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IMF: To Enhance the Shelf-Life of Food

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ABSTRACT

Drying is the oldest method of food preservation. By reducing the moisture content and water activity the microbial stability of the food materials can be increased. The minimum water activity (a_w) for microbial growth is approximately 0.6. But in case of dehydration the texture, palatability and some physical properties of the food materials can be decreased. Intermediate moisture food (IMF) are shelf-stable products having water activities of 0.6-0.84, and the range of the moisture content from 15%-40% and are edible without rehydration. Osmotic dehydration has many advantages include low processing temperatures, short drying times, and 20%-30% lower energy consumption than typical dehydration processes. Sugar is the most important agent used as the humectants for candied intermediate moisture fruits, and salt is used for intermediate moisture vegetables and fish. Most of the fresh fruits can be transformed into IMF or candied fruit (also known as crystallized fruit) without adding synthetic colors and flavors or gelling agent. In this review paper the how different IMF enhance the self-life of the food materials are discussed.

KEYWORDS: *Intermediate moisture food (IMF), Osmotic Dehydration, Shelf-life, water activity.*

INTRODUCTION

Intermediate moisture foods are shelf stable products.[1] The purpose of IMF is to achieve a water activity(a_w) that the food can be stored safely without refrigeration but the quality of food will be totally fine by using sugar syrup or many types of sweetening agent. The mixing of ingredients to achieve a given (a_w), which is allowed safe storage to maintain enough water for palatability on an empirical basis. Intermediate moisture foods (IMF) are rely heavily on the addition of humectants and preservatives to prevent or reduce the growth of microorganisms. The rates of chemical reactions deteriorate foods prepared to an intermediate moisture content and water activity (a_w). The water content is the controlling factor for lipid oxidation model systems comprised of a solid support and an oxidizable liquid. Metal chelating agents like EDTA give good protection to oxidation i.e. exhibited the highest efficacy, about 10-15 times better than BHA[2] which is a radical scavenger. IMF is based on a cereal: legume mixture with calcium and flavour, which supplies proteins, carbohydrates and vegetable oils; high energy density (3.22 cal/g) and covers up to 51% of calcium needed. [3] It can be easily consumed as a tasty and soft food. This types of foods have a water activity (a_w) of 0.80, for it can be stored at room conditions. Methylcellulose, propylene glycol, citric acid, modified starches are the agents for making intermediate moisture foods.[4]

SHELF-LIFE & SAFETY

The main purpose of IMF is to achieve a water activity [2](a_w) that the food can be stored safely without refrigeration. The shelf life of a food is the time during which a food retains an acceptable quality from a safety and organoleptic view that

depends on four main factors: FORMULATION, PROCESSING, PACKAGING AND STORAGE CONDITIONS.[5] A microorganism named Staphylococcus aureus which concerns as it can grow and produce specific enterotoxins in water activities of 0.83-0.86 under aerobic conditions. For this reason, proper handling, storage, hygiene and good manufacturing practices are necessary to prevent Staphylococcus aureus. The molds of Aspergillis and Penicillium species can grow and produce harmful mycotoxins at water activity 0.77-0.85.[6]There are some primary pathogens of concern with low moisture foods and IMFs like Salmonella and Bacillus cereus,[7] which causes the most illnesses associated with low moisture foods or IMFs. A combination of a low pH, addition of sugar, salt and preservatives, and any thermal process are used to reduce the risk of bacterial growth that can eliminate pathogens and extend shelf-life. Chemical preservatives such as sorbate and propionates are used in case of yeasts and molds to inhibit their growth. Here is a bar graph to show the shelf life of different foods.[8][12] [13]

