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FEASIBILITY OF PACKAGING ARTIFICIAL,
FILLED AND NATURAL CHEESES IN SELECTED MATERIALS

By

Scott E. Ionson

A THESIS

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ABSTRACT

FEASIBILITY OF PACKAGING ARTIFICIAL, FILLED, AND NATURAL CHEESES IN SELECTED MATERIALS

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Retail cuts of natural, filled, and synthetic Mozzarella and Cheddar cheese were vacuum packaged in oriented polypropylene/PVDC/polyethylene/EVA (A), polyester/EVA/polyethylene (B), low density polyethylene (C), oriented nylon/PVDC/polyethylene/EVA (D), and polyamide/polyolefin (E). Physico-chemical changes occurring in the cheeses were measured through 35 wk of storage at 4 C. Color fading was evident after 22 wk in Filled and natural Cheddar samples packaged in B and E, hypothetically due to higher oxygen permeabilities for these films. Fading was accompanied in some instances with lower flavor scores. Low flavor scores were also given artificial Mozzarella cheese in film B after 35 wk. Extensive mold development on cheese was caused by a poor oxygen barrier in film C, flex-cracking in film B, entrapped oxygen in films A and E, and seal leaks in films A, B, and E. Important variables influencing the extent of mold and oxidation are material gas barrier

characteristics, flexibility, and susceptibility to flex-crack as well as cheese conformation, compressibility, and gas evolution.

for Kath

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INTRODUCTION

The popularity of cheese has increased substantially during the last 25 years. In order to keep up with demand, United States cheesemakers have increased production by 250% (Siapantas, 1979; Milk Industry Foundation, 1979). The largest area of growth has been with the Italian type cheeses which showed a 10-fold increase in sales between 1950 and 1974. Mozzarella cheese in particular gained in popularity with a 10-fold increase during the last 18 years (Siapantas, 1979).

Concurrent with the increased demand for cheese has been a relative decrease in fluid milk availability with production essentially stable (Milk Industry Foundation, 1979; Siapantas, 1979). As a result, milk for cheesemaking has been obtained mostly by shifting milk from other industries. The per capita production of fluid milk used for cheese-making in this country increased 70% between 1950 and 1975 (Siapantas, 1979). Presently, cheese production is by far the largest use of milk for manufacturing with approximately 25% of the total milk supply being utilized for cheese (Miller, 1978).

Cheese analogs are non-dairy imitation products made from caseinate mixtures, oils, acidulants, and flavors. They do not require ripening and can be made quickly and

simply in large quantities. The potential economic advantages of cheese analogs are evident since they are not directly dependent upon the milk supply. Also, the caseinates used in cheese analogs are imported and offer distinct cost advantages in comparison with domestic sources. Various sources estimate the costs of analogs to be 60 - 70% that of natural cheeses (Horn, 1970; Andres, 1976). Numerous other advantages have been claimed by various sources (Horn and Godzicki, 1972; Andres, 1976; Vernon, 1976; Moore, 1979). The cheeses are said to have a better shelf-stability as characterized by more consistent flavor during storage and reduced mold contamination. Additional merits include uniform quality and nutritional equivalency relative to natural cheeses.

The greatest market potential for cheese substitutes is as ingredients in fabricated or formulated foods (Andres, 1976; Siapantas, 1979). They can be added as a partial replacement or complete substitution for more costly natural cheeses. The analogs are also approved for use in the national school lunch program (Taylor and Wilson, 1975). Presently, a number of cheese substitutes are being sold in consumer portions at local retail outlets. Major marketing advantages at the retail level include reduced cost, nutritional equivalency, and health orientation (e.g., essentially cholesterol-free and polyunsaturated fatty acids).

Filled cheeses are also beginning to gain momentum in the retail market (Koren, 1970; Moore, 1979). These

products are manufactured from a skim milk-vegetable oil homogenate and therefore are dependent upon fluid milk supplies. However, they can be made from polyunsaturated vegetable oils, a definite advantage to cholesterol conscious consumers.

Retail cheese packaging has been evolving throughout the past several decades. Originally, portions were cut and tight wrapped at the retail market resulting in considerable waste and limited shelf life (Davis, 1965b). Major trends and developments in the last several decades have moved towards centralized packaging facilities and increased and/or national distribution of cheese packs (Giblin, 1967; Anon., 1967; Sacharow and Griffin, 1970). These trends are directly related to the development of films and packaging methods for cheese and meat products. The objectives of the new developments have been motivated by the desire to protect the cheeses from the rigors of distribution under long-term storage conditions.

The objective of this study was to investigate the feasibility of vacuum packaging artificial, filled, and natural cheeses in selected flexible materials. A vacuum packaging method was chosen due to its increasing popularity, and positive influence on the shelf-stability of cheese. The flexible films were supplied by American Can Company and varied considerably from one another in terms of their gas and vapor barriers, flexibilities, and suitability for use in vacuum packaging. Artificial Mozzarella, artificial

Processed American, natural Cheddar, natural Mozzarella, and a corn oil filled Cheddar-type cheese were packaged and stored for 35 wk at 4 C. Quality changes occurring in the products and packages were assessed throughout storage.

LITERATURE REVIEW

Cheese is a general term used to describe a large variety of fermented milk-based products regularly consumed in all parts of the world. Each variety possesses unique chemical, physical, and microbiological characteristics resulting from the different ingredients, cultures, and procedures used during manufacture. Many systems have been devised for classifying natural cheeses. The one presented below is based upon the consistency or resistance of body and the method of ripening (Campbell and Marshall, 1975).

- I. Very Hard - 30 to 35% moisture
 - a) Ripened by bacteria (Romano, Parmesan, and aged Asiago)
- II. Hard - 35 to 40% moisture
 - a) Without eyes, ripened by bacteria (Cheddar, Colby, Stirred Curd, Provolone)
 - b) With eyes, ripened by bacteria (Emmentaler, Swiss, Gruyere, and medium Asiago)
- III. Semi-soft - 40 to 45% moisture
 - a) Ripened by bacteria (Brick, Muenster, and fresh Asiago)
 - b) Ripened by bacteria and microorganisms on surface (Limburger, Port du Salut)
 - c) Ripened primarily by blue mold in interior (Roquefort, Gorgonzola, Stilton)
- IV. Soft
 - a) Ripened usually by surface organisms - 45 to 52% moisture (Brie, Camembert, Bel Paise)
 - b) Unripened - 52 to 80% moisture (Cottage, Cream, Neufchatel, Mozzarella, and Pizza)

Processed cheeses are formed by grinding, heating (65 to 71 C), and emulsifying natural cheeses in stainless steel kettles. Inorganic salts are added to aid in emulsification (Kosikowski, 1977). Many different combinations and varieties of natural cheese can be used in the production of processed cheese.

Imitation cheeses are also made by heating and mixing ingredients under vacuum in steam jacketed kettles. Mozzarella and Processed American are the most frequently encountered substitutes on the market followed by grated Romano and Parmesan, Cream Cheese, Provolone, and Swiss (Siapantas, 1979). Large blocks for institutional or industrial use can be obtained from Anderson Clayton and Cheese-Tek, whereas Fisher and Kraft supply substitutes for retail sale.

Filled cheeses are manufactured similarly to natural cheese after preparation of a skim milk-vegetable oil homogenate (Rao-Jude and Rippen; 1967; Koren, 1970). They are inoculated with culture and occasionally ripened. Many vegetable oils may be used to replace the butterfat. Corn oil is commonly used due to its polyunsaturated nature. They have enjoyed relatively good success on the retail market (Moore, 1979). Current products on the market include Cheez-ola (Fisher) and Kraft's Golden Image.

