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SHELF LIFE OF FREEZE DRIED YOGURT

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SHELF LIFE OF FREEZE DRIED YOGURT

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ABSTRACT

SHELF LIFE OF FREEZE DRIED YOGURT

By

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This study investigates the shelf life of freeze dried yogurt. The freeze drying process has gained popularity in recent years because of minimal structural change in the food system. Low-fat fresh yogurt was freeze dried and packaged in pouches. Three differnt materials, Low Density Polyethylene, Laminate (PET/Al/PP), and Kraft paper were evaluated. The shelf life studies were done at both ambient conditions (70 F, 50% RH) and accelerated conditions (100 F, 85% RH). Analytical methods used to monitor the quality of yogurt were culture viability, package head space analysis, color change and change in pH. Also sensory analysis was done to compare flavor changes between fresh yogurt and reconstituted yogurt after storage. Results indicate that a good quality freeze dried yogurt powder with viable organisms can be obtained. The laminate pouch showed the best results for extended shelf life of freeze dried yogurt.

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1.0 INTRODUCTION

Since its introduction in the United States less than fifty years ago, yogurt consumption has increased immensely. Per capita consumption of yogurt has increased from .90 lbs in 1974 to 2.7 lbs in 1980 (Mullins, 1983). Much of the success of yogurt can be attributed to an overall concern with diet. Forty percent of yogurt is consumed as a snack and another twenty percent each, account for breakfast and lunch (Anonymous, 1984). In addition, innovative packaging has complemented yogurt and yogurt products. The role of plastic packaging in recent years has been favored over paper and further enhanced yogurt consumption (Keck, 1983). Multi-color graphics and package design are reasons for this dominance.

Freeze drying, a novel dehydration technique, developed in the mid forties, is gaining popularity in food preservation because the process involves a minimal structural change in the food (Anonymous, 1980). At present freeze drying has become a standard practice in the food industry for the preservation of fruit juices, instant coffee, eggs, meat, mushrooms and many other products (Zaidi et-al, 1979).

The purpose of this investigation was to evaluate the influence of different packaging systems on the shelf life of freeze dried yogurt. The quality of reconstituted freeze dried yogurt was evaluated using both sensory and analytical tests. Analytical methods included: culture viability, package head space analysis, color change and change in pH. Sensory analysis was done to compare flavor change between fresh yogurt and reconstituted packaged freeze dried yogurt subjected to storage at room conditions (72 F, 50% RH) and accelerated conditions (100 F, 85% RH).

2.0 LITERATURE REVIEW

2.1 Yogurt

Yogurt is a coagulated milk product obtained by lactic acid fermentation of milk by *Lactobacillus bulgaricus* and *Streptococcus thermophilus*.

The micro-organisms in the final product must be viable and abundant (Tamime & Deeth, 1977). Yogurt is a relatively tart, high acid product with a characteristic flavor different from other fermented milk products (Vedamuthu, 1976). Sellers (1978) defines yogurt as a fermented milk with a custard-like consistency. This semi-solid characteristic differentiates yogurt from other fermented milks. Reed (1981) described yogurt as having a smooth, shiny appearance and a fresh, sour aromatic flavor. Definitions for yogurt are many and remain open and sometimes controversial. What cannot be disputed is yogurt's obvious popularity.

Recognized by various spellings and names, yogurt is known around the world (DeHaast et-al, 1979). Not just an established dairy product, yogurt is a perfect alternative to junk and snack foods (Helferich and Westhoff, 1980).

2.1.1 History:

The fermented milk product yogurt as it is called in the United States, derives its name from the Turkish word jugurt (Tamime and Deeth, 1980).

Although there is no precise record of its introduction, yogurt is recognized as a product of one of the oldest methods of food preservation (Anonymous, 1984). Many have called yogurt the most famous food product known to man for over 4500 years (Steinberg, 1982). The actual discovery of yogurt is unclear but many theories have been suggested and all areas of the world lay claim to its origin. In actuality the discovery of yogurt (as with most fermented foods), was probably accidental since the phenomenon of bacterial fermentation was not realized nor understood at the time of discovery. The earliest form of yogurt was accepted because unlike milk, it could be stored and consumed for several days. The earliest scientific knowledge of yogurt and lactic acid bacteria was around 1900 (Helferich and Westhoff, 1980). It wasn't until 1939 that yogurt was introduced into the United States from France. Plain yogurt was the only flavor produced. In the late forties, fruit preserves were added on the bottom (sundae style). Twelve flavors including plain were now available.

Around 1951 a fluid yogurt was introduced that was initially quite promising. Sales of regular yogurt soon overpowered the liquid product due in part to the introduction of Swiss Style (fruit suspended throughout), which entered the market a few years later. It is quite possible that in 1951 liquid yogurt was ahead of its time (Steinberg, 1979). In 1960 frozen yogurt was introduced in 4 oz. cups and was readily accepted. Demand continued to grow as frozen yogurt was sold in cones and marketed as a soft serve treat. In addition, a variety of frozen yogurt novelties entered the market place.

Yogurt and yogurt products have sparked new interest in the dairy industry. Yogurt drinks, bars and even yogurt liqueurs have been introduced in the past few years. Still, the market for yogurt and yogurt products is merely a fraction of what is seen in European countries. The eighties should provide ample opportunity for the yogurt market to grow, both in sales and in the development of new products and uses for yogurt.

2.1.2 Yogurt Trends:

Yogurt which was somewhat of a wallflower food category several decades ago, has been steadily blossoming during the past twenty years (Przybyla, 1983). Yogurt, although the smallest segment of the dairy industry is growing at the fastest rate (Mullins, 1983). Continuing the growth pattern of the past decade yogurt sales are expected to rise at a rate more than twice the U.S. inflation rate throughout the rest of the 80's and 90's (Anonymous, 1982). Annual sales growth of yogurt was greater than 16% during the 1960's, more than 14% during the 1970's and real sales growth of yogurt products is expected to be 8% throughout the 1980's (Anonymous, 1982). Yogurt sales since 1970 are shown in Table 1.

TABLE 1: Sales of Yogurt

	Yogurt Sales ($mils)	Annual % Change	Per Capita Yogurt Sales (Dollars)
1970	43.4		0.22
1971	61.2	41.1	0.30
1972	75.3	23.1	0.37
1973	92.2	22.4	0.44
1974	110.3	19.6	0.53
1975	150.1	36.1	0.71
1976	189.7	26.4	0.89
1977	215.9	13.8	1.01
1978	247.6	14.7	1.14
1979	278.6	12.5	1.27
1980	316.5	13.6	1.39
1981	362.7	14.6	1.63
1982	402.6	11.0	1.78
1992F	1,307.2	12.5 *	5.22

F - forecast by Business Trend Analysis
* - compound annual growth

Source: Dairy Field, 165(12):26,30

Yogurt consumption in the U.S. is now more than 2.7 lbs. per capita and has increased about 5% a year, which is higher than the average for all food products (Anonymous, 1985). The $622 million 1984 market will grow 22% by 1988 reaching $757 million (Anonymous, 1985). By 1990 total sales should reach $1.4 billion (Horwich, 1983). Others predict total sales volume will be slightly lower at $1.3 billion with 1.3 billion pounds being consumed by 1990 (Anonymous, 1982). Growth of the yogurt market from the 1960's to 1990 estimates are outlined in Table 2.

Enhanced by its image as a health food, yogurt should be one of the top selling dairy products in 1988 (Anonymous, 1985). Yogurt consumption has been helped by the fitness trend and is now a symbol of todays health conscious consumer (Anonymous, 1985). As popular as yogurt has become across the United States, per-capita consumption in Europe is thirty times as high. There clearly is plenty of room for total market expansion (Banner, 1985). Yogurt acceptance in different forms presents a real opportunity for the dairy industry to boost consumption by catering to unfulfilled market segments (Steinberg, 1983).

As manufacturers create line extension and develop new products with yogurt they should also concentrate on new outlets for its use. The food service industry is virtually an untapped market. Restaurants, fast food chains and vending machines are possible selling places.

TABLE 2: Growth of the Yogurt Market

	Yogurt Sales (Mil. lbs.)	Annual % Change	Per Capita Sales (lbs.)
1960	44.1	--	.26
1961	49.0	11.1	.28
1962	45.0	-8.2	.25
1963	50.4	12.0	.28
1964	53.0	5.2	.29
1965	60.6	14.3	.32
1966	70.0	15.5	.37
1967	90.2	28.9	.47
1968	123.5	36.9	.63
1969	169.0	36.8	.85
1970	171.6	1.5	.86
1971	236.3	37.7	1.16
1972	284.0	20.2	1.38
1973	317.9	11.9	1.53
1974	343.2	8.0	1.64
1975	445.4	29.8	2.11
1976	481.7	8.1	2.27
1977	533.5	10.8	2.49
1978	565.4	6.0	2.61
1979	566.7	0.1	2.59
1980	588.8	3.9	2.67
1981	635.9	8.0	2.86
1982	683.6	7.5	3.02
1992F	1,223.6	6.0 *	4.89

F - forecast by Business Trend Analysis
* - compound annual growth

Source: Dairy Field, 165(12):26,30

The potential marketing of yogurt to the food service industry is great. It can be used as a light protein source, as an additive or component in ethnic foods, in garnishes and dips or as an element in salads or salad bars (Anonymous, 1983). The use of yogurt as a cooking ingredient or as a food additive is still relatively undeveloped. The challenge is to appeal to the non-users by creating new and exciting forms of yogurt as well as developing new uses for yogurt. Yogurt is cultured dairy products' glamorous star and the opportunities are great (Krier, 1985).

2.1.3 Packaging Trends:

Yogurt packaging has gone through many changes since neolithic times when it was first discovered in goat skin bags and later fermented in clay pots (Anonymous, 1983). In the 1930's yogurt was a staple food product throughout most of Europe. Yogurt was sold in Europe in small crockery pots or jars (Steinberg, 1979). A sheet of printed cellophane covered each container, held in place by a rubber band. Jars held as little as 90 grams (3.5 oz.) and as much as 225 grams (8 oz.) of yogurt. In Switzerland during the same time period yogurt was sold in glass jars with metallic foil covers.

When yogurt was introduced to the United States it was sold in thick returnable glass jars that held 8 oz. In the late forties waxed paper cups were used. Today nearly 90% of yogurt packaging is in plastic containers (Dryer, 1985).

Briston (1980) claims growth of the yogurt market owes a great deal to the plastic container. Slack resistant polystyrene containers and TFFS (thermoform, fill, seal) systems with peelable foil-laminate lid stock are popular yogurt packages (Harte et-al, 1984). Spin welded containers, which allow shipment of bottoms and tops separately are increasing in popularity.

Yogurt packages exist in a variety of sizes. Multi-packs which are making a strong showing in the marketplace represent less than 5% of total yogurt container production (Table 3). The eight-ounce cup remains the favorite with the six-ounce size a popular second. In Table 4 yogurt sales by package size are presented.

Many companies now realize the importance that packaging plays in marketing. Creative packaging and vivid graphics have become a marketing tool that yogurt manufacturers use to secure shelf space and attract consumer attention. Keck (1983) stresses that the package shape, the artwork or graphic design and the use of color are areas to concentrate on when upgrading the container for better visibility and efficiency.

Innovative yogurt containers are very familiar items in the dairy case (Keck, 1983). Manufacturers strive for differentiation and identity through packaging. Future changes in yogurt packaging may include tamper evident containers and an increase in aseptics. Liquid yogurt is

TABLE 3: Yogurt Production by Container Size

Size	% of Total Production
8 oz.	51
6 oz.	33
32 oz. (2 lb.)	11
16 oz. (1 lb.)	3
18 oz.	1
Other *	2

* Includes institutional and multi-pack sizes.

Source: Dryer, J. 1985. Dairy Record

TABLE 4: Yogurt Sales by Package Size

Percentage of Sales	Package Size
84.4	8 oz.
9.6	32 oz.
4.4	64 oz.
1.4	16 oz.
0.1	5 oz.
0.1	5 lb.

Source: Dryer, J. 1985. Dairy Record.

most suited for aseptic containers but recently General Nutrition Centers introduced "heat-processed yogurt after culturing" in aseptic containers (Anonymous, 1986). Tetra-King is also promoting a package they feel is ideal for liquid and semi liquid yogurt. Product is filled into polystyrene containers made from roll-stock in a continuous process. If the product is sensitive to light and oxygen polystyrene can be coated with aluminum foil. Packaging has made a substantial contribution to the dairy industry. Yogurt is helping to improve the packaging for dairy products by its use of sophisticated shapes and decorating techniques (Keck, 1983).