Ingredients	Parts by weight
Chopped meat by-products (tripe, udders, cheek trimmings, tongue trimmings, gullets, etc.)	32.0
Defatted soy flakes	31.0
Sucrose	21.7
Flaked soy bean hulls	3.0
Dicalcium phosphate	3.0
Dried non-fat milk solids	2.5
Propylene glycol	2.0
Bleachable-fancy tallow	1.0
Mono- and diglycerides	1.0
Sodium chloride	1.0
Potassium sorbate	0.3
FD & C red dye	0.006
Garlic	0.2
Vitamin and mineral premix	0.06

Analysis of examples of Intermediate moisture foods:[9]

Cubes	Water content (%)	Average percent salt	pH	Water activity
Roast beef	22.2	3.0	5.75	0.79
Barbecue beef	16.2	2.7	5.05	0.66
Roast pork	22.4	3.6	5.70	0.74
Barbecue chicken	19.7	4.0	5.20	0.70
Chicken a la King	14.9	3.6	5.90	0.61
Beef stew	17.3	3.7	5.80	0.65
Corned beef	16.2	5.4	5.85	0.62
Chili with beans	13.9	2.6	5.65	0.79
Sausage	24.2	4.5	4.90	0.78
Ham	19.9	4.5	5.90	0.72

Characteristics of some recently developed IMFs [9]

Characteristic	IMF Catfish	IMF Coconut milk	IMF Cheese
a_w	0.8	0.75-0.8	0.82
Water (%)	26.6	30-35	~25
pH	6.4	7	5.2
Additives	K-sorbate	0.1% sorbic acid	K-sorbate
	P.G.[a]		P.G.
	Sorbitol		NaC1
	Sucrose		
	NaC1		

P.G. = propylene glycol.

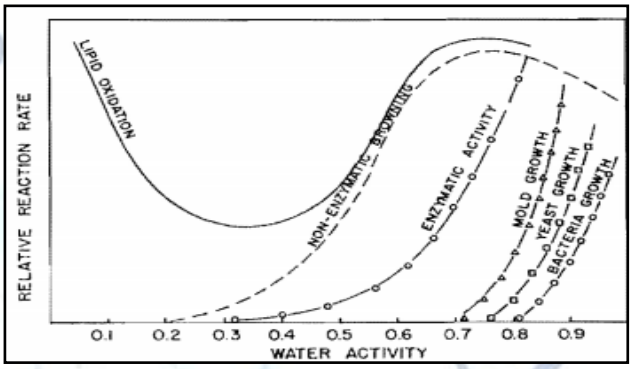


Fig.1:Rate of reactions vs water activity graph [9]

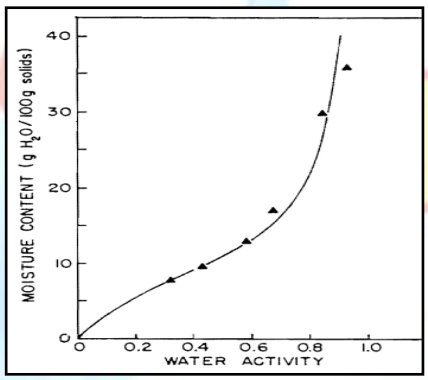


Fig2: moisture content vs water activity graph[10]

Water Activity (a_w) [11]:

The unbound water is termed as the water activity (a_w).[12] The ratio of vapor pressure of water in food to the vapor pressure of pure water at the same temperature is defined as water activity. Solutes are dissolved in water to bind the water molecules and to make them not available for microorganisms to use.[13] It is measured on a scale of 0 (no moisture) to 1.0 (pure water). To describe the water activity (a_w) of air, the term "Relative Humidity (RH)", which is (a_wx 100)? By having a water activity below 0.90, most bacteria are not able to grow in foods. Browning, staling and oxidation are the undesired chemical reactions for baked food products, greatly influenced by a_w as well. [14]