Retail Cheese Packaging

Packaging Methods

At the retail level, three methods currently predominate the film packaging of cheese: tight wrapping, vacuum-gas flushing, and vacuum packaging. An excellent comparative discussion of the three methods is provided by Pearson and Scott (1978).

Tight wrapping is the traditional method of retail cheese packaging. It involves either machine or hand wrapping of plastic films or foils around cheese portions followed by heat sealing. There is some evidence that tight wrapping is becoming more popular in recent years (Pearson and Scott, 1978). One reason for this may be nostalgic appeal since tight wrapped cheeses are often dipped in wax either before or after film packaging. Material costs are generally less since expensive laminated films are generally not utilized (Table 1). Cost savings are also evident in the packaging machinery. The ALPMA ASVP is a common, automatic tight wrapping machine and was found to be the most economical of all packaging systems when using Saran wrap (Pearson and Scott, 1978). Tight wrapping is also applicable to many different cheese shapes, sizes, and textures. Packaged cheeses will also stack more easily and thus optimize available space. The disadvantages associated with tight wrapping are that it is time consuming and labor intensive in the absence of automatic machinery. Also, the materials utilized are more easily

Table 1. Economic Evaluation of Major Packaging Methods*

Packaging Method	Gas Flush (1/2 lb pkg)	Vacuum-Pack (1/2 lb pkg)	Tight-Wrap (Automatic) (1-lb pkg)	Tight-Wrap (Manual) (1-lb pkg)	Wax-Dip Process ⁶ (1-lb pkg)
Machine Cost	\$38,000 -	\$65,000 -			
Initial Investment)	45,000	75,000	\$40,000 - 60,000 (estimate)	\$22,000 (estimate)	\$5,000
Average Machine Speed	75/min	60/min	40/min	22/min	30/min
Machine Operation Cost ¹	\$0.64	\$1.16	\$1.45	\$0.53	\$0.10
Film Cost ¹	\$23.80- ²	\$36.40- ³	\$10.50- ⁴	\$7.70 - ⁴	\$8.44- ⁵
Labor Cost	\$39.00	\$41.00	\$45.00	\$56.82	\$5.56
Gas Cost- ¹	\$00.60	n/a	n/a	n/a	n/a
Total Cost- ^{1,7}	\$64.04- ²	\$77.86- ³	\$59.65- ⁴	\$64.05- ⁴	\$14.10

- 1 - Based on 1,000 lb cheese wrapped, exclusive of printing or labeling costs.
- 2 - Represents different films. Low cost is American Can "Am Tough"; high cost is Curwood "200 XL".
- 3 - Wide cost range due to physical draw characteristics and quality of film (i.e. deeper the draw, higher the cost of the film)
- 4 - Based on 60 gauge Saran Wrap at \$0.07/1,000 sq. in.
- 5 - Based on average cost for wax of \$0.27/lb.
- 6 - If waxed-dipped, these costs should be added to cost for tight-wrap packaging.
- 7 - Includes machine depreciation on straight-line basis over 10-yr period.

* Taken from Pearson, 1978.

punctured than more complex laminated structures. A punctured area is, however, localized and does not necessarily cause total package failure. Most cheeses packaged by this method may also have lower shelf life relative to vacuum packed and gas flushed cheeses. Pearson and Scott (1978) estimated a shelf life of approximately four months for most cheese varieties compared to five months for most gas flush and vacuum techniques. Additional shelf life for tight wrapped cheeses can be obtained by wax dipping or the use of sorbates.

Vacuum-gas flush techniques currently predominate retail cheese packaging (Pearson and Scott, 1978). With this method, laminated films containing cheese are evacuated and subsequently flushed with either carbon dioxide or nitrogen. The use of carbon dioxide results in a partial collapse of the bag due to a reaction between the gas and water to form carbonic acid. The materials presently used generally have good gas barriers and provide excellent shelf life for most cheese varieties. The available roll-stock form-fill-seal machinery is fast, versatile, and able to accommodate a variety of cheese shapes and sizes. The most common gas flush packaging machine used is the Hayssen RT. This machine utilizes rollstock materials which are formed into bags around the cheese, evacuated, gas flushed, and heat sealed.

Unfortunately, the necessary films are expensive due to the more stringent requirements necessary for a good

gas flush package. Also, additional expense is required for the gases which are utilized. Difficulty in stacking due to film overlaps and lack of nostalgic appeal are other detriments. Finally, a leak or puncture affects the entire package and does not remain localized.

Several methods of vacuum packaging are currently in use. One method involves the use of special films capable of shrinking after application of heat. Final closure is accomplished either by a heat seal or metal clip. This method can provide excellent shelf-stability for most cheeses if used with the proper materials and is equivalent to gas flushed packages in that respect. Shrink films are also ideally suited for use with irregularly shaped and soft cheese. However, relatively expensive materials are required, and the systems are more labor intensive. Vacuum packaging can also be accomplished by evacuation of cheese-filled pouches. This system uses films and packaging machinery similar to that employed in gas flush operations (Anon., 1977).

A third method utilizes reel-fed, "deep draw" materials which are thermoformed into cavities, filled with cheese, evacuated, and heat sealed with an additional layer of plastic film as a lid. Machines presently available which utilize "deep-draw" forming films include: Hooper 1000, ALPMA VAC, Kock Multi-Vac. The machines are fast, efficient, and reduce labor costs. Both of the evacuation methods provide shelf life comparable to that

obtained with a gas flush system (Pearson and Scott, 1978). However, evacuation systems require expensive laminated materials. Large film overlaps are generally present in the final package which reduce consumer appeal and create difficulties in cartoning and storage. Punctures and leaks also result in total package failure due to loss of vacuum.

A relatively recent method called secondary sealing makes use of evacuation and shrink film principles (Anon., 1977). Cheese portions are bagged in shrinkable film, evacuated by a deep draw method, heat sealed, and then passed through a heat chamber. The resulting package is free from ears and excess materials, and has an excellent seal due to the double protection afforded by heat sealing and shrinkage. Additionally, localized punctures will not cause total package failure. The Cryovac 8300 rotary packaging machine was developed for secondary sealing of cheese (Anon., 1978a).

Packaging Films

Many films for retail cheese packaging are presently being manufactured. These include a vast array of structures based on aluminum foil, polyethylene (PE), polyamide, polyester, and paper. They can be used singly or in combination as laminated structures and are supplied as pre-formed bags or rollstock. Films developed specifically for use in cheese packaging can be obtained from Curwood, Standard, American Can Company, Milprint, and Cryovac.

Basic Film Types. Most tight wrapped methods utilize relatively simple materials and avoid the more costly laminated structures. The majority of tight wrapped packages use clear Saran Wrap (Pearson and Scott, 1978). Saran Wrap is a polyvinylidene chloride (PVDC) material manufactured by Dow which has excellent barrier characteristics. Aluminum foil laminates are also used for some tight wrapped cheeses.

Gas flush and vacuum packaging systems require complex laminates. The shortcomings of single films can be overcome by combining two or more materials to form laminated structures. The components of laminated films are chosen so that each contributes a property or properties desirable to the total system. For example, PVDC and nylon are often used as components of laminates and provide excellent barrier and flexural properties, respectively.