2.2 Freeze Dehydration

Freeze dehydration is the process by which water molecules are removed from a solid product to the vapor phase without going through the liquid state, known as sublimation. Freeze drying consists (Hall, 1966) of

a. Freezing the product

b. Supplying heat so moisture is removed without passing through the liquid phase, by,

c. Maintaining a vacuum in the vaporizing chamber.

Ice in the product is vaporized by the addition of heat to the shelves of the drying unit, while refrigerated coils condense the vapor which is held under vacuum. Sublimation can only be accomplished when the vapor pressure and temperature of the substance being dried is held below the triple point temperature of the water or aqueous solution in the product (King, 1970). In Figure 1 is shown the phase diagram for water.

Heat is applied to the product under controlled conditions. Key components of the freeze drying system are the vacuum pump and condenser. The energy needed to sublime the water may be provided by heating fluid through coils beneath trays on which frozen product has been placed (Lingle, 1986). During the beginning of the drying process, sublimation of the ice occurs at the surface. As drying proceeds the ice zone withdraws into the center of the product and the evolving vapor must be conducted through the previously dried outer layers (Anonymous, 1984).

An important step in freeze dehydration is pre-freezing. The crystalline structure, solubility, activity, viability and color of the product are influenced by the freezing process (Anonymous, 1984). The freezing phase is of extreme importance since it determines the success of the drying process and quality of the dried product (Anonymous, 1984). Generally, rapid pre-freezing results in smaller ice crystals, slower drying rates and a final product of overall better quality (Mellor, 1978 and Karel, 1975).

The water present in products prior to freezing exists as free and bound. During pre-freezing ice will easily crystallize out of free water. Any remaining free water is usually eliminated by sublimation during primary drying (Mellor, 1978).

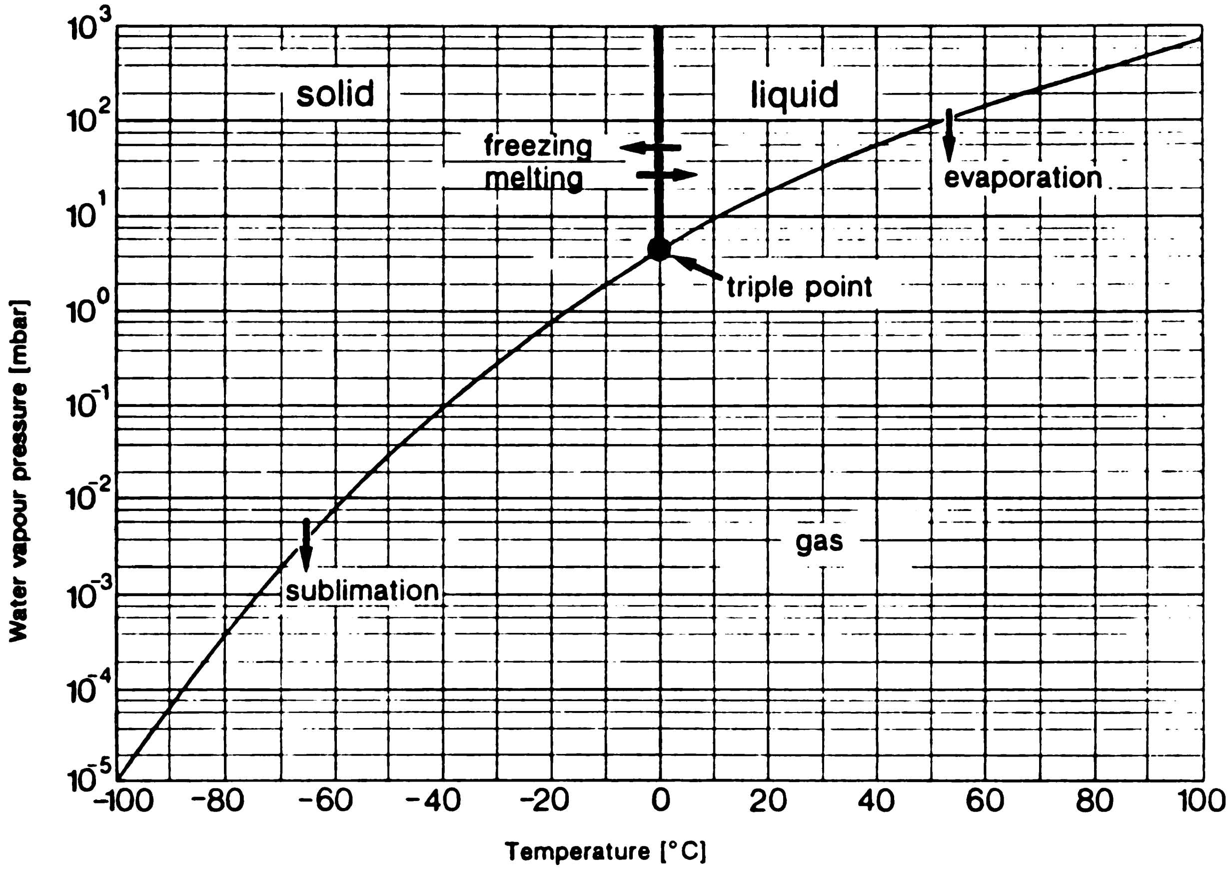

FIGURE 1: Phase Diagram for Water

Primary drying continues while there are still areas in the product containing ice which can be sublimed (Anonymous, 1984). The ice crystals formed by freezing are sublimed by vigorous and then gentle heating under vacuum. Bound water which may be linked to weak hydrogen bonds is evaporated during secondary drying. Secondary drying begins with the disappearance of the ice crystals in the product. Moisture in the product will then be desorbed under high vacuum and at a temperature that is safe for the product being dried. Bound water linked by the much stronger electrostatic forces will remain in the product, resulting in a moisture content of at least 1 percent after freeze drying. A third of the total drying time needed to evaporate the majority of bound water is during secondary drying (Mellor, 1978).

2.2.1 Product Quality

Freeze drying for food preservation produces the highest quality product obtained by any drying method (King, 1970). Freeze drying is used for foods more than any other product category (Litchfield, 1981). Because of low processing temperatures, near absence of liquid water and minimal thermal degradation, reactions such as nonenzymatic (Maillard) browning, protein denaturation, lipid autoxidation and other enzymatic reactions are minimized.

Freeze dried products suffer little or no thermal degradation because of low drying temperatures (less than 130 F, 54.4 C). Freeze drying as compared to other drying methods may offer better preservation of vitamins and other nutrients (King, 1970). It can also preserve the appearance and texture of many food products (Zaide et-al, 1979).

Most freeze dried products have good retention of volatile flavor and aroma compounds. Volatiles are generally lost during the early stages of drying. (Mellor, 1978). Generally, freeze dried products display outstanding retention of flavor, color, nutrient and aroma attributes and offer rapid product re-hydration (Lingle, 1986). Packaging is important in maintaining the quality of freeze dried products. Vacuum packages or packages containing protective gas atmospheres which are impermeable to oxygen and moisture will maintain a shelf stable product for extended time periods. Flexible pouches which are often used for freeze dried food products are light weight and take up little volume during shipping, handling and storage.

Currently only a limited number of products can be economically produced by freeze dehydration (Litchfield, 1981). Although products are usually high quality, it is by far the most costly of all dehydrating techniques (Mans, 1985). The freeze dehydration process requires specialized equipment, is very energy intensive and involves long drying times (Liapis, 1979 and Litchfield, 1982). It may require 12 to 30 hours vacuum drying time to obtain a moisture level of 2 % in the product. Lipid oxidation because of a large internal surface area and low moisture contents can be a problem in freeze dried foods, as in other dehydrated foods. Complete oxygen removal as well as packaging in an oxygen and moisture impermeable container are needed to insure storage stability. Other deteriorative reactions associated with unstable pre-freezing conditions can cause color and texture changes, off flavors, and nutrient losses. If proteins are denatured during drying the texture can again be affected, resulting in poor re-hydration (King, 1970).

Products which have been successfully freeze dried are coffee, strawberries, cooked shrimp, soups, mushrooms, cooked beef, peas ice cream, cultured cream and natural cheese. Much research and process understanding is needed to develop uniform products. With better processing techniques and energy utilization it may be possible to overcome the high economic factors.

2.2.2 Re-hydration:

Re-hydration may be considered the last stage of the freeze drying process. For freeze dried foods, re-hydration rate is a good measure of the products quality (Mellor, 1978). Product quality is related to the structure rigidity at the surface where sublimation occurs. This rigidity prevents collapse of the solid matrix which remains after drying. A porous non-shrunken structure is left, which readily re-hydrates (King, 1970 and Liapis, 1979 and Zaidi, 1979). To determine product damage encountered during drying the re-hydration ratio can be employed. This is the ratio of the weight of water regained to the weight of water lost (King, 1970).

2.3 Color Analysis

Changes in color of freeze dried products can be a result of poor prefreezing techniques. Deteriorative reactions will also alter the color of freeze dried products, as seen with browning. Generally, browning is associated with off odors and flavors which render the product unacceptable. Monitoring color changes is important, since it is a visible sign that represents an important quality attribute to the consumer (Szczesniak, 1983).

Sensory perception of color by the eye is responsive to a tri-stimulus band of wavelengths corresponding to red, green, and blue. Numerical representations are denoted as X, Y and Z which are international standards of the International Committee on Illumination (CIE). Spectrophotometers such as the Hunter color cell use the color scales L, a and b to indicate different degrees of color. Values can be converted to the international standard by means of established equations.

- 'L' defines lightness, 0 for black to 100 for perfect white.
- 'a' measures redness when positive, gray when 0 and green when negative.
- 'b' indicates yellowness when values are positive, gray when 0 and blue when negative.

The values obtained from a spectrophotometer correspond to the observers perception of color after the responses of the eye have been processed by the optic nerve from the brain (Hunterlab Associates Laboratory, 1976). The optical sensors in a spectrophotometer respond to the different wavelengths of light similar to the three color responses of the eye. In Figure 2 is shown how the three dimensional coordinate system of L, a and b values relate to perceived color.

2.4 Deteriorative Reactions

Dried products with a moisture content below the point where microbial growth is inhibited may still deteriorate by chemical, bio-chemical and physical means (McWeeny, 1980). Low-fat yogurt initially frozen and then freeze dried can undergo deteriorative reactions. The majority of problems related to dried foods can be prevented with proper handling, packaging and control of storage conditions.

2.4.1 Bacteria:

Powders with a moisture content of 5% or lower provide a poor medium for bacterial growth. If stored properly and protected from moisture, dry foods will not support proliferation of microorganisms (Gravini, 1985).

2.4.2 Non-Enzymatic Browning:

Non-enzymatic browning (Maillard reaction) is a major deteriorative factor in the storage of dehydrated dairy food products (Kim et-al, 1981). The Maillard reaction is influenced by time and temperature of storage and moisture content. Considerable damage to the nutritional quality of the product will occur if conditions of storage are such to

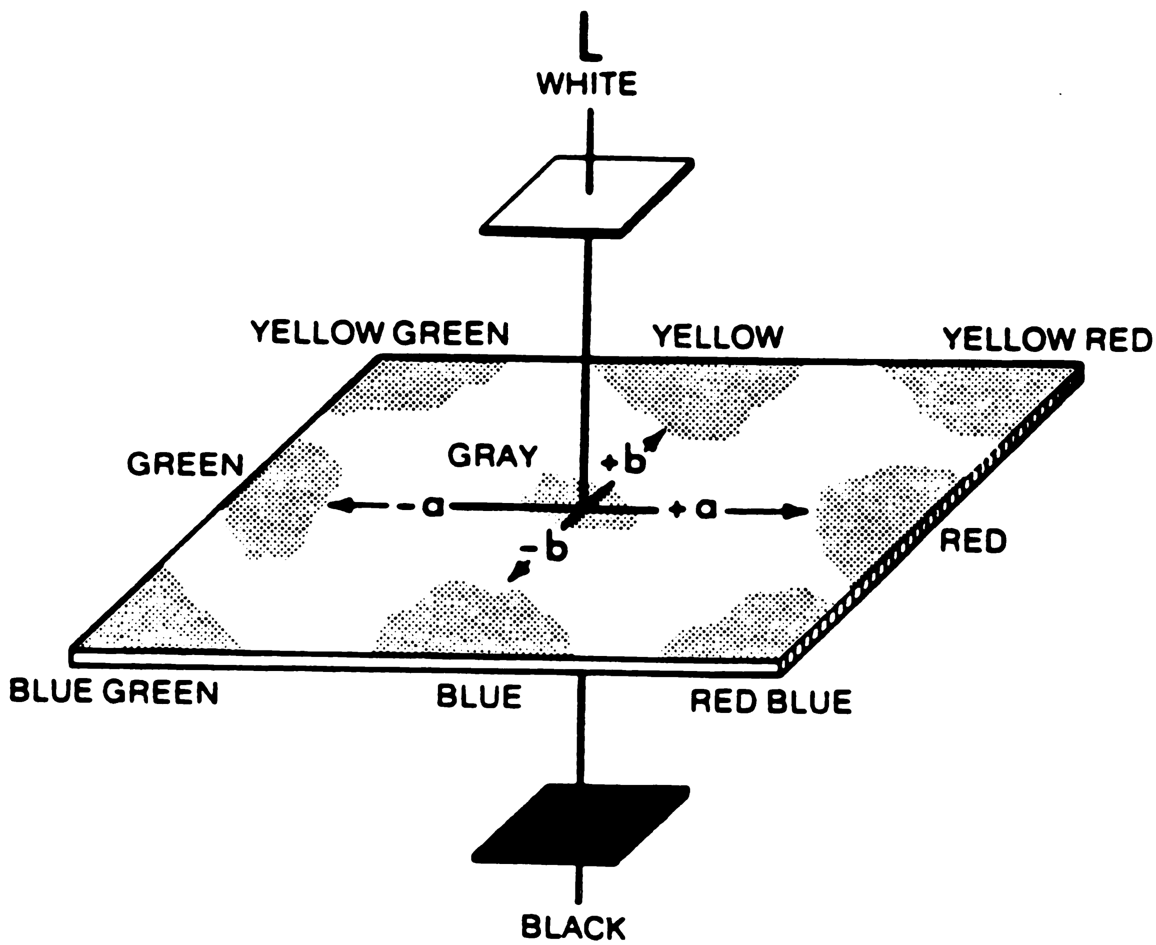

FIGURE 2: L a b System for Color Description and Qualification.

promote Maillard reactions.

