of a *major brand* of intermediate moisture dog food has generally a water activity of 0.85.

It is recognized that the sweet taste imparted by the concentration of sucrose or glucose used for the stabilization of pet foods in the intermediate moisture range is incompatible with the normal meat flavor.

It is likewise apparent that meats stabilized by a high concentration of salt have limited acceptance and can not be considered for use as a major part of the daily caloric intake. On the other hand, preservation in the intermediate moisture range offers a number of attractive features. Intermediate moisture meats can be prepared with relatively simple equipment, do not require sophisticated packaging and can be stored and transported without refrigeration (36).

In considering the use of metabolizable compounds, guidance is provided by Rault's law which identifies the relationship between water activity and the amount of water and solute in a solution.

$$A_w = \frac{N_2}{N_1 + N_2}$$

Where N_1 and N_2 represent the number of moles of warer and solute respectively. Since approximately 6 moles of non-dissociated solute are required to depress the A_W of a kg of to 0.9, the organic solute must have a moderately high solubility and preferably a low molecular weigth. In addition, the solute must meet requirements for human consumption and have a relatively low taste impact. Glycerol is considered as the additive with the greatest probability for success.

The production of intermediate moisture human foods stays behind the production of intermediate moisture pet foods. In the first place, pet food uses sugar and salt to lower the water activity. While dogs don't seem to mind these excessive additive in their meat, such a combination is something less than exciting to human consumers. Using high concentration of glycerol reduces palatability. Secondly, intermediate moisture food does not have a desired texture and efficient flavor.

3. *Conclusion*

Today the commercial potential for IMF seems to be immense. They offer a combination of shelf stability, convenience, ease of nutrient content adjustment and safety. The expantion of the IMF pet food market clearly proves the practical potential for these foods. In contrast, these types of foods for human consumption are evaluated on the basis of fare more complex requirements, such as organoleptic quality, safety, food preferences, prejudices and taboos. In this concept, modern IMF have been slow in human food systems, primarily bacause of poor organoleptic acceptebility, but the relevant problems are believed to be solved in the near future, by developing new formulations containing humectants of high organoleptic acceptability, finding more effective antimicrobial agents and controlling the non-enzymatic browning reactions.

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