Packages used for gas flushing require materials which must have good machinability, flex crack resistance, good barrier characteristics, and heat sealability. Amtuf, Triguard, and Superfilm are three materials manufactured by the American Can Company designed for use on Hayssen RT machines as either gas flush or vacuum packages. Milprint also manufactures three films used for gas and vacuum packaging of cheese. Table 2 presents the structures and some of the barrier characteristics of these and other common cheese packaging films.

Shrink films have the ability to draw down on the

Table 2. Available Cheese Packaging Materials *

Manufacturer	Tradename	Structure	Barrier Properties		Application
			Oxygen	H ₂ O	
Cryovac	Barrier Bag	Ethylene vinyl acetate (EVA) PVDC/EVA	1.9-3.2cc/100 in ² /24 hr (1 atm, 22.8 C)	0.5-0.6 g/100 in ² /24 hr (37.8 C, 100% RH)	Shrink Film
Cryovac	S Bag	Shrinkable PVDC	6.5-19.5 cc/100 in ² /24hr/ml thickness (1 atm, 22.8 C)	1.0-1.8 g/100 in ² /24 hr/ml thickness (37.8 C, 100% RH)	Shrink Film
Milprint	Basic	Biaxially oriented polypropylene/EVA sealant	0.125-0.5 cc/100 in ² /24 hr (22.8 C)	0.6-0.8 g/100 in ² /24 hr (37.8 C)	Gas Flush, Vacuum Pack-aging on Hayssen-type machines
Milprint	N/A	Biaxially oriented polypropylene/polyethylene/PVDC coating/polyester/EVA sealant	Same as Milprint Basic	Same as Milprint Basic	Same as Mil-print Basic
Milprint	N/A	Biaxially oriented polypropylene/polyethylene/PVDC coating/K-Cello/EVA sealant	Same as Milprint Basic	Same as Milprint Basic	Same as Mil-print Basic
American Can Company	Amform	Polyamide/Plexar/EVA Polyethylene/Polyamide/Plexar/EVA	N/A	N/A	Gas Flush, Vacuum Pack-aging on Thermoform machines

Table 2. (Cont'd.)

Manufacturer	Tradename	General Structure	Barrier Properties		Application
			Oxygen	H ₂ O	
American Can Company	Superfilm	Polyester/PVDC coating/Biaxially oriented polypropylene/EVA	≤ 1 cc/100 in ² /24 hr (22.8 C)	≤ 0.5 g/100 in ² /24 hr (22.8 C)	Gas Flush, Vacuum Packaging - Hayssen
American Can Company	Amtuf	Biaxially oriented polypropylene/PVDC coating/polyethylene/EVA	Same as for Superfilm	Same as for Superfilm	Same as for Superfilm
American Can Company	Triguard	Biaxially oriented polyamide/polyethylene/PVDC coating/polyethylene/EVA	Same as for Superfilm	Same as for Superfilm	Same as for Superfilm
American Can Company	Triguard S	Biaxially oriented polyamide/polyethylene/EVA	≤ 3 cc/100 in ² /24 hr (22.8 C) 50% RH (22.8 C)	≤ 1 g/100 in ² /24 hr (22.8 C)	Natural Swiss Cheese on Hayssen Machines

*Information collected via manufacturer brochures and personal conversations with sales representatives.

contents of a package when heated. They are produced by "orienting", or stretching the film under controlled conditions (Hanlon, 1971). PVDC, polyethylene (PE), polyester, polypropylene (PP), polyvinyl chloride (PVC), and rubber hydrochloride are all capable of shrinking characteristics. Shrink films for cheese packaging must have good shrink properties, abuse resistance, and seal strength. They are also produced with excellent barrier properties. Cryovac manufactures two shrink bags designed for use in cheese and meat packaging. The Barrier Bag is a laminate of ethylene vinyl acetate (EVA)/Saran/EVA. The use of EVA in cheese packaging has been increasing. Its properties can be varied by adjusting the component proportions (Hanlon, 1971). Cryovac's S Bag is a shrinkable film of polyvinylidene chloride.

Films for use in thermoform machines must be easily heat formed for molding into cavities. Polyamide/PE laminate and these two in combination with Surlyn, are often used (Anon., 1976; Anon., 1977). Surlyn is an ionomer resin with excellent strength and the ability to seal at relatively low temperatures (DuPont, 1976).

All of the materials and laminates discussed have been designed to provide the excellent barrier properties and general requirements necessary for most cheese varieties. Other films have also been created which accommodate the special needs of more unusual varieties. These will be discussed in a separate section of this review of the

literature.

Basic Film Requirements. Packaging films should be suitable for printing, and should not contribute off flavors or odors to the cheese. Also, the films must not contain toxic substances capable of migration into the food. Polymer materials are generally inert, but potential hazards from monomers, adhesives, plasticizers, and inks should be assessed (Shaw, 1977). Toxicological safety data must be provided by the manufacturer to the Food and Drug Administration before approval of the materials for use in food packaging.

An extremely important requirement of packaging films is that they adequately control the headspace environment of the packaged cheese to prevent oxidative deterioration, dehydration, and undesirable mold development. Seal integrity, selective barrier properties, and the ability to cling closely to the cheese body are all variables which can be controlled by selection of suitable films. However, the packaging method utilized and characteristics related to the particular cheese variety being packaged also have effects on the headspace environment. Therefore, this topic will be discussed in the next section with consideration given to all these variables.

Behavior of Packaged Cheese

The shelf life of cheese is difficult to measure. The dynamics of product deterioration can be related to many factors, including sanitation practices, manufacturing procedures, cheese variety, initial milk or ingredient quality, packaging, and storage conditions. The "pasteurizing" effect of the heat treatment (65 to 71 C) given Processed and artificial cheeses during manufacture can improve resistance to mold development. Also, both of these products generally contain sorbates which are effective anti-mycotic agents. The use of sorbates for controlling mold development on cheese will not be discussed in detail. Emphasis will be placed on shelf life variables related to packaging materials and methods. Factors which can be controlled by use of suitable packaging materials and methods are mold development, oxidation, and dehydration.

Mold Development

Molds thrive in acidic conditions and grow within a pH range of 2.0 to 8.5. Many are psychrotrophic and develop well at normal refrigeration temperatures, although the optimum temperature for growth is generally from 25 to 30 C (Frazier and Westhoff, 1979). Film wrapping prevents rind formation so that ample surface moisture and nutrient are available to support mold growth provided sufficient oxygen is available.

Many cheeses are ripened by molds and require oxygen

for proper development. Internal mold ripened varieties (e.g. Blue, Gorgonzola, Roquefort) reportedly lose their blue marbling after storage in vacuum packages (Kosikowski, 1977). Nonetheless, many Roquefort-type cheeses are tight wrapped in aluminum foil, or plastic laminates. Hard, thermoformed trays with aluminum foil lids have also been used to package crumbled Blue cheese varieties (Sacharow & Griffin, 1970). External mold ripened cheeses (e.g. Brie and Camembert) can develop off flavor if allowed to ripen anaerobically. Many different films and foils have been used for packaging these varieties. Perforated foil laminates are often employed, the perforations being adjusted to allow a certain amount of oxygen gain and yet prevent dehydration (Kiermeier and Wolfseder, 1972; Jallon and Fallon, 1979). Plastic lined metal cans have also been used. These cheeses are autoclaved for several minutes at 2 - 3 psi and have better shelf stability. However, flavor changes are often associated with metal can types of package systems (Kosikowski, 1977).