Non-enzymatic browning in dried dairy products can be attributed to two possible reactions. Caramelization of lactose may occur or reaction between free amino groups of milk protein and the carbonyl group of reducing sugars (lactose) (King, 1970). Lactose and casein are the two principle reactants in the browning of dairy products. Whey proteins are also involved in some circumstances. Sugar-amino of Maillard browning is most prevalent because it requires a low energy of activation and is autocatalytic (Nickerson, 1974). Direct caramelization has a high energy of activation and is of less importance unless high preheating treatments are used. Deterioration results in color changes, off flavors, vitamin destruction, losses in protein quality and eventually nutritional value of the product.

Other physical changes associated with non-enzymatic browning occur through secondary reactions. The primary reaction between the protein and reducing sugar initiates these secondary changes. Although not fully understood it is known that the sugar becomes irreversibly bound and through a series of degradative changes yields brown pigments (Parry Jr., 1974). These reactions are also responsible (Gordon, 1974) for:

- poor palatability and appearance
- loss of nutritional value destruction of essential amino acids and vitamins
- loss of biological value and digestibility of the protein

- solubility losses
- carbon dioxide production

Product discoloration is normally slow during storage. However, in unfavorable storage conditions the amino-sugar reaction is accelerated. The rate of discoloration due to non-enzymatic browning may increase 2-fold with a temperature increase of 3-4 C (37.4-39.2 F) (McWeeny, 1980). This type of deterioration is also dependent on the moisture content of the product.

Warburton (1978) suggests that the maximum safe storage conditions for dried milk are 40% relative humidity or a moisture content of 4-6% at 25 C (77 F). Quality may also be maintained better at temperatures lower than 34 F (1.1 C) but the most important criteria is storage in a dry environment.

Manufacturing conditions can also contribute to product browning. It is essential to avoid excessively high temperatures, long exposure to heat and high moisture processing conditions.

2.4.3 Rancidity:

Hydrolytic rancidity may initiate off flavor development in dry milk products. Hydrolysis is catalyzed by lipase enzymes (lipolyses) which produce free fatty acids and partial glycerides. Hydrolytic rancidity can also cause deterioration of milk or milk products as a result of pre or post manufacturer contamination by microorganisms

(Deeth, 1983). Lipase is activated during homogenization but pasteurization and high heat treatments lesson the chance of occurrence by inactivating the enzymes. Less available fat in low fat milk products reduce the possibility of hydrolytic rancidity.

2.4.4 Staleness:

Another defect associated with dry milk products is known as stale off-flavor. There have been various suggestions as to what may cause staleness. Some associate staleness with the milk fat while others attribute it to protein-lactose reactions. Still others believe that staleness is a conglomeration of off-flavor compounds occurring simultaneously in the lipids and the protein-lactose complexes (Hall, 1966). Stale flavors develop rapidly in milk powders under conditions of high humidity and elevated storage temperatures (Parry Jr., 1974).

2.4.5 Oxidation:

The most common type of deterioration in lipid containing dry foods in the presence of oxygen is through oxidative rancidity. Lipid oxidation is prominent in freeze dried foods because of large internal surface areas and low moisture contents. Dehydrated and freeze dried foods are particularly sensitive to molecular oxygen.

Oxygen can combine with unsaturated fatty acids by free radical mechanisms. Free radicals and peroxides produced from this reaction react further to yield degradation products such as volatile aldehydes, ketones and fatty acids (Warmbier, 1976). These produce characteristic off flavors, odors and oxidative rancidity. Volatile carbonyl compounds which result from lipid oxidation are organoleptically detectable at levels of parts per billion (Patton, 1962).

The focal point for lipid oxidation in milk is the fat globule membrane (Richardson, 1983). In dried milk products triglycerides are relatively susceptible to oxidation whereas the phospholipids are more stable. When phospholipids are present in the triglycerides they serve as an antioxidant to a limited extent. When water is present the reverse is true, the triglycerides are relatively stable and the phospholipids are oxidized (Patton, 1962).

Oxidation varies with light intensity, relative humidity and temperature. Sunlight and ultraviolet light can accelerate fat oxidation, as can trace metal catalysts. In food products many vitamins, pigments, some amino acids and proteins are oxygen sensitive (Karel, 1974).

Levels of oxygen greater than 1% can cause rancidity problems. For products packaged in air detectable off odors can be noticed within a week. Non-fat dry milks are much more stable than dried whole milks. Non-fat dry milk can be stored for over one year in air at room temperature because the susceptible lipids have been largely removed during processing (Labuza, 1971).

2.4.6 Role of Moisture and Storage Temperature:

The best way to minimize unacceptable changes in dehydrated foods is to keep them cool and dry. Both temperature and moisture content should be kept low (McWeeny, 1980). Freeze dried foods are very moisture sensitive because of their open structure. Even the slightest intake of moisture by the product is undesirable. Although freeze dried products are generally superior to other dehydrated foods, they are highly susceptible to oxidation (Sacharow, 1980).

Chemical reactions that take place in dried foods are related to the interaction of water with the various components. The water activity (Aw) is a measure of the available water in a food which can be used in chemical reactions and for microbial growth. Water activity measures the relative vapor pressure above the food (Saltmarch, 1980).

When milk products are dried, lactose forms an amorphous glass which is relatively stable. As moisture is absorbed the glass portion dilutes and collapses into a stage of crystal structure. Crystallization can begin at an Aw of 0.42. Warburton (1978) suggests the maximum safe storage moisture content is 6% with an equilibrium relative humidity of 40% at 25 C (77 F). The first indication that the moisture content has reached the upper limit is crystallization. Moisture is released and the powder becomes sticky, forms lumps and may eventually form a solid cake.

The optimum Aw where dehydrated foods are most stable and have the longest shelf is near the BET monolayer. The Aw in this region is around 0.2 - 0.3 for most foods. For non-fat dry milk 0.3 is the critical maximum water activity (Labuza, 1981). In terms of percent moisture 4% is near the calculated monolayer value of 3.96%. Below 4% oxidative deterioration occurs and above this value non-enzymatic browning is accelerated.

As Aw increases above the monolayer many deteriorative reactions increase exponentially. For some reactions rates level off at high Aw's and may even decrease. This is true of non-enzymatic browning. When the water content of dehydrated products is above the critical monolayer Aw, non-enzymatic browning will double or triple for every 0.1 Aw increase. As the moisture content continues to increase to a water activity of 0.6 - 0.8 the reaction rate reaches a maximum because mobilized reactant species become dilute (Kim et-al, 1981).

If storage conditions are such, to promote Maillard reactions in dehydrated milk products, other unfavorable changes may also occur. Some of the major problems are:

- destruction of essential amino acids (lysine and histidine)
- loss of solubility

- development of stale and caramelized flavors
- damage to the nutritional quality (loss of biological value of the protein)
- protein becomes insoluble especially upon reconstitution
- losses of several vitamins
- caking, lumping, loss of volatiles

An increase in moisture content in dehydrated products also provides an opportunity for growth of molds, yeasts or bacteria. The overall quality of dehydrated milk products is better at lower storage temperatures and most importantly powder must be protected from moisture.

2.5 Culture Viability

Yogurt and any products labeled as such should contain viable cultures (Anonymous, 1981). Bacterial cultures have been successfully preserved by freeze dehydration for extended periods of time. To increase the shelf life of freeze dried cultures, various work has been done with suspending media and protective additives during culture preparation. The suspending media is the most important factor to increase the survival rate of bacteria after freeze drying and in minimizing the death rate of dried organisms during storage (Morichi, 1974). Protective agents in the suspending medium can reduce the death rate of microorganisms in frozen storage and increase the survival rate of microorganisms during and after freeze-drying (deValdez et-al, 1983). Preservatives or protective substances are added to the cell suspension to protect portions of cells which may normally be destroyed during the freeze drying process.

A general term for freeze dehydration in all types of solvents is cryo-sublimation. In the strictest sense, freeze drying involves aqueous solutions only and lyophilization pertains to solvents other than water (Zaidi et-al, 1979). The process of freeze drying has been widely employed for the preservation of biological materials in situations where inherent characteristics of the material must be unaltered (Robinson, 1981). For this reason, great success has been made with bacterial cultures.

Freeze dried cultures from Miles Laboratories are packaged in laminate pouches. Suggested storage for maximum cultural activity is -18 C (0 F) or colder. Cultures can be kept at room temperature 22 C (72 F) for up to 24 hours with negligible loss in activity. Cultures can also be maintained in a regular home freezer for up to five months (Anonymous, 1984). Cultures distributed from Chris Hansen's Laboratories are dried in the frozen state and contain large numbers of viable organisms with optimum activity. Cultures can be sent through the mail in lightweight aluminum pouches and stored under refrigeration with little activity loss.
Freeze dried cultures can be stored for 5 to 6 months

without activity loss at below freezing temperatures of - 20 C (- 4 F), (Sellers, 1978). Morichi (1974) agrees that freeze dried cultures should be stored at as low temperatures as possible. Cell death occurs logarithmically during storage.

Starter cultures preserved by freeze drying tend to have a prolonged lag phase upon reconstitution and are mainly used for propagation of mother cultures (Tamime,1981). Recent developments have made it feasible to produce freeze dried cultures for direct inoculation into the bulk starter tank or alternatively into the processed milk (Robinson, 1981).

During preparation for freeze dehydration preparation and during the process as few as 50% of the cultures may survive. Those cultures which do survive normally are acceptable acid producers in milk. High initial concentrations of cells are favorable for an increased survival rate. Concentrations of more than 1×10^{11} per ml. is recommended by Morichi (1974) to insure adequate survival. Gilliland (1981) suggests maintaining cultures under vacuum after drying to increase survival since freeze dried cultures are extremely sensitive to oxygen. Naghmoush (1978) agrees that storage of freeze dried cultures under vacuum and or at low temperatures will prolong their activity.

Robinson (1981) describes freeze dried cultures as being in a state of "suspended animation." Although viability is excellent freeze dried cultures need a longer time to attain optimum performance. It may take 14 to 16 hours to develop proper acidity but once acidity has been reached freeze dried cultures will be virtually undistinguishable from other types of inoculants. Re-hydration and reactivation of the cultures is a critical step in obtaining maximum cell activity. A major concern is cell sensitivity of _L. bulgaricus_ to re-hydration temperatures of 20 - 25 C (68 - 77 F).

Under unfavorable re-hydration conditions cells which have survived the freeze dehydration process may become injured or lose their viability.

deValdez et-al (1985) have studied the relationship between residual moisture content and the viability of freeze dried lactic acid bacteria. Their findings are summarized as follows:

- overdrying is harmful to survival
- cell survival decreases as dehydration increases
- a minimal amount of water must remain for a satisfactory survival rate.
- increased survival rates could be obtained by maintaining optimal moisture content in the freeze dried samples and by adding adonitol (a polyhydric alcohol $C_5H_{12}O_5$) as a cryoprotective agent.