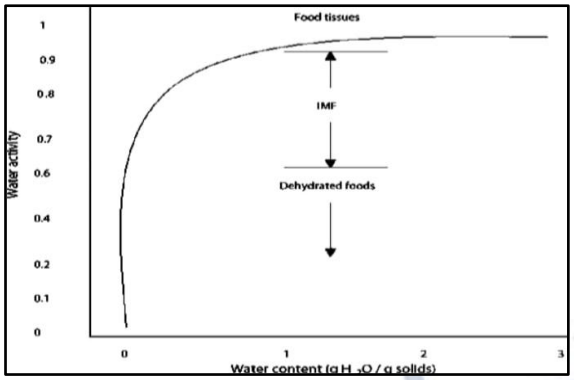


Fig3: Water activity vs water content graph [15]

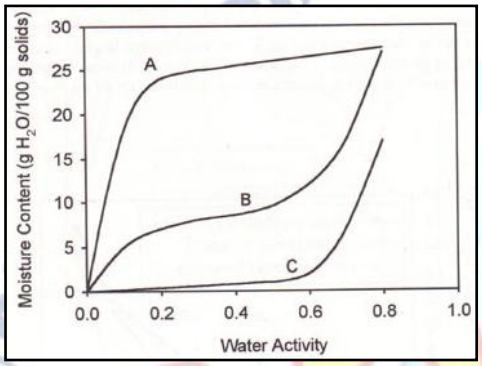


Fig4: Water activity vs moisture content graph [16]

Definition of (a_w):

$a_w = p/p^*$

Where p is the partial vapor pressure of water in the solution, and p* is the partial vapor pressure of pure water at the same temperature.

Alternate definition:[17]

$a_w = l_w x_w$

Where $l_w$is the activity coefficient of water and x_w is the mole fraction of water in the aqueous fraction.[18]

Equilibrium relative humidity (ERH): a_w x 100%

Estimated mold-free shelf life in days at 21^{0}C:[19]

MFSL: $10^{7.91-8.1Aw}$

Water activity of some intermediate moisture foods:[2][13]

Range	Food
0.85-0.75	Sweet condensed milk, fruit cake, salted fish, molasses, jams , dog food, dried fruits, icings, soy sauce,
0.75-0.65	Dates, figs, nuts, Parmesan cheese, dulce de leche
0.65-0.60	Honey, chocolate bars, marshmallows, biscuits.

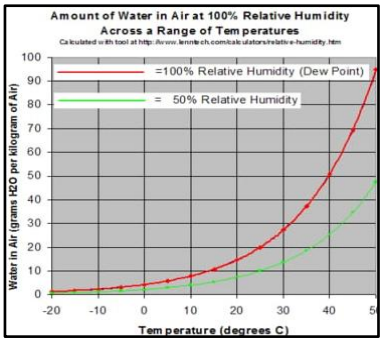


Fig 5: Water in air vs temperature graph.

Process for IMFs:[20][21]

There are many processes to have intermediate moisture foods with low water activity. Some ways of processing is described below [22] :

- ✓ **Partial drying[23]:**

Partial drying [24] is the most employed for raw foods that naturally have a high amount of humectants such as raisins, apricots, prunes and sultanas to achieve a water activity between 0.6-0.84 in food products. Humectants are basically solutes (such as sugar or salt) which immobilize water in food. The process of drying removes free water, and the humectants [25] in the product bind the rest of water not allowing the water to be utilized for chemical reactions or for microbial use.[26][27]

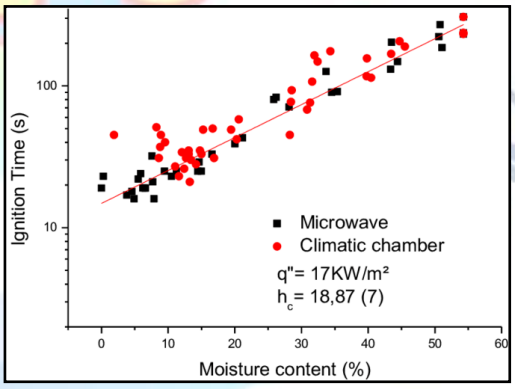


Fig 5: Moisture content vs Ignition time graph

- ✓ **Osmotic drying using a humectants:[29]**

The process named osmotic dehydration[30] is used for soaking food in highly concentrated solutions of humectants. Salt and sugar are the most commonly used humectants for the osmotic dehydration process. For osmotic pressure water diffused from the food to the humectant solution. Humectants replaced the water, which results in a lowered water activity for the food product.[41]