For most cheese varieties, mold growth is the major cause of product deterioration (Davis, 1965b; Kiermeier and Wolfseder, 1972). Vacuum packaging, gas flushing, and tight wrapping techniques are all designed to exclude oxygen from beneath the cheese film and thus prevent mold development. Dolby (1966) devised an oxygen balance sheet to clarify the dynamics of oxygen concentration beneath film wrapped cheese.

Oxygen Balance Sheet for
Film Ripened Cheese

Oxygen Gain

- a) Enclosed under film in wrapping
- b) Leakage through defective seals, in overlaps, or end folds.
- c) Leakage through punctures or chafed areas in film.
- d) Permeation through film.

Oxygen Loss

- e) Absorption by cheese (bacterial action, reducing systems)
- f) Utilization by mold.
- g) Balance available for mold growth and oxidation

Entrapped Oxygen. Shrink films generally provide close film contact with the cheese body resulting in minimal oxygen entrapment. Very soft or non-uniform cheeses (Mozzarella, Pizza) in which entrapped oxygen may be a problem due to the irregularities of the cheese are commonly packaged in shrink films (Vander Pleog, 1979; Anon. 1967). It is possible, however, to trap oxygen at the seal area, particularly if nozzle evacuation and clip sealing are used. Processed and artificial cheese can be hot poured directly into packaged materials. This also provides close film contact with the cheese. Bulk Processed cheese is generally packaged by pouring directly into wax-coated cellophanes (Kosikowski, 1977). Sliced Processed cheese may be rolled off cold drums, sliced and automatically packaged, or packaged hot by extrusion into a tube which is then sealed, compressed into a flat strip, cooled, cut, and overwrapped. This is currently being done using DuPont's 50CS Mylar polyester film on an extruder made by

Green Bay Machinery (Anon., 1978b).

The concentration of entrapped oxygen can be decreased beneath a package due to gas evolution by the cheese. Volodin and Shiler (1977) assessed the oxygen and carbon dioxide concentrations beneath the wrapper in ripening Rossikii and Kostroma cheese. Metal, PVDC, and polyethylene film were used as packaging materials. Their results indicated that oxygen concentration declined rapidly after the first few days of storage, while that of carbon dioxide increased. No mold growth was observed when the oxygen concentration in the gas underneath the wrapper was less than 2% and that of carbon dioxide greater than 27%. Most cheeses produce a small amount of carbon dioxide, the extent of its evolution being dependent upon the microorganisms present. Emmental varieties, however, produce extensive carbon dioxide during storage, making mold development due to entrapped oxygen unlikely.

Entrapped oxygen could also be utilized by the cheese. Dolby (1966) reported that fresh packaged Cheddar cheese had considerable reducing power and was able to utilize entrapped oxygen, making it unavailable for mold development. Reductive power was elevated at higher temperatures, hypothetically due to increased culture activity. Older cheeses, with their lower microbial populations, did not utilize oxygen as readily beneath the packaging films. Mold growth on samples packaged in two of the films used

by Dolby increased at lower temperatures for cheese which was 14 days old at packaging. Dolby suggests holding cheese at higher than refrigeration temperature for one to two days immediately after packaging in order to utilize entrapped oxygen. Ironically, this practice was common with earlier methods of packaging rindless cheese (Jones, 1944).

This information may have relevance in the retail packaging of Processed, imitation, and non-ripened cheeses. Both imitation and Processed cheeses contain relatively fewer microorganisms and would, therefore, exert decreased reducing potential. A greater potential for mold growth might be anticipated for these products since oxygen would not be as readily utilized. Non-ripened cheeses might benefit from the higher storage temperature after retail packaging assuming that they were packaged soon after production and do not suffer in quality. Cheese which has ripened for several weeks or months would not have sufficient reducing power for this to be of value in retail packaging.

Gas Barrier Properties. It is important to control the amount of oxygen permeating through the material. Sacharow and Griffin, 1970, suggested an oxygen barrier for cheese of not less than $5\text{cc}/100\text{in}^2/24\text{ hr}$ at 73 F (22.8 C) and 50% relative humidity. However, Pearson and Scott (1978) reported that cheese requires a barrier to oxygen no less than $1\text{cc}/100\text{in}^2/24\text{ hr}$. No reference to temperature or

relative humidity was included in the latter estimate. These estimates should only be regarded as general guidelines. Cheese variety and conditions of storage can affect the necessary barrier requirements.

As indicated earlier, the extensive gas evolution of Emmental varieties may inhibit mold development. Films for use in these cheeses often have relaxed barrier properties which allow diffusion of carbon dioxide from the package and prevent package rupture. Triguard S, manufactured by American Can Company, was produced expressly for use in packaging Swiss-type cheeses. Its permeation rate is approximately three times that of the other films listed in Table 2 . A material developed by Schmidt, Stoltzenger, and Wolf (1974) consists of one essentially gas impermeable layer and one layer of permeable material with a middle film of polyethyleneimine. This film has carbon dioxide absorbing properties and as such is also a suitable film for packaging Tilsit and Emmental cheeses.

When selecting a film, it is important to be aware of its hydrophilic properties. Storage at high relative humidity or direct contact between a hydrophilic material and cheese portion can adversely affect the water vapor and gas barriers. Decreasing temperature will improve the barrier characteristics of films, the extent of change being dependent upon the particular material (Hanlon, 1971; Karel, 1975).

Seal Leaks. Seal leaks are probably the most common and important factors leading to mold development in film packaged cheese (Davis, 1965b; Paine, 1977). Seal leaks have been cited as the major cause of decreased shelf life in tight wrapped cheese (Pearson and Scott, 1978) compared to cheese packaged by gas flush or vacuum techniques. Wax treatment after tight wrapping or the use of sorbates may both be used to improve package and product stability.

Heat sealing is commonly used for both vacuum and gas flush systems. Extensive leaking of the heat seal can potentially cause total package failure in gas flush and evacuation methods. Shrink bags are either heat sealed or closed with a metal clip. Clips can be potential weak spots and should provide firm closure without tearing the film. Conochie (1972) obtained a better closure using a rubber strip under tension in a helical configuration. Prior to sealing, the inside necks of the bags were coated with butter oil.

Paine (1977) reported on the efficiency of heat seals in a thermoform vacuum packaging system. Two material reels were used in the machine. Film from the first was vacuum formed into rectangular pockets which were then filled with approximately 1/2 lb blocks of Cheddar cheese. Material from the second reel was used for "lidding" the pack after evacuation. After packaging, the cheeses were stored and checked for leakers. The results are presented in Table 3. They can be summarized as follows:

Table 3. Summary of Results for Seal Leak Study*

	No. of Packs Examined	No. of Leaks	%
Total	640	197	30.9
Routine	329	98	29.8
Restarts	88	22	25.0
<u>Pack Weights (g)</u>			
200	38	6	21.0
200-209	63	16	25.4
210-219	97	24	24.7
220-229	97	24	24.7
230-239	148	42	28.4
240-249	150	53	35.3
250-259	29	9	31.0
260	18	8	44.4
Packs Weighing 220 g	198	46	23.2
Packs Weighing 240 g	197	70	25.5
Leaks Caused by Wrinkled Thermoforms		8	1.3
Packs with Cheese Visi- ble in Seal Area	26	17	65.4

* Taken from Paine (1977)

1. Many size variations were present between cut cheese portions.
2. A larger number of leakers occurred with larger portions.
3. Whenever seal contamination was visible, the packs had extensive leakage.