The ability of a compound to preserve the viability of cells has been associated to the presence of an amino group or a secondary alcohol group (deValdez et-al, 1983). Morichi (1974) found 1% to 3% residual moisture was optimal to ensure the best survival of freeze dried organisms during storage. Less than 3% moisture could be obtained in freeze dried preparations stabilized with glutamate, arginine or lactose. Porubcan and Sellers (1975) developed a spray-drying process for yogurt and related cultures. The resulting culture powder has a concentration and activity equal to that produced by lyophilization. Residual moisture was less than 5%, product quality suffered little or no change after 6 months at 21 C (70 F).

Various additives and suspending media have been examined for their role in protecting lactic acid bacteria against freeze drying. Skim milk has been used extensively as a suspending medium for freeze drying of bacteria. Addition of additives can help improve the protective activity of skim milk. *L. bulgaricus* in particular responds poorly to lyophilization, spray drying and conventional frozen storage. Because freeze drying will kill bacterial cells, protective agents must be added before freeze drying. deValdez et-al (1983) explained the mechanisms by which microorganisms are killed by freezing or dehydration and the complexity of protecting organisms from injury. The major factor causing cell death is osmotic shock. Morichi (1974) felt that suspending medium is the most important way to increase the survival rate of bacteria after freeze drying and to minimize the death rate of dried organisms during storage. Naghmoush et-al (1978) states that the activity of freeze dried cultures following storage is the most important point effecting culture behavior and performance. Cabrini et-al (1982) examined yogurt cultures freeze dried with various substrates and stored for 1 to 2 years at 4 C (39.2 F). They found yogurts freeze dried with cryoprotective agents had high bacterial counts after storage but were not given much protection during the freeze drying process. After one year most samples had counts of 10^6 to 10^7 per ml. and were suitable as starters.

Wright and Klaenhammer (1983) studied the use of calcium as a protective agent for L. bulgaricus during freeze drying. They found superior survival of L. bulgaricus although the specific role of calcium was unknown. Adonitol was strongly recommended by deValdez et-al (1983) as a cryoprotective agent for production of freeze dried cultures for use as starters. Both S. thermophilus and L. bulgaricus were included in this study. In a separate study performed by deValdez et-al (1983) cysteine was found to be the best protectant for L. bulgaricus. B. glycerophosphate in milk or sodium glutamate offered the best protection for S. thermophilus. An appropriate selection of the suspending medium and cryoprotective agent was essential in order to obtain a maximum number of viable cells. Choice of protecting agents is limited based on processes, types of bacteria and storage conditions.

Additional work was done to determine the effect of storage on total cell count, viable count and cell activity of treated lactic acid cultures by (Naghmoush et-al, 1978). The likelihood of maintaining active freeze dried cultures for extended time periods at room temperature was examined.

Lyophilized concentrates can be expected to perform well under industrial conditions and should be able to replace more conventional cultures and eliminate excessive handling (Speckman et-al, 1973). Problems include the expense of lyophilization as well as the cryoprotective ingredients and re-hydration media needed. Robinson (1981) and others agree that freeze dried cultures provide convenience and reliability as the ideal inoculum for a bulk starter.

2.6 Packaging Dried Products

The package affects the quality of foods by controlling the degree to which processing, storage and handling can effect components of foods (Karel, 1974). Storage factors which can be controlled by packaging are light, oxygen, moisture, contamination and attack by biological agents. Campbell (1975) describes a desirable package as being impervious to moisture, light, gasses and easily filled, sealed, handled and emptied with reclosing features.

Packages for dehydrated foods must take into account the products sensitivity to moisture, oxygen and bacteria. In dried products where the moisture content is below 3% growth of bacteria is eliminated. Thus, packaging should focus on the two prime causes of spoilage, moisture and oxygen.

The protection of foods from moisture exchange is an ancient requirement (Labuza, 1981). Dried foods in the range of 1% to 3% moisture have equilibrium relative humidity values below 20%. The relative humidity of ambient air is rarely this low, which allows low moisture foods to absorb water rapidly (Paine, 1983). Absorption of atmospheric moisture is critical for freeze dried products because of their open structure. The slightest degree of moisture absorption in a freeze dehydrated product can cause discoloration, flavor loss and lumpiness which results in poor reconstitution. Although these factors may not cause complete spoilage in dehydrated foods, they are unacceptable for the consumer (Sacharow, 1980).

Low moisture foods can also be very susceptible to oxygen. This is especially true of freeze dried products because of large internal surface areas. Many dehydrated foods are sensitive to light. Light accelerates the development of rancidity by means of oxidative spoilage. To protect dried products from oxygen, gas packaging or packaging under vacuum is suggested.

2.6.1 Vacuum Packaging:

Vacuum packaging is used to remove most of the oxygen from a package. The package is evacuated and sealed under vacuum to increase product shelf-life. Packaging dehydrated foods in flexible packages under vacuum may cause problems. Materials must withstand the vacuum process and not rupture at corners and seals. The shape of vacuum packages may also be considered a negative attribute due to their bulky appearance.

2.6.2 Gas Packaging:

Gas packaging is another method used to reduce the oxygen level to 1% to 2% in the package. Air is replaced by flushing the package with an inert gas. Nitrogen is the most common gas used.

Another option when packaging dehydrated products which are prone to deterioration from oxygen, is the use of antioxidants. Antioxidants are defined by the United States (U.S.) Food and Drug Administration (FDA) as substances used to preserve food by retarding deterioration, rancidity or discoloration due to oxidation (Anonymous, 1986). Antioxidants are those compounds that terminate the free-radical chain in lipid oxidation; Chelators, which bind metal ions such as iron and copper that catalyze lipid oxidation; oxygen scavengers, or those compounds that react with oxygen in closed systems; and "secondary" antioxidants, which function by breaking down the hydroperoxides (Anonymous, 1986). The most common food antioxidants are phenolic substances. Many natural occuring antioxidants tend to be less effective and are often inactivated by mild heat treatments. Antioxidant effectiveness may also be dependent on the water present in the system. Selection of an appropriate antioxidant is determined by its effectiveness in certain fats, animal fats or vegetable oils, its carry through properties and possible synergistic effect (negative or positive).

Bachelors Foods, Ltd., (United Kingdom) produce dehydrated foods. They use flexible pouches without either gas or vacuum packaging, having found the amount of oxygen inside the package is seldom a problem. Instead barrier films are used to prevent external oxygen from reaching the product (Anonymous, 1980).

2.6.3 Polyethylene:

Polyethylene is a very versatile film and an important component of laminates. It is a good moisture barrier, has excellent heat sealing properties and is resistant to acid or alkali solvents. Low density polyethylene (LDPE) is a poor oxygen barrier. Polyethylene is the major plastic material used for flexible packaging. Polyethylene finds wide use in laminations or co-extrusions because of its toughness, heat sealability and low cost (Anonymous, 1986).

2.6.4 Aluminum Foil:

For packaging dried products, aluminum foil is used mainly in laminate systems. Aluminum foil is available in many thicknesses and is impermeable to water vapor, gases and light. It is tasteless, colorless, non-toxic and will not support bacterial or mold growth.

Aluminum foil is not heat sealable and thin gauges (which are used for economic reasons) do not provide the strength or abuse resistance needed (Martin, E.L., 1986). These problems are overcome by laminating aluminum foil to paper and/or plastic films. Thus barrier properties can be obtained with the thinnest amount of foil. In addition, strength, scuff resistance, durability, puncture resistance and heat sealability are offered from the laminate system.

2.6.5 Polyester:

Polyester has excellent tensile strength, is tear, heat, abrasion and chemical resistant. Polyester is a good gas and water vapor barrier. It has good resistance to grease and oils. Polyester has good thermal properties in applications over a wide temperature range. It is a primary material for boil in bags and retort pouches (Rounsville, 1986).

2.6.6 Polypropylene:

Polypropylene is more rigid, stronger and lighter than polyethylene. It is resistant to grease, abrasion and chemicals. Polypropylene is an excellent water barrier and with PVDC coating, an excellent gas barrier. Polypropylene is stable to high temperatures and has good tensile strength (Rice, 1982). A special advantage of polypropylene is its lightness. It is the lightest in weight of the plastics used in packaging. Biaxially oriented polypropylene has become the most widely used of the transparent plastic films due to the versatility provided by coatings and co-extrusions (Martin, 1986).

A three-ply laminate structure of polyester/aluminum foil/polypropylene for use with dried yogurt has the following properties. Polyester on the outside provides toughness, abuse resistance and has a good printing surface. Aluminum foil as the middle layer provides a barrier to light, moisture and oxygen (Kahn, 1982). On the inside, polypropylene is compatible with the product, provides additional protection against moisture and can be sealed.

Rasic (1978) suggests packaging yogurt powder into composite containers for storage at room temperature. He recommends gas flushing to extend the shelf life. Ardito et-al (1980) examined dried skim milk packaged in (i) Nitrogen flushed cans (ii) Pigmented LDPE and (iii) a Paper LDPE/Al/LDPE laminate. Product quality was acceptable in all three packages stored at 23 C (73.4 F), 65% RH and at 30 C (86 F), 80% RH for six months. After 120 days at a higher temperature of 38 C (100.4 F), 90% RH, product in the pigmented LDPE was unacceptable. Product was good in the other packages. The package recommended for this product was the laminate versus the cheaper LDPE or more expensive cans. Sacharow (1980) suggested that non-fat dry milk (NFD) is not as sensitive to oxygen and does not require vacuum or gas packaging. Most consumer portion packages are made from aluminum foil laminates comprised of Paper/PE/Al/PE. Carnation Company, found success for their small pouches of powder products with metallized polyethylene laminated to paper. This package enabled them to maintain the 12 month shelf life (Anonymous, 1985).

For packaging dehydrated powder products flexible pouches were emphasized. Flexible pouches are lightweight which leads to tremendous space and shipping advantages. They are economical, requiring no energy usage during storage. Flexible pouches also lesson disposal problems often encountered with other containers (Kahn, 1982). Further development will insure product package compatibility with better barrier characteristics to keep the product dry, retain flavors within the package and prevent the entry of oxygen and light.

The final package choice must fulfill the requirements imposed by the product. Packaging development has an essential contribution to make, both in packaging new products and making existing ones more efficient either in production, storage or convenience (Anonymous, 1980).

2.7 Yogurt Products and Uses

Yogurt is sold in various forms in the United States. Yogurt is available for commercial use as a liquid, spray dried and freeze dried powder. Dried yogurt is sold as an ingredient for bakery mixes, soups, salad dressings and confectionary products (Vedamuthu, 1982). Advantages of dried yogurt versus fresh include functionality, availability, cost, shelflife and product standardization

(Anonymous, 1978). Like most fresh products yogurt is subject to degradative changes typical of perishable products. Freeze dried yogurt contains more viable bacteria than spray dried yogurt due to shorter drying times. Freeze dried yogurt is generally priced higher as a result of higher processing costs.

The drying of yogurt is an old method of preservation. Dried yogurt can be produced by sun drying, spray drying or freeze drying. Sun drying is used mostly in rural areas of the middle east while the other methods are used for commercial purposes (Tamime and Deeth, 1980).

2.7.1 Freeze Drying:

Freeze drying is accomplished by removing water from the frozen product under high vacuum. The final product is a fine powder which can be stored at room temperature, if packaged under vacuum or inert gas. To reconstitute the product the original amount of water is added to the powder with stirring. Reconstituted yogurt has a weaker consistency than freshly made product which is overcome by the use of stabilizers. Dried yogurt will also have reduced flavor and fewer numbers of lactobacilli than the initial yogurt (Rasic and Kurmann, 1978).

Several dried yogurts are manufactured in France, Russia, Switzerland and West Germany. The powder has a moisture content between 1% to 3%. Manufacturers claim a product virtually undistinguishable from original yogurt

(Helferich, 1980). Little product of this nature has been made thus far in the United States. Yogurt-based foods are an untapped market which could help boost sales and consumption of yogurt (Steinberg, 1983).

DMV Campina one of Europe's largest dairy cooperatives has found great success with yogurt based products. They first introduced a yogurt based diet drink. Since then they have developed a high protein yogurt spread, yogurt bars and yogurnaise, a yogurt mayonnaise containing 25% oil which is 55% less than normal mayonnaise. They have also been able to stabilize yogurt in various liquors (Krier, 1984).

Nolan (1982) described how yogurt is used in baked goods to increase sales appeal, improve moisture, shelflife and the flavor of bread, cookies, donuts and a variety of other yeast raised products. Donuts with 30% yogurt were preferred to regular donuts. Yogurt donuts were able to mask the fried fat flavor and enhance glaze, fillings and icings. The following reasons were given for adding yogurt to breads.

- Improve moisture in the dough and in the finished loaf. The yogurt acts as a humectant which holds moisture in the loaf. Bread can be held on the shelf an additional 12 to 24 hours.
- Yogurt improves the product flavor making it "cleaner" tasting.
- Yogurt improves breads protein level
- Yogurt adds sales appeal as a "health food"

- Mold growth is slightly deterred as a result of the lower pH.