The results of using osmotic dehydration process, we get in two way mass transfer in regards to the moisture lost and the gain of solids, with moisture loss being much greater than the addition of solids. There are advanges of osmotic dehydration including low processing temperatures, short drying times, and 20-30% lower energy consumption than typical dehydration processes. Sugar is used for candied Intermediate moisture fruits and salt is used for Intermediate moisture vegetables and fish. To manipulate the sensory properties of the food product, a mixture of humectants can be formulated additionally. By using this osmotic drying process, using a humectants result in a soft texture in the final product.

✓ **Dry infusion[31]:**

The combination of partial dehydration and osmotic dehydration using a humectant is called dry infusion. At first the food product is dehydrated and and then the resultant product is added to a humectant solution to reach the desired water activity (a_w). [32]As it results in a higher quality and more appealing product, this method is desirable. It is two processing steps combined, so more energy is used for this method. By using this dry infusion[33] process we can make IMFs to produce safe, palatable food that can be consumed much later than it is produced.

✓ **Formulated Intermediate moisture foods:**

To achieve water activity (a_w) in the IMF[51] range, many types of foods are specially formulated. Many food ingredients are mixed with salt and/or sugar, and additives (such as potassium sorbate[34] and propylene glycol) and then they are subjected to processing methods such as cooking, extrusion or dehydration to get the reasult in an Intermediate moisture final product.[45] Confectioneries and pet foods are the example of Formulated Intermediate moisture foods.

- **Water activity of aqueous solutions of some potential food humectants (22⁰C):[35][36]**

Humectant	Concentration %wt/wt	Approximate water activity
Sucrose	58.4	0.90
	67*	0.86
Glucose	47*	0.92
Invert sugar	63*	0.82
Sucrose 37.6% and Invert sugar 62.4%	75*	0.71
NaCl	9.3	0.94
	19.1	0.85
	27*	0.74
Lactose	14.5*	0.99
Maltose	48.8*	0.95

* Saturated solution.

Applications of intermediate moisture foods:

✓ **Fruits and Vegetables[39]:**

To protect against microbial contamination and reduce water activity, sugar is added to fruit. It allows the fruit to be more stable at room temperature. There are some examples like strawberries, prunes, peaches, apricots and pineapples. By osmotic dehydration, IMF blueberries are prepared. Until the desired moisture level is reached, they are soaked in sugar for one to two days followed by a freeze drying process.

✓ **Meat:[40]**

Without refrigeration fermented meats, sausage, jerky, and corned beef can last many months. In the Middle East and Mediterranean countries, pastrima is a beef product that is often eaten raw. Pastrima is a type of Intermediate moisture food that can be stored for several months in humid climates. Here salt is used for drying to reduce water activity and increase microbial safety. Nitrites are added additionally for preservation. [41]

✓ **Pet Food:[42]**

Pet foods which are semi-moisted such as Chewy dog treats and soft cat treats are shelf-stable, soft and have low moisture content. To achieve lower water activity, ingredients are added to Intermediate moisture pet foods such as soy flakes and wheat flour in addition to solutes such as glycerol, salt and sugar. Extrusion is one of the most used processing techniques, to attain the Intermediate moisture pet foods. [43]Intermediate moisture pet foods leave fewer odors and are less messy than canned wet pet food. Intermediate moisture pet foods are convenient products. So Intermediate moisture pet foods are found to be more palatable to pets than dry pet food products. [45]