Paine's recommendations were as follows:

1. Find the optimum shape of cheese block which produces the least fragmentation and cut to these dimensions.
2. Modify the cheese to make it cut satisfactorily, or
3. Improve the cutting method to handle existing cheese variability.

Additional research by Paine indicated that non-visible smearing of product at the seal area could decrease the strength of the seal by as much as 5 to 10%.

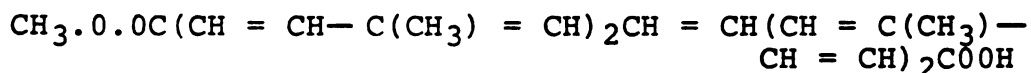
Further refinements in machinery and materials might also help reduce the number of leakers. For example, additional samples packaged by Paine on a modified machine showed a reduction in leakers. Secondary sealing of cheese portions as described earlier might also reduce seal failure.

Oxidation

During the 1950's, New Zealand market conditions forced prolonged refrigerated storage of ripening of Cheddar cheese with rinds. A significant portion of the cheese supply was subsequently lost due to color fading and a tallowy flavor, both of which were associated with mechanical holes and slits in the hoops. This stimulated research on these

defects. The appearance of defects was found to increase with increasing oxygen exposure, lower storage temperature, increasing moisture content, and increasing salt content. The development of both problems was attributed to oxidation of the annatto dye and cheese fat (Riddet, Whitehead, Robertson and Harkness, 1961; Bishop, 1961).

Oxidation typically begins on the exposed food portion, is dependent upon the presence of oxygen, and is catalyzed by light, metals, enzymes, heat, and ionizing radiation (Dugan, 1976). Oxidation can particularly be a problem in consumer sized portions due to their relatively high surface area. The sensitivity of the annatto pigment to oxidative deterioration is clearly evident in light of its highly double bonded structure (Davis, 1965c):



Dolby (1966) reported that a lower storage temperature can inhibit oxidation in Cheddar cheese. He found that vacuum packed Cheddar cheese stored at 2 C had higher peroxide values than those stored at 13 C. This was attributed to greater reducing power at the elevated temperature as a result of increased bacterial activity. Corroborative results were reported by Riddet, Whitehead, Robertson and Harkness (1961) who observed a higher incidence of tallowing discoloration in Cheddar cheese at lower temperatures. Temperature may influence both oxidation kinetics and microbiological activity. Young and

active cultures could reduce or eliminate necessary oxygen and thus inhibit oxidation despite the positive effects of temperature on oxidative kinetics. Dolby (1966) also reported that mold growth and fat oxidation never occurred together. It was conjectured that mold development utilized oxygen within the package.

A considerable amount of work on flavor and chemical changes occurring in packaged consumer portions of cheese was conducted by Kristoffersen, Stussi, and Gould (1965). The study assessed the flavor stability of sliced and chunk style cheese using several packaging materials. Packaged samples were stored at 4.4 C with and without exposure to fluorescent light. Two polyethylene materials, four laminated polyethylene materials, and a PVDC film were used for packaging. The method of wrapping and permeability characteristics were not discussed and the role of oxygen not well defined.

Flavor loss occurred for both light-exposed and protected Cheddar and Swiss cheese. After seven days of storage, the sample quality between light-protected and exposed cheeses was different, although equally undesirable. Flavor defects in light-exposed samples were described as oxidized and metallic after seven days of storage. The flavor deterioration in light-protected cheeses occurred in two steps: first, an initial undesirable quality in the samples which, secondly, developed into defects described as acid, fermented, whey tainted, and utensil.

Packaging materials did not seem to influence the development of off flavors.

Flavor deterioration in chunk size cheeses was surface related with inner portions of the samples being least affected. Similar work with Processed cheese showed no flavor loss in the light-protected samples and improved stability in the light-exposed samples. The increased stability suggests that heat treatment either destroys factors related to the development of off flavors or otherwise improves stability.

The effects of package material on flavor defects in light-exposed samples was also investigated by Kristoffersen, Stussi, and Gould (1965). It was concluded that aluminum foil laminates and polyethylene overwrapped with a ultraviolet light screening material (Uvinul D-49) provided superior flavor stability. The authors related the flavor deterioration in light-protected cheeses with atmospheric contact since the coating of cheese samples with distilled acetylated monoglyceride (Myvacet 7-00) prior to packing in polyethylene improved stability in light-protected but not light-exposed cheeses. However, the use of antioxidants and gas flush techniques did not improve flavor stability in light-protected or exposed samples.

As indicated earlier, the role of oxygen and atmospheric contact was not well defined in the study. One would anticipate that light-protected cheeses packaged in PVDC would react similarly to Myvacet due to its excellent gas

barrier properties. It is also unclear as to why gas flush packaging or the use of anti-oxidants did not improve stability in the light-protected cheeses. It is possible that oxidation was initiated during the cutting and packaging operations. Additional oxidative deterioration would then continue autocatalytically without oxygen. Hydroperoxides may also have been produced during initial storage of the uncut cheese, or by lactic acid organisms. However, this does not explain why the Myvacet application successfully retarded deterioration. It may have chemically inhibited oxidative mechanisms in the cheeses.

Photooxidation is distinguished from spontaneous, auto-oxidation in several ways. Light energy can greatly catalyze oxidative initiation reactions by stimulating the production of free radicals or by causing the formation of singlet oxygen. After initiation, light can catalytically degrade hydroperoxides by photolysis. Ultraviolet light (UV) and some wavelengths of the visible spectrum have been shown to cause light-induced off flavors in dairy products. Green, red, blue, brown, and red colored materials have all been utilized to prevent light-induced off flavors in food products (Sattar and deMan, 1975).

A second study by Kristoffersen, Stussi, and Gould (1965) was conducted to assess the chemical changes in Cheddar cheese wrapped in plain polyethylene film under light-protected and exposed conditions. The thiamine disulfide test for sulfhydryl groups, 2-Thiobarbituric acid test, peroxide test, and the copper method for alpha-amino

nitrogen determination were employed to follow chemical changes. The latter three tests revealed only slight differences in the fat and protein systems of the samples during seven days of refrigerated storage. The thiamine disulfide test showed that sulfhydryl group (SH) concentration decreased after seven days of storage for both light-protected and light-exposed samples. It is conjectured that because of the poor oxygen barrier of polyethylene, sulfhydryl groups of cheeses were most likely oxidized.

Data for chunk cheese after 14 days of storage indicated that sulfhydryl groups decreased more gradually as compared to slices, maintained a higher level in the light-exposed samples, had higher levels in cheese packed in aluminum foil laminates, and rather dramatically increased after approximately one week in the light-exposed samples.

The last phenomenon was interpreted as a possible compensatory effect of light under certain conditions and tends to override the factor(s) contributing to the decrease in sulfhydryl groups. The relationship between this and light exposure is difficult to assess, however, due to the excellent screening properties of aluminum foil.

Coating chunk cheese with Myvacet 7-00 before packaging resulted in greater stability of sulfhydryl groups after 14 days of light-protected storage. The authors concluded that greater stability of sulfhydryl groups in coated cheeses can be related to improved flavor stability.

A relationship was indicated between flavor stability, persistence of active sulfhydryl groups, stability of oxidation-reduction potential (Eh), and increasing pyruvic acid concentration.