Salsburg (1983) described a spray dried yogurt that is "entirely nutritious with a mild lactic flavor." The powder is semi-instant and can be dispersed easily with agitation in cold or preferably warm water. It is packaged in a multiwall paper sack with a sealed polyethylene liner.

Stauffer Chemical Company in the U.S. has a variety of spray dried cultured dairy products which duplicate the characteristics of fresh yogurt (Anonymous, 1978). The spray dried yogurt powder is suitable for use as a flavor base. Suggested applications for the dried yogurt powder are: chocolate confections, cream fillings for candy, fruit toppings, baked potato toppings, cheese spreads and process cheeses, snack products (dusting powder), cookies and cake fillings, whipped toppings, meat sauces, gravy bases, salad dressings, breads and other baked goods.

Carnation Company introduced yogurt bars and Slender Yogurt diet drink (Anonymous, 1982). Beam Import Company combines yogurt with French Cognac. Yogurt is thought of as being nutritious and having fewer calories than cream, while still having the smooth, silky mouthfeel that is expected in a liqueur. Yogurt also helps extend product shelf life with no refrigeration required. The technology that has been developed will be used to develop a yogurt powder to be used in food applications similar to powdered milk (Anonymous, 1984).

More recently, Pet Inc., introduced a calcium fortified cereal called "Dairy Crisp." The cereal is fortified with nonfat dried yogurt (Anonymous, 1985). To-Fitness, Inc., a Florida based manufacturer has the first instant yogurt with active cultures to be manufactured and marketed in the United States (Anonymous, 1986). The products containing active cultures, are available in powder form and can be stored without refrigeration indefinitely. "Instant Culture" the name given to the product comes in three forms and fourteen flavors. Jet-Set is the name given to a yogurt powder the consumer can reconstitute to the consistency of regular yogurt in five minutes. Expectations are that these new products will revolutionize the $1.5 billion U.S. yogurt market (Anonymous, 1985). Steinberg (1983) suggests that yogurt is an ideal base for dips and salad dressings. Suitable not only for salads, it can be used with hot or cold vegetables, meats and fish. The tangy lactic acid taste will intensify flavors and aromas and enhance added ingredients. Miller Cheese Company of New York has introduced a yogurt based cheese. Described as tasting like muenster with a slightly tangy aftertaste, it is available plain and with herbs and spices (Anonymous, 1986).

Dried yogurt is suitable for export to foreign countries, especially those with a protein deficiency. It has great potential for use in warm regions and can be easily reconstituted. Robinson (1978) describes a dried concentrated yogurt and cereal flour mixture that has found widespread acceptance in certain areas of the middle east. The dried mixture is valuable during periods of the year when fresh milk is unavailable. A.B. Milkfoods of Sweden developed a yogurt powder which is said to look and taste like natural yogurt when reconstituted with water (Anonymous, 1983). They suggest it provide an alternative for countries lacking in fresh milk. The powder is packaged in 25 kilogram paper bags with an inner liner and has a one year shelf life. Yogurt powder of various consistencies is available for use in medical preparations, desserts, sauces, spreads and other products.

With new styles, flavors and uses for yogurt being introduced they should appeal to both the health and quality conscious consumer. As a result yogurt sales should experience a period of renewed growth (Anonymous, 1986).

3.0 MATERIALS AND METHODS

3.1 Yogurt Preparation

The lowfat yogurt used in this study was manufactured in the M.S.U. dairy plant (for formulation see Appendix A). Yogurt preparation followed the sequence of steps shown in Figure 3.

3.1.1 Bulk Starter Culture:

Bulk starter culture obtained from the Michigan State University (M.S.U.) Dairy Plant was prepared as follows:

1. Five gallons of whole milk was sterilized by heating in boiling water (212 F, 100 C) for over one hour.
2. The sterilized milk was cooled to 115 F (46 C).
3. One 70 ml can of Chris Hansen's R-1 Redi-Set concentrated deep-frozen yogurt culture was thawed and aseptically added to the mix. The ratio of *Streptococcus thermophilus* to *Lactobacillus bulgaricus* was approximately 1:1.
4. The culture was incubated for approximately three hours at 112 - 114 F (44.4 - 45.6 C).

3.1.2 Uncultured Mix:

Milk received from the M.S.U. Dairy Plant was standardized into the composition desired (see Appendix B).

The uncultured mix was blended with a Lightin Mixer (Model 10 X) and vat pasteurized at 190 F (87.8 C) for 30 minutes. The mix was then cooled to 150 F (65.6 C) prior to homogenizing. All utensils and equipment were sanitized before use.

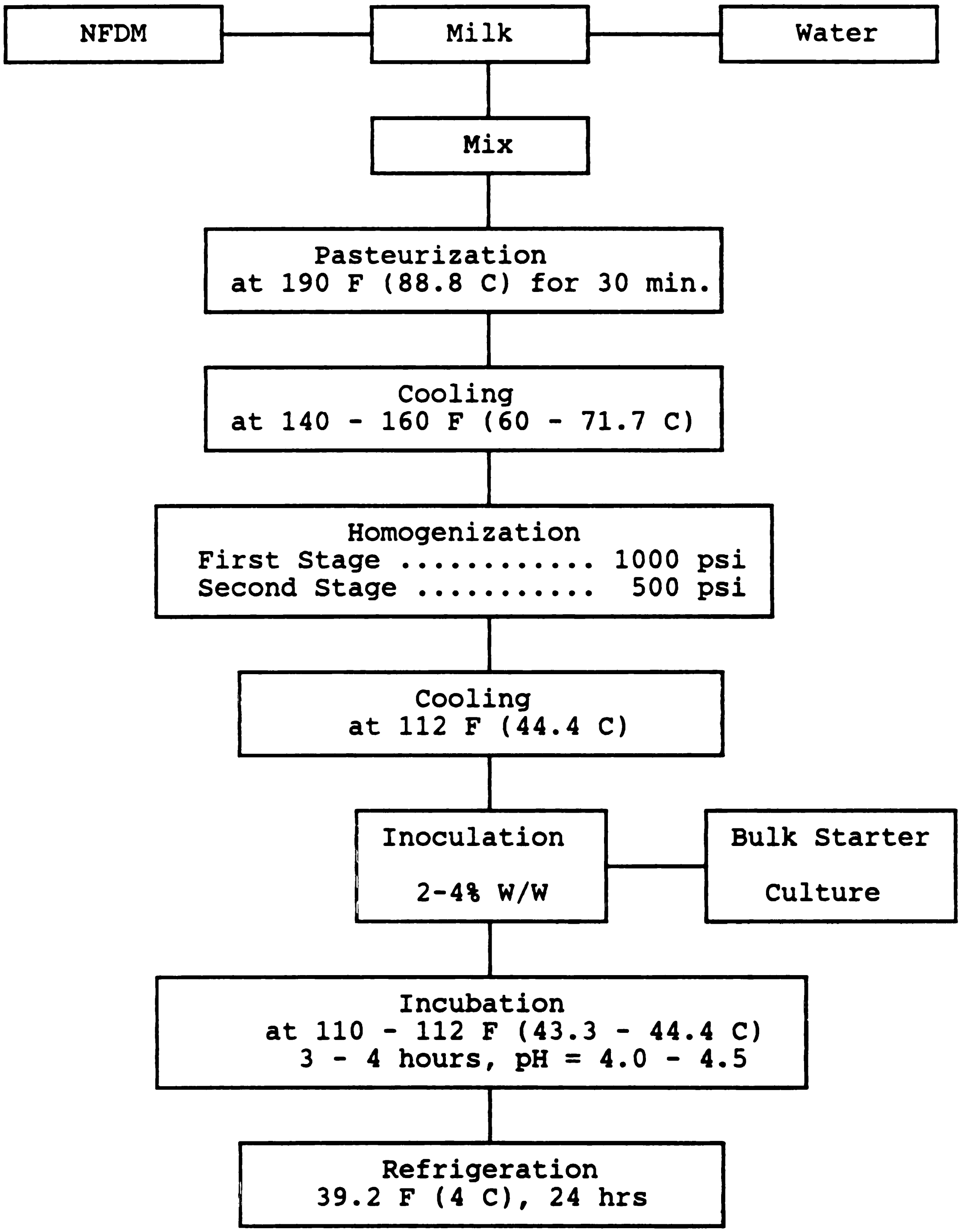

FIGURE 3: Flow Diagram for Yogurt Preparation.

3.1.3 Homogenization:

The mix was homogenized at 1500 pounds per square inch (p.s.i.) in two stages using a Manton Gaulin 75 K pilot plant homogenizer. The first stage was operated at 1000 p.s.i. (70.3 Kg/sq.cm.) and the second stage at 500 p.s.i. (35.1 Kg/sq.cm.).

3.1.4 Yogurt Mix:

Uncultured mix was cooled after homogenization to 112 F (44.4 C). Bulk yogurt culture was then added to the mix. The formulation used is described in Appendix A. Incubation was carried out at 110 - 112 F (43.3 - 44.4 C) for a period of 3 to 4 hours or until a pH of 4.3 to 4.5 was obtained. Yogurt was refrigerated at 39.2 F (4 C) for at least 18 hours prior to evaluation.

3.1.5 Freeze Dehydration:

A Virtis pilot plant Freeze Dryer (Model FFD42 WS) with a 50 lb condensing capacity was used to freeze-dry the fresh yogurt. The freeze dryer was operated according to procedures in the instruction manual. Prior to freeze drying, yogurt was frozen on stainless steel trays at 0 F ± 4 F (-17.8 C ± 2.2 C). Yogurt was spread evenly over each tray approximately one half inch thick. Four to five trays were dried per run. Each drying cycle lasted at least 48 hours or until the yogurt was dry and crumbly. Heat was applied to the shelves at 112 F ± 5 F (44.4 C ± 2.8 C) to aid in the drying process. Vacuum was maintained at 50 microns or less throughout the drying cycle and was measured using a McCloud Gage. Five runs were needed to dry 100 pounds of fresh yogurt. Figure 4 shows the flow diagram describing the dehydration and packaging of yogurt.

3.2 Packaging

3.2.1 Dried Yogurt:

Approximately 1120 grams of yogurt was packaged under atmospheric conditions and stored under ambient conditions of 72 F (22.2 C), 50% Relative Humidity (RH) and accelerated conditions of 100 F (37.7 C), 85% RH. Two of each of the following package types were stored at ambient temperature for 10 weeks and at accelerated conditions for 4 weeks.

1. The first package was a laminated Pouch (5.75 in. by 7.87 in.) of polyester/foil/polypropylene with a thickness of 5.5 mils. Pouches were sealed on a Sentinel Thermo Heatsealer under atmospheric conditions. Bar temperature was set at 375 F (190.6 C) with 40 pounds of pressure for 1.5 seconds. A half inch top seal was made.

2. Dow Ziploc Freezer Bags (2.7 mil Low Density Polyethylene (LDPE)) were also used. LDPE bags, 7 in. by 8 in. were made into pouches by reducing the size of the Ziploc bags to that of the laminated pouch. Edges were reinforced by a Sentinel Impulse Heatsealer. Bar pressure was maintained at 30 p.s.i. (5.3 Kg/sq.cm.), with 0.5 seconds heating and 4 seconds cooling time.