✓ **Baked goods and Confectioneries:[46]**

Cakes are considered as Intermediate moisture foods because their moisture content is in between 18%-28%, and are having low enough water activity that preserve with safety and quality.[47] There are some examples of baked goods and confectioneries that come under this category are fruit cakes, pie fillings, candies, marshmallows, jams, pizza crust. A candy-like product named Tutti-frutti that can be made from a variety of fruits, most commonly papaya. Mainly raw pieces of unripe papaya are boiled and layered with sucrose until reaching 68 degrees brix. Then the

solution is air-dried until a moisture content of 25.7% is reached. [13]

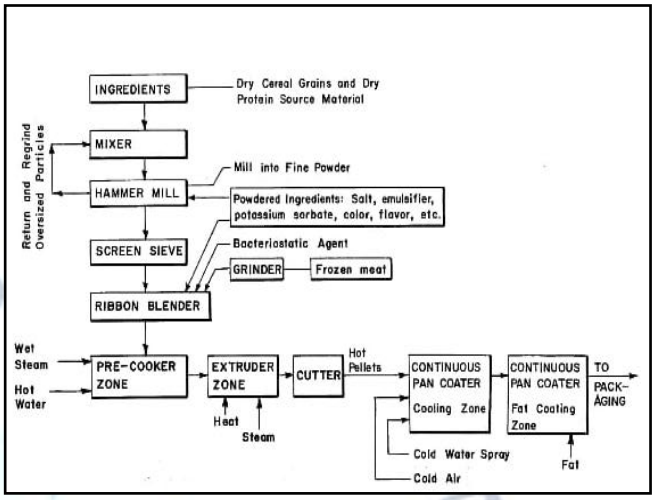
Advantages of Intermediate moisture foods:

Intermediate moisture foods utilize hurdle technology by lowering water activity (a_w), reducing pH and using preservatives, to achieving microbial stability and safety. IMF processing methods can reduce water activity to 0.60-0.84 and most of the bacteria cannot grow under a water activity of 0.90.[46] IMFs are ready-to-eat and not required refrigeration. To prolong shelf life and delay flavor and color changes, nitrites and sulphites are added to food. Propylene glycol is a water activity reducing agent and acts as a plasticizing agent to give food its desired texture. IMF food processing is less rigorous compared to canning, dehydration and freezing and results in less nutrient loss. IMF processes are occurred at lower temperatures, pressures, and there is no water leaching of nutrients. Since IMFs do not require refrigeration [50], IMF production is more energy efficient compared to conventional processes including canning and freezing [48]. IMFs are common in developing countries because the energy required for canning and freezing is costly. IMFs are not readily subject to spoilage, even if packages have been damaged prior to opening, as with thermo stabilized foods, because of low water activity (a_w).[47]

Disadvantages:

Some of the IMFs contain high levels of additives (i.e. humectants, nitrites, sulphites etc.) which may cause health concerns and possible legal problems. The cause of concern is high sugar content because of the high calorific intake. So, the efforts are been made to improve the quality of such foods by decreasing sugar and salt addition, as well as by increasing the moisture content and a_w, but without sacrificing the microbial stability and safety of products if stored without refrigeration.[49]

Fruit products from IMFs have potential in markets.[49]Applications of this technology[50] are to produce stable products at ambient temperature is limited by the high concentration of solutes required to reduce water activities to safe levels. This usually affects the sensory properties of the food.[51]



CONCLUSION:

IMFs are shelf stable and it retains the activity of microorganisms by lowering water activity (a_w). By using IMF many fruits and vegetables can be stored without refrigeration. These are the advantages of IMFs. There are also some disadvantages like diabetes patients can't take IMFs because of their high sugar content (i.e. humectants).