Dehydration

Cheese is an intermediate moisture food with a high water activity. Without packaging, the cheese develops a rind due to water evaporation from the surface. This rind retards but does not stop further loss of moisture from the cheese. Pearson and Scott (1978) recommend a water barrier of not less than $1 \text{ g/100 in}^2\text{24hr}$ for cheese packaging materials. Most modern cheese packaging films and foils all provide good barriers to water (Table 2). Except in cases of extensive seal leaking or pinholing, film packaged cheese generally does not lose more than 0.1% moisture (Davis, 1965b).

Packaging Ripening Blocks of Cheese

In general, the packaging requirements for ripening blocks of cheese are similar to those necessary for retail portions. Most cheese for ripening was traditionally packaged by bandaging and dressing (Davis, 1965a). Bandaging involves the application of a calico or cheese cloth bandage followed by treatment of the cheese with greased muslin. The structure was either sewn or glued on with a flour paste. Dressing the cheese involved the application of a wax, oil, or fat. Cheese treated in this manner

developed a protective rind as a result of surface dehydration.

A substantial portion of cheese for ripening is presently packaged in films and foils. Tight wrapping with Pliofilm or Parakote films has been utilized for large ripening blocks (Kosikowski, 1977). Shrink films such as Cryovac's Barrier Bag are also utilized. In the case of rindless Swiss-type cheese, where gas promotion during ripening is considerable, films which absorb carbon dioxide or have lower barrier properties can be utilized. Cryovac Barrier Bags, and other expandable materials, can also be employed but space must be provided to allow for package expansion (Kosikowski, 1977). Blue cheeses can also be ripened in Cryovac bags. However, the cheese wheels must be perforated after packaging to allow access of oxygen (Kosikowski, 1977).

EXPERIMENTAL PROCEDURES

Materials

Cheese Substitutes

Analogs of Mozzarella and Processed American cheese were used in this study. Both non-ripened and non-dairy products were prepared according to the recommendations of Western Dairy Products (Petka, 1976). Tables 4 and 5 present the ingredient list and proximate compositions of the analogs as calculated for their production in the present work.

Ingredients. The protein type used in the fabrication of cheese analogs reportedly influences their textural and flavor characteristics (Horn, 1970; Bell, Wynn, Denton, Sand, and Cornelius, 1975; Roe, 1974). A variety of different milk and vegetable sources have been utilized either singly or in combination. In this study, Savortone 491, a commercial sodium-calcium caseinate mixture supplied by Western Dairy Products was used. More specific information on Savortone is presented in Table 6.

The specifications for a fat system for use in both analogs are outlined in Table 7. These characteristics of the fat system help contribute to the proper body and texture of the product without imparting a "greasy"

Table 4. Formulation and Proximate Composition of Artificial Mozzarella Cheese

Ingredient	Formula (kg)	Approximate %
Savortone 491	15.30	26.00
H ₂ O Fraction A	20.00	34.00
H ₂ O Fraction B	5.90	10.00
H ₂ O Fraction C	4.10	7.01
Paramount X	5.32	9.00
Crisco Oil	5.32	9.00
Glucono-Delta Lactone*	1.70	2.90
Salt	1.20	2.00
PFW Flavor	0.06	0.10
TOTAL	58.90	100.00

*Supplied by Pfizer

Table 5. Formulation and Proximate Composition of Artificial Processed American Cheese.

Ingredient	Formula (kg)	Approximate %
Savortone 491	13.30	21.51
H ₂ O Fraction A	18.80	30.40
H ₂ O Fraction B	2.30	3.72
H ₂ O Fraction C	8.00	12.94
Paramount X	5.50	8.89
Crisco Oil	5.50	8.89
Citric Acid	0.50	0.81
Salt	1.10	1.78
Sodium Citrate	0.24	0.39
Sodium Aluminum Phosphate*	0.18	0.29
Hydrolyzed Cereal Solids**	2.60	4.20
Cheddar Flavor	3.80	6.14
Color	0.02	0.03
TOTAL	61.84	100.00

* Kasal-Stauffer Chemical Co.

**Mor-ex-CPC International

Table 6. Savortone 491 - Calcium/Sodium Caseinate^aA. Description

Savortone 491 is an interreacted spray dried milk protein product manufactured from specially selected premium quality edible casein.

B. Physical Properties

1. Organoleptic
 - a. Flavor and Odor: bland and clean, no "off" or foreign flavors or odors (10% solution).
2. Color - white to light cream.

C. Analytical Data

1. Typical Analysis

a. Protein (N x 6.38 - moisture free basis)	94.0%
b. Fat	1.2%
c. Ash (moisture free basis)	4.6%
d. Moisture	4.4%
e. pH (5% solution at 20 C)	7.4

2. Typical Microbiological Estimate

a. Total Plate Count (col/g)	< 5000
b. Yeast and Mold Count (col/g)	< 100
c. E. Coli (per 100 g)	None
d. Salmonella (per 100 g)	None

D. Packaging

Packed in printed 50 lb net weight kraft paper bags having polyethylene liners. The polyethylene liners are separately closed and the paper bags secured with mechanically stitched tapes.

E. Shipping and Storage Recommendations

Ship and store in closed containers under clean, cool, dry conditions. Maximum recommended storage time is six months.

^a Courtesy Western Dairy Products

Table 7. Suggested Fat Systems for Use in Imitation Mozzarella and Imitation Processed American Cheese*

Hydrogenated Vegetable Oil	
Wiley Melting Point	44.4 - 45.6 C
SFI** - 10.0 C	19.4
21.1 C	13.3
26.7 C	8.3
33.3 C	-3.3
37.8 C	-10.6
43.3 C	-14.4
Vegetable Oil	
Wiley Melting Point	18.3 C
AOM (Active Oxygen Method)	90 hr
Free Fatty Acids	0.05%

*Courtesy of Western Dairy Products

**Solid Fat Index

character (Horn, 1970; Bell, Wynn, Denton, Sand, and Cornelius, 1975; Roe, 1974). Paramount X, obtained from Durkee Foods, was used as the source of hydrogenated vegetable oil. Partially hydrogenated Crisco oil (Procter & Gamble) was used as the second fat component. Additional information on the characteristics of these two ingredients is outlined in Table 8.

A number of acidulants can be used for the production of analogs (citric, malic, lactic, gluconic, or adipic). Each of these can have variable effects upon the taste, stringiness, firmness, and melting qualities of the cheese (Bell, Wynn, Denton, Sand, and Cornelius, 1975). Optimum pH is 5.1 for Mozzarella analogs and 5.3 for Processed American analogs (Bell, Wynn, Denton, Sand, and Cornelius, 1975). Following the recommendations of Western Dairy Products, the acidogen, glucono-delta-lactone, was used as acidulant in the artificial Mozzarella product. The Processed American analog was manufactured using citric acid.

Texture and sliceability can be controlled in part by addition of corn products or other starch derivatives (Horn, 1970). Mor-ex, a malto-dextrin product by CPC International was used in the manufacture of artificial Processed American cheese.

Only the Processed American analog contained emulsifying salts. Their addition can influence melting, shredding, and slicing characteristics. Sodium citrate and sodium aluminum phosphate obtained from Stauffer Chemicals were used.

The development of a good flavor has been a major

Table 8. Fat Systems Utilized in Imitation Mozzarella and Imitation Processed American Cheeses.