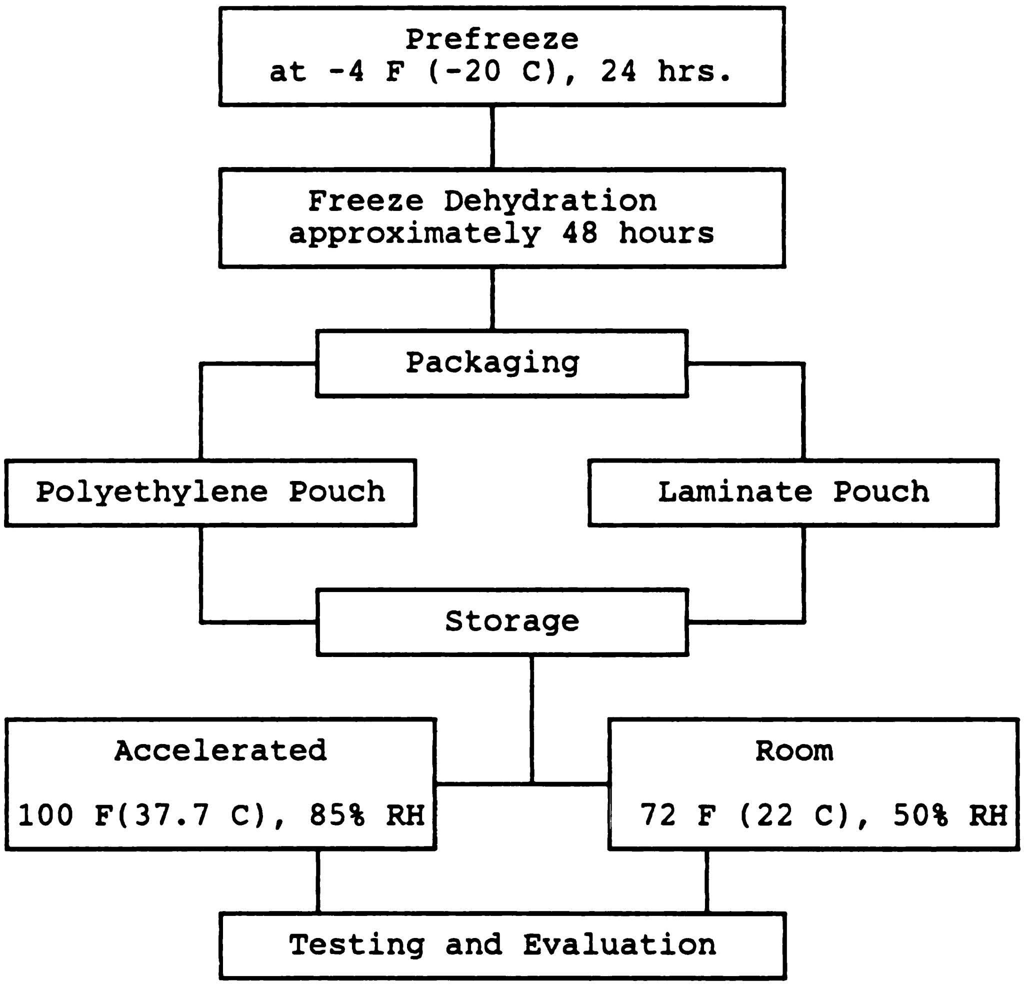

FIGURE 4: Flow Diagram for Yogurt Dehydration and Packaging.

3. Preliminary tests were also performed using Kraft paper bags. The dimensions of these bags were 10.5 in. x 9 in. x 5 in. and made from virgin kraft paper. Due to high rates of oxygen transmission and moisture gain, product deteriorated within one week. Therefore no further tests were performed using this construction.

3.3 Sampling

3.3.1 Fresh Yogurt:

Prior to freeze drying, portions of the fresh yogurt were removed. The following tests and evaluations were made to monitor the quality of fresh yogurt.

1. Color Analysis - using a Hunterlab D25D2 L Digital color and color difference solid state digital colorimeter (see section 2.3 for details).

2. pH Measurement- using a Orion Research Analog Model 301, electronic pH meter.

3. Sensory Analysis - flavor only based on the scorecard for the Collegiate Dairy Products Evaluation Contest (see Appendix C).

4. Culture Viability - plating on Lee Agar (see Appendix D) for the simultaneous enumeration of *Lactobacillus bulgaricus* and *Streptococcus thermophilus*.

3.3.2 Dried Yogurt:

After the product was freeze dried, moisture content, color, sensory properties and culture viability were initially evaluated.

Moisture content was measured on triplicate samples dried in a vacuum oven at 155 - 158 F (68.3 - 70 C) for 15 to 18 hours under a vacuum of 735 mm Hg. The procedure initially followed was that described in the AOAC (1975) for dry milk. However due to fluctuations in moisture readings and a great degree of caramelization, yogurt was dried at the lower temperature for a longer time period.

3.3.3 Stored Dried Yogurt:

Two pouches each of the laminate and LDPE pouches were removed from ambient and accelerated storage conditions for testing and evaluation. Product was examined after one, two, three and four weeks. In addition, product from both pouch types stored at room conditions was examined after two months. Pouches of product from the same conditions were combined and evaluated by the following methods:

1. Headspace Analysis - Duplicate readings from each pouch were made to determine percentage of oxygen, nitrogen and carbon dioxide present in the package headspace. A 5 cc sample was removed and injected into a sampling port of a Model 2153 Carle Gas Chromatograph. Percent of each gas was determined using a Spectra Physics 400 Dual Channel Computing Integrator. Series - Bypass technique was employed to allow carbon dioxide to exit the column first.

The following conditions were maintained:

Column Temperature	- 95 C
Carrier Gas	- Helium at 40 psi with a flow rate of ml/min
Chart Speed	- 5 in/min
Bridge Setting	- Thermistor
Output	- 64

Samples were run on the left column of the gas chromatograph which consisted of an 8 inch 80% Porapak N + 20% Porapak Q and a 6 inch Molecular Sieve - 5 A.

2. Moisture Content - was determined using the vacuum oven technique described earlier. Triplicate samples from each package type and storage condition were evaluated.

3. Color Analysis - Triplicate readings of dried yogurt from each package type and storage condition were made using the Hunterlab Color Cell as described before.

4. Culture Viability - After 2 and 4 weeks, samples of dried yogurt were taken and prepared according to Standard Methods for the Examination of Dairy Products (1985). Each sample was plated in triplicates to determine viability of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* during storage. Samples from both pouch types stored at room conditions were also evaluated after more than two months storage.

5. Reconstitution - The dried yogurt was reconstituted using tap water with known pH as described in Appendix E. Hardness content of this water was measured at 340 ppm. Tap water was used for the reconstitution because it represents a readily available source for the consumer.

6. Sensory Analysis - Qualified judges rated samples of reconstituted yogurt which had been refrigerated for 24

hours. Product from each package and storage condition was evaluated for flavor change. The scoring was done using a procedure similar to that described in the ADSA guide used at Collegiate Dairy Products Evaluation Contests (Appendix C and F).

7. pH - The pH of each reconstituted yogurt sample was determined. pH of the tap water used for reconstitution was also determined.

3.4 Material Permeability Tests

3.4.1 Water Vapor Transmission Rate (WVTR):

The WVTR of the LDPE material was measured gravimetrically at 100 F (37.8 C) and 85% RH. The dish method described in ASTM Standard E 96 (1980) was employed. Triplicate samples were stored for 20 days at the above conditions. WVTR values (weight gain per day) were determined using a Spectra Physics 400 Dual Channel Computing Integrator. The computations used to obtain the relative constants are described in Appendix G.

3.4.2 Oxygen Permeability:

Oxygen permeability of the LDPE film was measured on a Modern Controls Inc. (Minneapolis, MN) Ox-Tran 100 Oxygen Permeability Tester. The procedure followed was in accordance with the manufacturer's operation manual and ASTM Standard D3985-81 (Oxygen Gas Transmission Rate Through Plastic Film and Sheeting Using a Caulometric Sensor, Annonymous,1984). Sample calculations are described in Appendix H.

3.4.3 Carbon Dioxide Permeability:

Modern Controls Inc., Permeatran C (Minneapolis, MN) Carbon Dioxide Permeability Tester was used to measure the carbon dioxide transmission rate through the LDPE film sample. (See Appendix I). Test samples were mounted with a masking element to reduce the effective surface area to 5 sq.cm. The procedure used followed the instructions found in the operators manual.

4.0 RESULTS

4.1.1 Culture Viability:

Culture viability of S. thermophilus and L. bulgaricus was monitored throughout the study. Initially in the fresh yogurt there was 2-3 times the number of L. bulgaricus organisms in comparison to S. thermophilus. Freeze drying resulted in a 1800 times reduction of S. thermophilus and a 39,000 times reduction of L. bulgaricus (Table 5). It is, therefore, important to use procedures that insure high initial counts of organisms to compensate for this sharp reduction during the freeze drying process.

During storage at room conditions (72 F, 50% RH) S. thermophilus and L. bulgaricus decreased slightly after the initial freeze drying process (Table 5). Storage at accelerated conditions (100 F, 85% RH) resulted in a larger reduction of both organisms. Yogurt was packaged in a LDPE pouch and a laminated foil pouch. A very slight difference in survival rates of the organisms was observed in the different package types.

Initial counts of S. thermophilus and L. bulgaricus were 4.10×10^{5} and 5.30×10^{4} respectively, after freeze drying and storage for ten weeks at room conditions (72 F, 50% RH) in the LDPE pouch, a reduction to 3.7×10^{3} for S. thermophilus and 3.0×10^{3} for L. bulgaricus was found. This indicates that organism survival rate is only

TABLE 5: Average Values of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* Present in Fresh Yogurt, Initial Freeze Dried and Packaged Freeze Dried Yogurt plated on Lee Agar.

Samples	Storage Time (weeks)	S. thermophilus	L. bulgaricus
Fresh Yogurt	0	7.7×10^{8}	2.1×10^{9}
Initial Freeze Dried	0	4.1×10^{5}	5.3×10^{4}
LDPE[a]	2	2.9×10^{4}	1.9×10^{3}
	4	3.2×10^{4}	2.3×10^{3}
LDPE[r]	2	5.2×10^{4}	1.2×10^{4}
	4	4.6×10^{4}	2.4×10^{4}
	10	3.7×10^{3}	3.0×10^{3}
Laminate[a]	2	3.3×10^{4}	3.9×10^{3}
	4	2.7×10^{4}	3.2×10^{3}
Laminate[r]	2	6.6×10^{4}	7.3×10^{3}
	4	4.7×10^{4}	6.5×10^{3}
	10	3.8×10^{4}	4.0×10^{3}

NOTE: All average values determined from triplicate samples.

a. Accelerated Conditions 100 F, 85% RH.
r. Room Conditions 72 F, 50% RH.

moderately affected during storage in both packages.

4.1.2 Headspace Gas Composition:

Head space analysis was done to monitor the change in the concentrations of oxygen, carbon dioxide and nitrogen, which can affect the shelf life of the product during storage. Storage of freeze dried yogurt at room conditions in both types of pouches showed a decrease of oxygen in the headspace to about 14%. during the first four weeks. The oxygen content increased back to the initial level of 17% after ten weeks (Table 6). The decrease in oxygen content in both package types is probably a result of oxidative rancidity or protein oxidation. Extended storage of the product in the LDPE pouch allowed oxygen to permeate back into the headspace to reach equilibrium. In the laminate pouch subjected to accelerated conditions, carbon dioxide was detected in the headspace. This is probably due to nonenzymatic browning reactions which produce carbon dioxide. The presence of carbon dioxide detected during the first week of storage in the laminate pouch at room conditions may have been due to a sampling error resulting from the presence of residual carbon dioxide from the previous sample. Inadequate flushing of the syringe may account for the carbon dioxide detected.

4.1.3 Color Analysis:

The Hunter Spectrophotometer was used to compare color

TABLE 6: Average Values of Gas Present in the Package Head Space of Freeze Dried Yogurt Stored at Room and Accelerated Conditions.

Samples	Storage Time (weeks)	Percentages CO_2	O_2	N_2
LDPE[a]	1	N[b]	20.99	77.57
	2	N	14.55	85.46
	3	N	14.46	85.54
	4	N	14.25	85.75
LDPE[r]	1	N	17.66	82.33
	2	N	14.73	85.21
	3	N	14.54	85.46
	4	N	14.38	85.67
	10	N	17.71	83.04
Laminate[a]	1	0.36	15.83	83.81
	2	0.17	14.90	84.94
	3	0.48	14.44	85.04
	4	0.47	14.47	85.07
Laminate[r]	1	0.23	16.96	82.78
	2	N	14.60	85.40
	3	N	14.52	85.48
	4	N	14.23	85.77
	10	N	17.30	82.43

NOTE: All average values determined from duplicate readings from each of the two pouches.

a. Accelerated Conditions 100 F, 85% RH.
b. Gas concentration insufficient to detect.
r. Room Conditions 72 F, 50% RH.

changes in freeze dried yogurt during storage in different packaging materials. The Hunter L,a,b scale was designed to give measurements of color units of approximate visual uniformity throughout the color solid. Thus, "L" measures lightness and varies from 100 for perfect white to zero for black, approximately as the eye would evaluate it. The chromaticity dimensions ("a" and "b") give understandable designations of color as follows:

- "a" measures redness when plus, gray when zero and greenness when minus
- "b" measures yellowness when plus, gray when zero and blueness when minus

Measured L,a,b, values (Table 7) do not indicate an absolute measure of product whiteness. Whiteness is the attribute by which an object is judged to approach the preferred white. Ideal white is bluish, and departures from this ideal white toward yellow reduce whiteness ratings about four times as much as departures toward gray. Whiteness indices can be used to provide correlation with visual whiteness rankings of "product whiteness" for a number of product applications whereby, blue whites will be evaluated higher than neutral or yellow whites of the same lightness (ASTM E 313-73).

Whiteness indices were calculated using the experimentally determined L,a,b values. The relationship between Hunter L,a,b values and the International Commission on

TABLE 7: Average Hunter Color Cell Values of Fresh Yogurt, Initial Freeze Dried and Dried Yogurt Stored in Polyethylene and Laminate Pouches.