References:

[1] "Hazard analysis and risk based preventive controls for human food: Draft Guidance for industry". (PDF)
[2] Water activity in foods
[3] Food processing and technology: principles and practice (4th ed.). Kent: Wood head publishing/ Elsevier Science.
[4] World Health Organization, Food and Agriculture Organization of the United Nations (2015). "Code of hygienic practice for low-moisture foods". Codex Alimentarius.
[5] Leistnar, Lothar (2000). "Basic Concepts of food preservation by hurdle technology". International journal on food microbiology.
[6] Sagar V.R.; Suresh K.P. (2010). "Recent advances in drying and dehydration of fruits and vegetables: a review". Journal of food science and technology.
[7] Handling and preservation of fruits and vegetables by combined methods for rural areas.
[8] Food preservation by moisture control: fundamentals and applications.
[9] "The storage and preservation of meat: ll moisture control". Lawrie's meat science.
[10] Lothar., Leistner (2002). Hurdle technologies: combination treatments for food stability, safety and quality.
[11] The technology of food preservation. Desrosier, James N. (4thed.).
[12] Nature of cakes. Cauvain, S.P.CAKES.
[13] Microbiologically safe foods for the 21st century. Heredia, Norma., Wesley, Irene., Garcia, Santos, 1961-,
[14] Willey InterScience. Oxford: Willey-Blackwell (2009).
[15] Lothar., Leistner (1992). "Food preservation by combined methods". Food Research International.