Paramount X*	
Wiley Melting Point	44.4 - 45.6 C
SFI -- 10.0 C	20.6
21.1 C	14.4
36.7 C	10.0
33.3 C	-2.8
37.8 C	-10.0
43.3 C	-17.8
Crisco Oil**	
Wiley Melting Point	N/A
AOM (Active Oxygen Method)	N/A
Free Fatty Acids	0.03%

*Supplied by Durkee Foods

**Supplied by Procter and Gamble

problem in producing quality analogs (Vernon, 1972). Many products were tested for this study, but none was found to impart the true flavor associated with the natural cheese counterparts. Artificial Mozzarella Cheese Flavor OS FTC 1541, purchased from Polak's Frutal Works, was chosen for use in the Mozzarella analog. CPF 7105 Cheddar Flavor was used in the imitation Processed American cheese. This is an enzyme modified cheese concentrate manufactured by Dairyland Food Laboratories, Inc. Approximately 0.04% annatto dye was added to the Processed American analog. Some color was also contributed by the Cheddar Flavor.

The addition of sorbates and other chemical preservatives was avoided in keeping with current market trends.

Manufacture of Cheese Substitutes. Schematic outlines for the production of both analogs are presented in Figures 1 and 2. The manufacture of artificial Mozzarella was a simple mixing and heating operation using the process cheese kettle at the Michigan State University Dairy Plant. This kettle is of double-walled construction and can be heated with steam or hot water. Large counter-current mixing blades are positioned inside the kettle for scraped surface blending. Total pot capacity for the production of analogs was approximately 59 to 63 kg.

Savortone 491 (caseinate blend) and a heated mixture of the two oils and the cheese flavor were blended in a kettle. Throughout manufacture, the kettle walls were maintained at a temperature of 90 to 95 C. Mixing