Samples	Storage Time (Weeks)	Hunter Cell Values L	a	b	Whiteness Index (WI)
Fresh Yogurt	0	80.4	- 2.2	9.6	20.54
Dried Initial	0	85.6	- 1.4	15.7	- 3.52
LDPE[a]	1	82.4	- 1.8	15.8	- 6.50
	2	81.3	- 2.0	16.2	- 9.56
	3	80.6	- 2.4	17.0	-13.33
	4	78.4	- 2.8	17.6	-17.38
LDPE[r]	1	84.2	- 1.6	15.6	- 4.16
	2	82.2	- 1.8	15.8	- 6.65
	3	82.6	- 2.4	16.4	- 9.18
	4	82.8	- 2.2	16.2	- 8.09
	10	78.5	- 2.8	15.8	- 9.25
Laminate[a]	1	82.2	- 2.0	15.6	- 5.71
	2	80.2	- 2.4	15.8	- 8.09
	3	80.2	- 2.6	16.2	- 9.92
	4	80.4	- 2.6	16.3	-10.25
Laminate[r]	1	80.2	- 2.4	15.2	- 5.34
	2	80.3	- 2.4	15.2	- 5.27
	3	80.1	- 2.4	15.2	- 5.41
	4	80.4	- 2.4	15.4	- 6.11
	10	82.7	- 2.5	15.8	- 6.27

NOTE: All average values determined from triplicate readings.

a. Accelerated Conditions, 100 F, 85% RH
r. Room Conditions, 72 F, 50% RH.

Illumination (CIE) X,Y,Z values is as follows:

$$X = 0.98041 \quad 0.01L^{2} + \frac{aL}{(175)}$$

$$Y = 0.01\ L^{2}$$

$$Z = 1.18103 \quad 0.01L^{2} - \frac{bL}{(70)}$$

Whiteness Index (WI) per ASTM Method E 313-73 is:

$$WI = 4\ \frac{Z}{1.18103} - 3Y$$

The calibrated standard white tile has a maximum WI of 72.0. Freeze drying resulted in a sharp reduction of WI from 20.5 for fresh yogurt to -3.5 (Table 7). During storage WI values decreased indicating a change in the products color from white to yellow. Throughout storage under accelerated conditions whiteness decreased in both package types. Four weeks of storage at accelerated conditions lowered the WI to -10.3 in the laminated pouch as compared to -17.4 in the LDPE. A similar trend was observed for storage at room conditions in both packages. Ten weeks of storage at room conditions resulted in a WI of -6.3 in the laminated pouch as compared to -9.3 in the LDPE. In general color changes were less prominent in the laminate pouch versus the LDPE pouch, due to its impermeable structure (Figure 5).

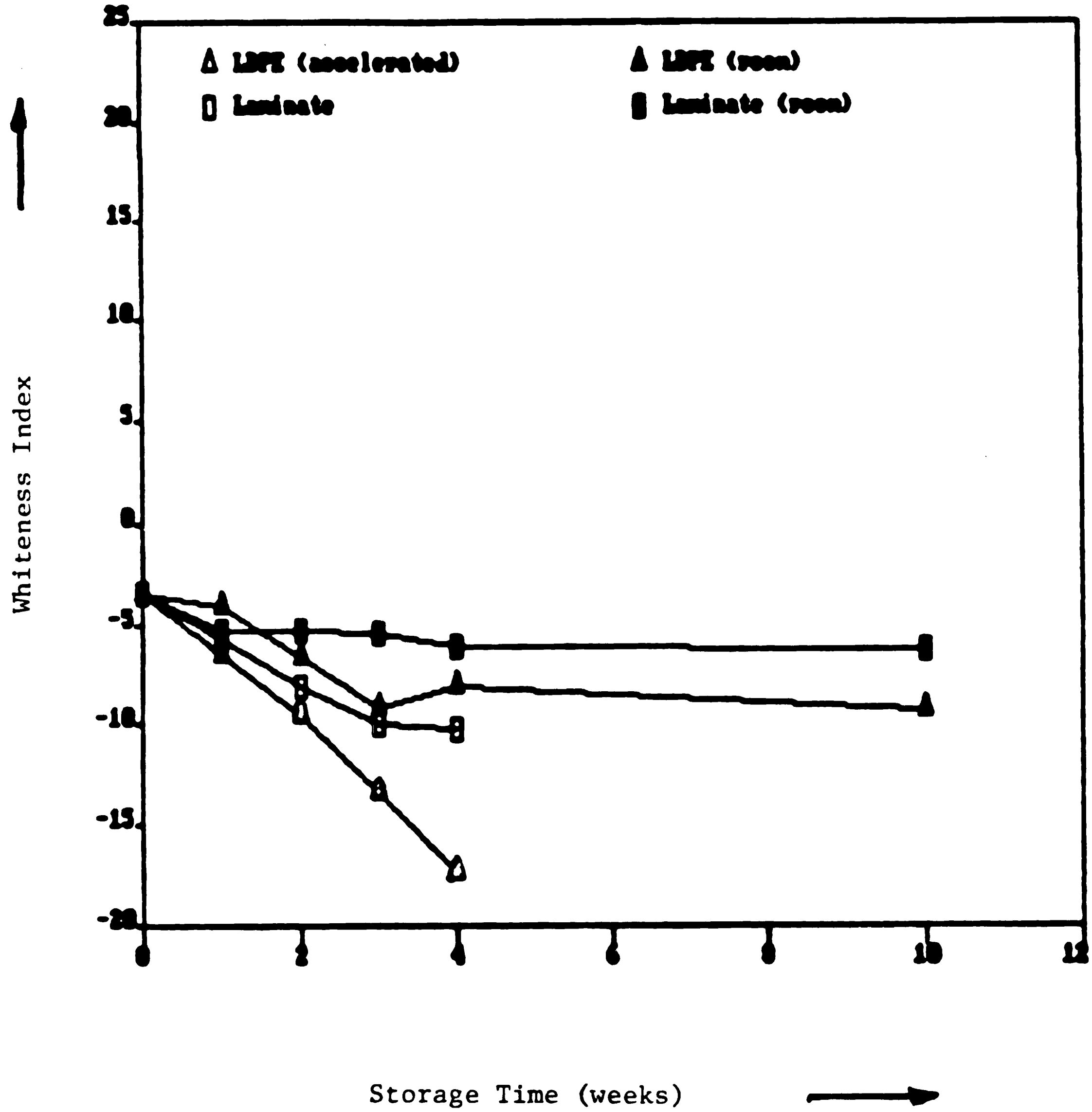

FIGURE 5: Whiteness Index for Yogurt

4.1.4 pH:

Rasic and Kurmann (1978) reported that the optimum flavor of yogurt is usually obtained at a pH value between 4.40 and 4.00. Low acidity of yogurt (pH above 4.6) induces whey separation due to a weak structure. High acidity (pH below 4.0) can cause a contraction of the coagulum and whey separation due to a decrease in protein hydration. pH values (Table 8) indicate that freeze drying did not affect the acidity. However, extended storage showed a decrease in pH from 4.0 to 3.9 indicating a slight increase in acidity.

4.1.5 Moisture Content:

Initial moisture content of freeze dried yogurt was found to be 2.71 (Table 9). Storage in LDPE pouches resulted in an increase in moisture content over time. An average moisture content of 3.80 was reached when stored at room conditions for ten weeks and 5.78 at four weeks under accelerated storage conditions (Figure 6). However, in the laminate pouch, the moisture content decreased to 1.50 and then stabilized at 2.00 after extended storage. This may be due to crystallization of lactose which could affect the amount of moisture in the freeze dried yogurt in the laminate pouch (Iglesias and Chirife, 1982).

Permeability constants for LDPE were determined at 70 F, 50% RH (Table 10). No moisture gain was observed for the laminate pouch subjected to storage for two weeks at 100 F (37.7 C) and 70% RH.

TABLE 8: pH of Fresh Yogurt, Initial Freeze Dried and Reconstituted Yogurt.

Samples	Storage Time (Weeks)	pH
Fresh Yogurt	0	4.0
Initial Freeze dried	0	4.0
LDPE[a]	1	4.0
	2	4.0
	3	4.0
	4	3.9
LDPE[r]	1	4.0
	2	4.0
	3	4.0
	4	3.9
	10	3.9
Laminate[a]	1	4.0
	2	3.9
	3	3.9
	4	3.9
Laminate[r]	1	4.0
	2	4.0
	3	4.0
	4	3.9
	10	3.9

NOTE: Average pH value of water used for reconstitution was determined to be 7.1.

a. Accelerated Conditions, 100 F, 85% RH.
r. Room Conditions, 72 F, 50% RH.

TABLE 9: Average Values of Moisture Content for Freeze Dried Yogurt.

Samples	Storage Time (Weeks)	Moisture Content
Initial Freeze dried	0	2.71
LDPE[a]	1	2.74
	2	3.92
	3	4.84
	4	5.78
LDPE[r]	1	2.00
	2	1.92
	3	2.65
	4	2.37
	10	3.80
Laminate[a]	1	1.77
	2	1.55
	3	1.81
	4	1.83
Laminate[r]	1	1.88
	2	1.59
	3	1.53
	4	1.57
	10	2.00

NOTE: Average values based on triplicate readings.

a. Accelerated Conditions, 100 F, 85% RH.
r. Room Conditions, 72 F, 50% RH.

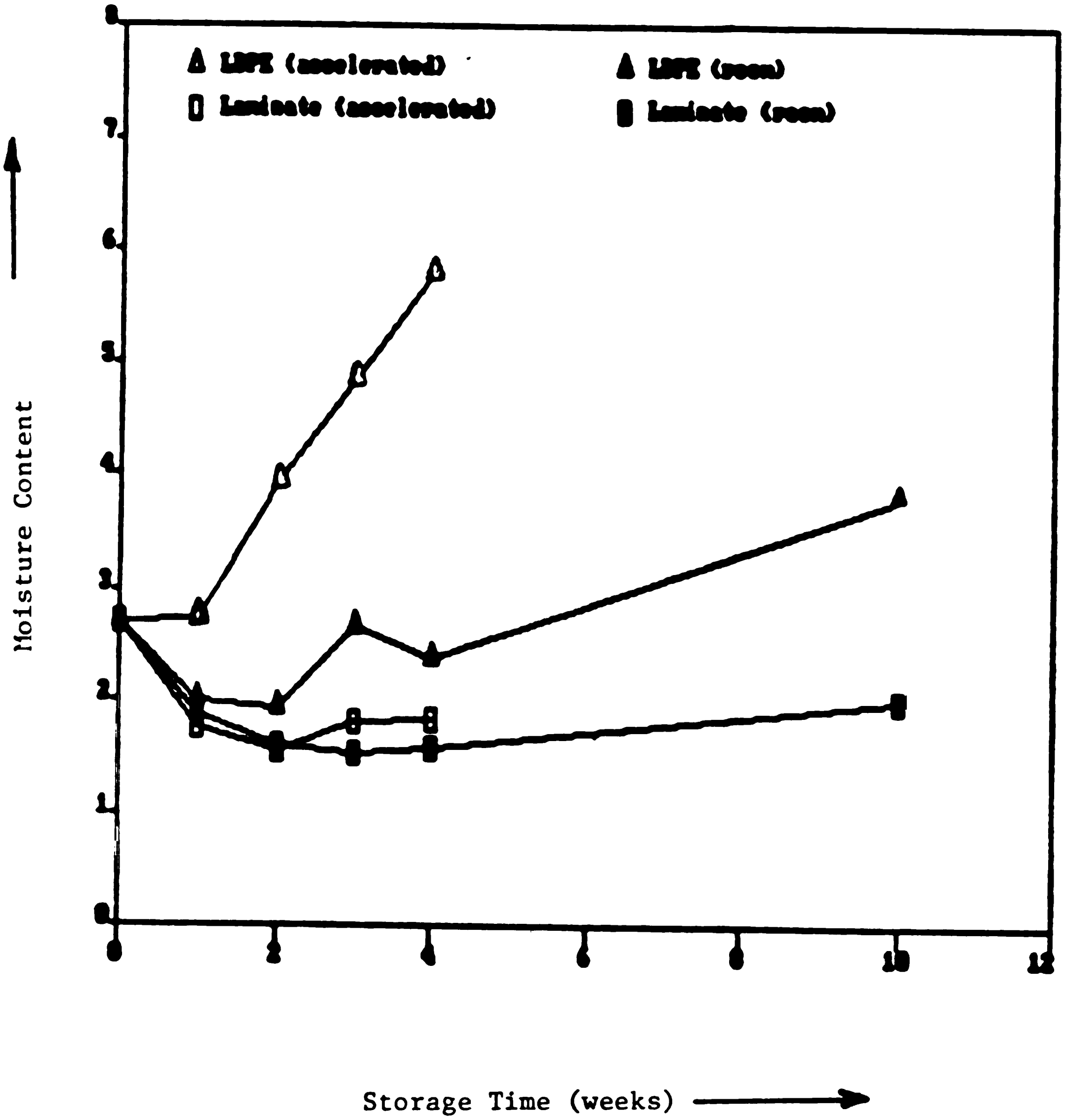

FIGURE 6: Moisture Content for Freeze Dried Yogurt.