[16] Dahle , H.K. (December 1979). “Nitrite as a food additive”. NIPH Annals.
[17] Vally, Hassan; Misso, Neil LA (2012). “Adverse reactions to the sulphite additives”.
[18] The deterioration of intermediate moisture foods. Science.gov (United States). Labruza, T.P.(1971).
[19] Mechanism of deterioration of intermediate moisture food systems.. Science.gov (United States). Labruza, T.P.(1972).
[20] Storage stability and Improvement of intermediate moisture foods, Phase 3. Science.gov (United States). Labruza, T.P.(1975).
[21] An intermediate moisture meat. African Journals Online (AJOL). STORAGESEVER (2008).
[22] Use of Edible Laminate Layers in intermediate moisture food Rations to inhibit Moisture Migration. Science.gov (United States) (2016).
[23] Evaluation of the efficacy of four weak acids as antifungal preservatives in low-acid intermediate moisture model food systems. . Science.gov (United States) Huang, Yang; Wilson, Mark; Chapman, Belinda; Hocking, Ailsa D (2010).
[24] An intermediate moisture meat. African Journals Online (AJOL). Bunmi.
[25] Strategies to increase the stability of intermediate moisture foods towards Zygosaccharomycesrouxii: The effect of temperature, ethanol, pH and water activity, with or without the influence of organic acids. DEFF Research Database (Denmark). Vermeulen, A,; Nielsen, Cecillie Lykke Marving; Daelman, J (2015).
[26] Effects of addition of hypocolloids on the textural and structural properties of high-protein intermediate moisture food model systems containing sodium caseinate.Science.gov (United States). Li, J; Wu,Y; Lu, N; Regenstein, J M; Zhou, P (2017).
[27] Shelf stable intermediate moisture fruit cubes using radiation technology. International Nuclear Information System (INIS). Mishra, Bibhuti B; SaxenaSudhanshu; Gautam, Satyendra; Chander, Ramesh; Sharma, Arun (2009).
[28] Water activity reduction of intermediate moisture yellow strip trevally (Selaroidesleptolepis) Directory of Open Access Journals (Sweden) Phomajun, P (2005).
[29] Stability and anti-glycation properties of intermediate moisture pineapple products. Science.gov (United States). Lavelli, Vera; Corey, Mark; Kerr, William; Vantaggi, Claudia (2011).
[30] Intermediate product selection and blending in the food processing industry. NARCIS (Netherlands) Killic, Onur A, Akkerman, Renzo; van Donk, Dirk Pieter; Grunow, Martin (2013).
[31] Intermediate product selection and blending in the food processing industry. DEFF Research Database (Denmark)Killic, Onur A, Akkerman, Renzo; van Donk, Dirk Pieter (2013).
[32] Effects of chemical composite, puffing temperature and intermediate moisture content on physical properties of potato and apple slices. Science.gov (United States). Tabtaing, S; Paengkanya,S; Tnthong, P (2017).
[33] Modeling Intermediate product selection under production and storage capacity limitations in food processing. DEFF Research Database (Denmark)Killic, Onur A, Akkerman, Renzo; van Donk, Dirk Pieter (2009).
[34] Influence of moisture content on microbial activity and silage quality during ensilage of food processing residues. Science.gov (United States) Zheng, Yi; Yates, Matthew; Aung, Hnin; Cheng, Yu-Shen (2011).
[35] Study of benzoate, propionate and sorbate salts as mould spoilage inhibitors on intermediate moisture bakery products of low pH (4.5-5.5).Science.gov (United States). Guynot, M E; Ramos, A J; Sanchis, V; MarAn, S (2005).
[36] A new method to determine the water activity (a_w) for low moisture foods for elevated temperatures. Science.gov (United States) Tadapaneni, Ravi Kiran; Yang, Ren; Carter, Brady; Tang, Juming (2017).
[37] Control of final moisture content of food products baked in continuous tunnel ovens. Science.gov (United States) McFarlane, lan (2006).
[38] System-level analysis of food moisture content requirements. Science.gov (United States) Levri, Julie A,; Perchonok, Michele H (2004).
[39] Corry, J. E. L. 1976. The safety of intermediate moisture foodswith respect to *Salmonella.* pp. 215-238. In R. Davies, G. G. Birchand K. J. Parker (eds.) Intermediate moisture foods. Applied Science Publication, London.
[40] Rothmayr(eds.) Freeze drying and advanced food technology. Academic Press, New York.
[41] Kaplow, M. 1970. Commercial development of intermediate moisture foods. Food Techno.
[42] Karel, M. 1973. Recent research and development in the field of low-moisture and intermediate-moisture foods. CRC Crit. Rev.Food Technology.
[43] Karel, M. 1975. Stability of low and intermediate moisture foods.pp. 643-674. ln S. A. Goldblith, L. Rey and W. W. Rothmayt(eds.) Freeze drying and advanced food technology. Academic Press, New York.
[44] Karel, M. 1976. Technology and application of new intermediate moisture foods. pp. 4-31. In R. Davies, G. G. Birch and K. J.Parker (eds.) Intermediate moisture foods. Applied Science Publishers, London.
[45] Labuza. T. P. 1970. Properties of water as related to the keeping quality of foods. Proc. 3rd Intern. Congr. Food Sci. Technology.618-635.
[46] Labuza, T. P. 1980. Water activity: Physical and chemical properties. pp. 320-325. In P. Linko, Y. Malkki, J. Olkku, and J.Larinkari (eds.) Food process engineering, Vol. I. Applied SciencePublishers, London.
[47] Labuza, T. P. 1980. The effect of water activity on reactionkinetics offood deterioration. Food Technology.
[48] Labuza. T. P, and M. Saltmarch. 1980. The non-enzymatic browning reaction as affected by water in foods. In L. B.Rockland and G. F. Stewart (eds.) Properties of water related to food quality and stability. Academic Press, New York.
[49] Lang. K. W. and M.P. Steinberg, 1980. Calculation of moisture of a formulated food system to any given water activity. J.Food Sci. 45:1228-1230.
[50] Flink, J. M. 1977. Intermediate Moisture Food Products in the American Marketplace. J. Food Proc. Pres.
[51] Hardman, T. M. 1976. Measurement of water activity. Critical appraisal of methods. pp. 75-88. In R. Davies, G. G. Birch and K.J. Parker (eds.) Intennediate moisture foods. Applied SciencePublishers, London.
[52] Harper, J. M. Food extrusion. CRC Crit. Rev. Food Sci. Nutr. Heidelbaugh, N.D., and M. Karel. 1975. Intermediate moisture food technology. pp. 619-641. In S. A. Goldblith, L. Rey and W.W