TABLE 10: Permeability Constants for WVTR, Oxygen and Carbon-dioxide Transmission of LDPE.

Permeability Constant	LDPE
Water Vapor[1]	$0.4333 \frac{\text{gm - mil}}{\text{sq.m. - mmHg - days}}$
Carbon Dioxide[2]	$32741 \frac{\text{cc - mil}}{\text{sq.m. - atm - days}}$
Oxygen[3]	$3780 \frac{\text{cc - mil}}{\text{sq.m. - atm - days}}$

1,2,3 Test Conditions 72 F (22.2 C) and 50% RH.

4.1.6 Flavor:

The flavor of reconstituted freeze dried yogurt during storage was monitored and compared to fresh yogurt. The sensory panel consisted of three expert taste panelists. Sensory evaluation was based on the American Dairy Science Association Flavor Scoring Guide for Swiss Style Yogurt (see Appendix C). Scoring ranged from a ten for yogurt with no defects to a one with several pronounced defects. A score below five indicates one or more serious flavor defects.

Freeze dried yogurt was packaged in pouches made from three different materials. These were:

a. Kraft Paper

b. LDPE Film

c. Foil Laminated Film

Freshly made yogurt was rated a nine by the judges (Table 11). Flavor tests of reconstituted yogurt stored in Kraft paper pouches was discontinued after two weeks because it was rated unacceptable by the judges. Initially, reconstituted freeze dried yogurt prior to storage scored an eight by two judges and a seven by the third (Table 11).

After ten weeks of storage at 70 F and 50% RH, the reconstituted freeze dried (LDPE) yogurt was evaluated a seven by two judges and a six by the third. Reconstituted yogurt (laminated pouch) after similar storage was evaluated to be a five by two panelists and a six by the third. Both of these were considered to be acceptable by

TABLE 11: Flavor Ratings of Reconstituted Freeze Dried Yogurt Based on the Collegiate Dairy Products Scorecard for Swiss Style Yogurt.

Samples	Storage Time (Weeks)	Flavor Panelists A	B	C
Fresh Yogurt	0	9	9	9
Initial Freeze Dried	0	8	7	8
LDPE[a]	1	7	7	7
	2	7	5	7
	3	5	5	6
	4	3	6	3
LDPE[r]	1	8	6	8
	2	7	6	7
	3	6	7	7
	4	6	7	7
	10	6	7	7
Laminate[a]	1	7	6	6
	2	6	7	7
	3	7	6	7
	4	6	6	6
Laminate[r]	1	8	5	9
	2	8	6	7
	3	7	6	7
	4	6	7	7
	10	5	6	6

a. Accelerated Conditions, 100 F, 85% RH.
r. Room Conditions, 72 F, 50% RH.

the panel.

Storage for four weeks under accelerated conditions of 100 F and 85% RH (LDPE) pouch resulted in an unacceptable flavor. However, storage of the dried powder in the laminated pouch under the same conditions resulted in a reconstituted yogurt which was evaluated to be acceptable (Table 11).

Defects that were noted in the sensory analysis of reconstituted yogurt were:

- Bitter Taste
- High Acid
- Lacks Freshness
- Weak Consistency
- Old / Stale
- Lacks Fine Flavor

Results indicate that the laminate pouch showed better flavor retention during extended storage (accelerated conditions) as compared to the LDPE pouch because of its better barrier properties (Table 11).

5.0 CONCLUSIONS

Reconstituted freeze dried yogurt is favorably accepted after being subjected to extended storage. Longer shelf life was obtained using a laminate (Polyester / Foil / Polypropylene) pouch versus a LDPE pouch or paper bag. The product had acceptable flavor ratings at the end of ten weeks of storage under room conditions for both the laminate and the LDPE pouch. Freeze dried yogurt packaged in LDPE pouches had similar properties under room conditions as yogurt in the foil laminated pouch but showed more deterioration under accelerated conditions as compared to the laminate pouch. High moisture and oxygen transmission rendered the third package, the paper bag, unacceptable within one week of storage.

Color degradation was more prominent in the freeze dried yogurt packaged in the LDPE pouch versus the laminate pouch. The pH remained fairly constant during storage in both package systems. The laminate pouch being a better moisture barrier maintained a lower moisture content as compared to the LDPE pouch. Viable counts of both yogurt organisms decreased during storage in the two packages. Levels of both organisms decreased by an order of 1×10^{6} to 1×10^{7} due to freeze drying and storage. Higher initial counts are therefore recommended prior to freeze drying and storage to ensure a quality product on reconstitution.

Some future areas of investigation are:

- Use of stabilizers for improved shelf life
- Packaging under inert gas or vacuum
- Using selected strains of yogurt organisms to better withstand freeze drying and storage or the use of cryoprotective agents to protect yogurt cultures during freeze drying and storage
- Flash freeze fresh yogurt to minimize destruction prior to freeze drying
- Storage of freeze dried yogurt at lower temperatures
- Effect of flavor changes in products using reconstituted yogurt

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APPENDICES

APPENDIX A

LOW FAT YOGURT FORMULATION

Ingredients	Amount for 100 lb batch (lbs)	
	Small Can	Large Can
Raw Whole Milk[1]	15.0	27.0
Water	17.6	31.8
Non Fat Dry Milk	3.2	5.7
TOTAL	35.8	64.5

Yogurt Culture[2] added later = 2.4 lbs

1. Milk fat was determined to be 3.6% by the M.S.U. Dairy Plant.
2. Bulk starter culture using Chris Hansen's deep frozen concentrated R-1 yogurt culture

APPENDIX B

MILK STANDARDIZATION FOR LOWFAT YOGURT

Raw whole milk contained 3.6% fat as determined by the M.S.U. Dairy Plant.

Percent Fat Required = 1.5% , 12.6% Solids Non Fat (SNF)

Assumed SNF in skim milk = 8.8%

Calculations: Based on a 100 lb batch.

1. For each 1.5 parts at 3.6% fat use 2.1 parts Non Fat Dry Milk (NFDM) plus water

2. Whole Milk Required = 100 (lbs) x (1.5 / 3.6) = 41.7 lbs.

3. Reconstituted NFDM Required = 100 (lbs) x (2.1 / 3.6)

   = 58.3 lbs.

4. Serum Required = 42.0 - 1.5 = 41.5 lbs

5. SNF Present = 100 (lbs) x 12.6% = 12.6 lbs.

6. SNF from Water and NFDM = 12.6 - (41.5 x 8.8%)
   = 8.95 lbs.

7. Amount of Water Required = 58.30 - 8.95 = 49.35 lbs.

Therefore a 100 lb batch consists of 41.7 lbs of milk, 49.4 lbs of water and 8.9 lbs of NFDM.

APPENDIX C

FLAVOR SCORING GUIDE FOR YOGURT

Flavor Criticism	Intensity of Defect Slight	Definite	Pronounced
Bitter	9	7	5
Cooked	9	8	6
Coarse	9	7	5
Foreign	8	7	6
High Acid	9	7	5
Lacks Fine Flavor	9	8	7
Lacks Flavoring	9	8	7
Lacks Freshness	8	7	6
Lacks Sweetness	9	8	7
Low Acid	9	8	6
Old Ingredient	7	5	3
Oxidized	6	4	1
Rancid	4	2	*
Too High Flavoring	9	8	7
Too Sweet	9	8	7
Unnatural Flavoring	8	6	4
Unclean	6	4	1

Source: ASDA guide for scoring flavor of swiss style yogurt

APPENDIX D

COMPOSITION OF LEE AGAR AND PLATING TECHNIQUES

Preparation for 1 liter (1000 ml) solution.

Ingredient	Amount
Tryptone	10.0 grams
Yeast Extract	10.0 grams
Lactose	10.0 grams
Sucrose	5.0 grams
Calcium Carbonate	3.0 grams
Potassium Hydrophosphate	0.5 grams
Agar	18.0 grams
Bromcresol Purple (BCP)	0.2 grams in 100 ml distilled water

Ingredients were weighed and distilled water added to make 1 liter. Components were thoroughly mixed on a magnetic hot plate. Prior to sterilization the pH of the medium was adjusted to 7.0 ± 0.1. The medium was sterilized by autoclaving at 249.8 F (121 C) for 20 minutes. The BCP solution was sterilized at the same temperature for 15 minutes.

Prior to pouring again, sterile petri dishes should be chilled to insure uniform distribution of the Calcium Carbonate. Per one liter of Agar, 10 ml of BCP is used. Agar must be thoroughly mixed to evenly suspend Calcium Carbonate. Plates are poured 4 to 5 mm thick and allowed to solidify. Plates may be refrigerated until used. Incubation of plates is at 98.6 F (37 C) for 48 hours. Time and temperature must be exact to assure culture identification.

APPENDIX E

RECONSTITUTION OF DRIED YOGURT

Based on a 14% solids and 86% water composition in yogurt.

A 100 lb yogurt batch contains 1.5 lbs. fat (1.5%) and 12.6 lbs. SNF (12.6%).

Hence amount of water in
a 100 lb batch of yogurt = 100 - 12.6 - 1.5 = 85.9 lbs

Therefore for each 14 parts of dried yogurt, 86 parts of water was used for reconstitution.

APPENDIX F

YOGURT SCORE CARD

Flavor

Score 10 .... No Criticism

Score 9 or less..	Bitter	Lacks sweetness
	Cooked	Low Acid
	Coarse	Old Ingredient
	Foreign	Oxidized
	High Acid	Rancid
	Lacks Fine Flavor	Too High Flavor
	Lacks Flavoring	Too Sweet
	Lacks Freshness	Unnatural Flavoring
		Unclean

Source: ASDA score card for swiss style yogurt

APPENDIX G

WATER VAPOR PERMEABILITY CONSTANT

Water Vapor Transmission Rate:

$$WVTR = \frac{\text{Weight Gain}}{\text{Time in Days}} = 0.0388 \text{ g/day}$$

$$\bar{P}_{H_2O} = \frac{\text{WVTR}}{\text{AREA (sq.m.) x VAPOR PRESSURE (mm.Hg.)}}$$

Vapor Pressure

@ 100 F, 90% RH = 46.92 x 0.90 = 44.72 mm.Hg.

$$\bar{P}_{H_2O} = \frac{0.0388 \text{ g/day} \times 2.7 \text{ mil}}{0.00541 \text{ (sq.m.)} \times 44.72 \text{ (mm.Hg.)}}$$

$$\bar{P}_{H_2O} = 0.4333 \text{ g - mil / sq.m. - day - mm.Hg.}$$

$$\bar{P}_{H_2O} = 0.0281 \text{ g - mil / 100 sq.in. - day - mm.Hg.}$$

APPENDIX H

PERMEABILITY CONSTANT FOR OXYGEN

$$\bar{P}_{O_2} = \frac{\text{VOLUME OF GAS PERMEATED (cc) x THICKNESS (mils)}}{\text{AREA (sq.m.) x TIME (days) x PRESSURE (atm.)}}$$

Film Thickness = 2.7 mils.

Reading from Ox-Tran = 14 mV

Ox-Tran Calibration : 1 mV = 100 cc / sq.m. - days

Gas Permeated from calibration equation = 1400 cc / sq.m. - days

$\bar{P}_{O_2}$ = 1400 x 2.7 = 3780 cc - mils / (sq.m. - days - atm)

$\bar{P}_{O_2}$ = 244 cc - mils / 100 sq.in. - days - atm

APPENDIX I

PERMEABILITY CONSTANT FOR CARBON DIOXIDE

$$\bar{P}_{CO_2} = \frac{\text{VOLUME OF GAS PERMEATED (cc)} \times \text{THICKNESS (mils)}}{\text{AREA (sq.m.)} \times \text{TIME (days)} \times \text{PRESSURE (atm.)}}$$

$$\bar{P}_{CO_2} = \frac{0.02 \text{ (cc)} \times 2.7 \text{ (mils)}}{0.0005 \text{ (sq.m.)} \times 0.0033 \text{ (days)} \times 1.0 \text{ (atm)}}$$

$$\bar{P}_{CO_2} = 32741 \text{ cc - mils / sq.m. - days - atm.}$$

$$\bar{P}_{CO_2} = 2112 \text{ cc - mils / 100 sq.in. - days - atm.}$$