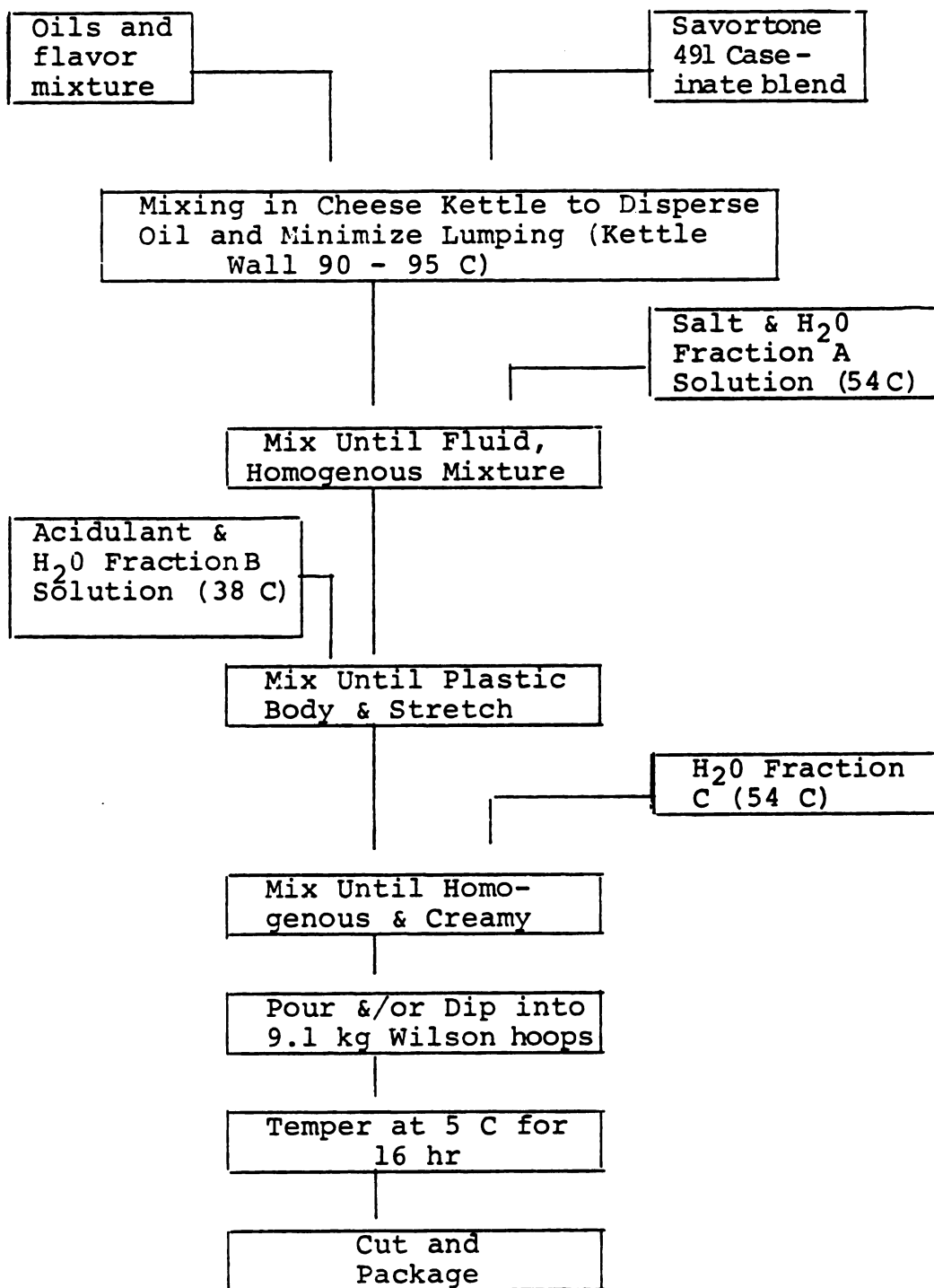


Figure 1. Flow Sheet for the Production of Artificial Mozzarella Cheese

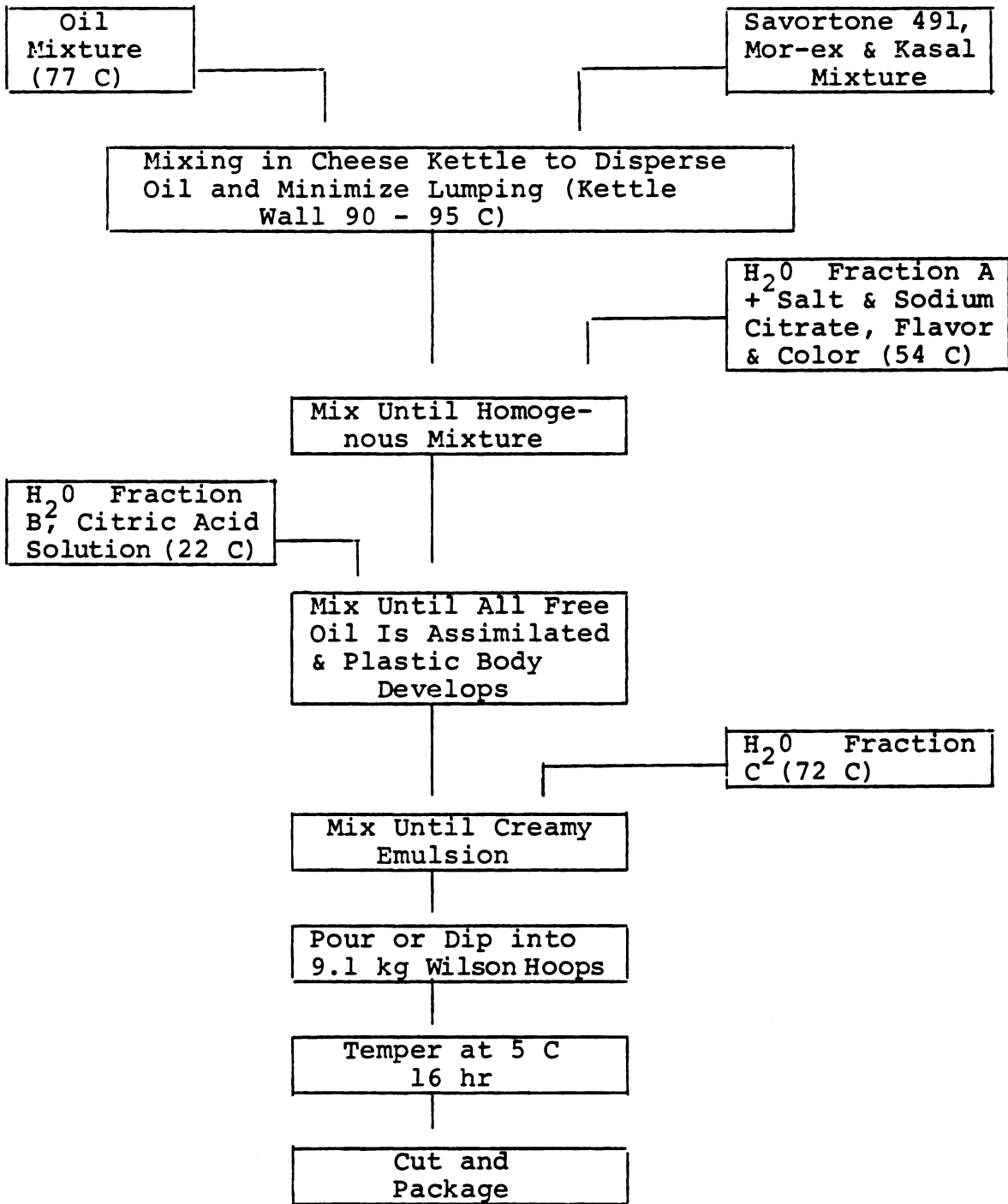


Figure 2. Flow Sheet for the Production of Artificial Processed American Cheese

was continued to optimize oil dispersion and minimize clumping. Salt and water fraction solution A was added to the mixing kettle. Some spillage of water did occur at this point due to the heavy agitation. The product was allowed to mix for approximately 1 min until a homogeneous and slightly viscous blend was obtained. After addition of the glucono-delta-lactone and water fraction B mixing continued for approximately 15 to 20 min until the onset of plastic body and some stretchability occurred. The final portion of water was added which, after blending, imparted flowability to the product. The analog was poured and dipped into four 9.1 kg Wilson hoops. Undispersed clumps were removed wherever possible. As noted in the flow chart, the analog was then tempered at 5 C for 16 hr prior to cutting and packaging.

The manufacture of the imitation Processed American cheese was very similar to artificial Mozzarella cheese. However, the blend did not assimilate the oils as readily. Accordingly, the mixing times were increased during the later stages. After addition of the acidulant and water solution, blending continued for approximately 30 - 40 min before addition of the final water portion.

The main problem encountered in production of the analogs was inadequate mixing. High shear force is imperative, and the kettle blades were not perfectly suited for the task. As a result, longer mixing times were required compared to those necessary to blend and disperse the ingredients in a small mixing bowl. Additionally,

the blending was not performed under vacuum as is commonly done in the manufacturing of some commercial products.

Rosano (Filled Cheese)

Rosano is a "filled" cheese routinely made at the Michigan State University Dairy Plant. A filled cheese contains essentially no butterfat since the source of fat is derived from a variety of vegetable oils. Rosano cheese is manufactured from milk with a total corn oil replacement for the butterfat so that this cheese could be called essentially "cholesterol free". Unlike the analogs previously discussed, culture inoculation and ripening are necessary for the production of Rosano. No artificial flavors or acidulents were added. In this study, five 9.1 kg hoops of cheese were taken from the curing rooms of the Dairy Plant.

Manufacture of Rosano Cheese. Skim milk and corn oil were first blended and homogenized at 42 kg/cm². The mixture was then pasteurized for 30 min at 62.8 C, cooled to 32.2 C and pumped into a 2,722 kg cheese vat. Final fat content in the filled milk was approximately 3.2%. Once in the cheese vat, the manufacturing steps for the production of Dagano cheese were employed.

Dagano culture was added at a rate of 100 ml per 454 kg of milk. This culture is a 1:5 mixture of Propionibacterium shermanii (Chr. Hansen's PS1) and a slow lactic acid producing culture (Marshall Superstart, Blend ME).

Both were added to the milk as frozen cultures. Single strength annatto cheese coloring was then added at a rate of 10 ml per 454 kg of milk and the mixture agitated for 25 - 30 min. Single strength microbial rennet (Emporase, Dairyland Food Labs, Inc.) was incorporated at a rate of 7 - 8 ml per 454 kg of milk. The milk was stirred for 3 min, and the mixture allowed to sit quiescently until formation of the curd (30 - 35 min). The coagulum was cut with a 9.5 mm wire knife and allowed to sit in the whey for approximately 10 min with only occasional agitation. Thirty percent of the whey was then drained, and 20% of the volume replaced with water at the same temperature as the milk. The curds were then slowly heated with agitation to 37.8 C in about 25 - 30 min. After cooking, the cheese curds were cooled for approximately 1 hr and 15 min, and then drained through a metal strain fitted into the exit gate of the cheese vat. Whey was drained down to the level of the curd bed with gentle agitation aiding the process. The packed curds were pushed to one end of the vat, cut, and dipped into rectangular, perforated metal forms. The cheese was pressed for 30 min at 1.4 kg/cm² to force out remaining whey. Pressure was then increased to 2.8 kg/cm² for approximately 2-1/2 hr. Cheese blocks were soaked in 22% saturated brine solution for 72 hr at 10 C, packaged in Cryovac shrink bags, and ripened for 24 days at 16.7 C before cutting and packaging for use in this study. The production report for the specific batch of Rosano cheese utilized is presented in Figure 3 .

Date:	8-11-78	kg of milk:	2377 + 80 kg corn oil
Operator:	Kim & Dick	Fat:	Skim
Past. Time:	30 min	Acidity:	Not indicated
Past. Temp:	62.8 C		

	<u>TIME:</u>
Starter added	7:30
Rennet added	8:05
Cutting	8:40
Whey out 30%	8:50
Began cooking	9:00
Water added 20%	9:05
Cooking finished	9:25
Drain	10:35
Stirring	10:45
Dip	10:55
I Press - 1.4 kg/cm ²	11:30
II Press - 2.8 kg/cm ²	12:00
Hours soaked in brine, temp 10 C, 22°B	72
Kg of cheese, 10% yield	245
Days in curing room at 16.7 C	24

Starter = 34 kg
 Rennet = 541 ml
 Color = 54 ml

Figure 3. Production Report for Rosano Cheese

Natural Cheddar

Natural Cheddar cheese is regularly produced at the Dairy Plant. Five 9.1 kg hoops were taken from the curing rooms for use in this study. The actual production report for the cheese taken for use in this study is presented in Figure 4.

Manufacture. Pasteurized milk (62.8 C - 30 min) containing 3.6% fat and 0.16% titratable acidity measured as lactic acid was pumped into a 2,722 kg cheese vat at 32.2 C. One and one-half cans of frozen multi-strain lactic cultures (Chr. Hanson's DVS 961) were stirred into the milk. Each can contained 360 ml of frozen culture. Single strength annatto cheese color was then added at a rate of 30 ml per 454 kg of milk. Titratable acidity was measured at 0.16%. The milk was allowed to sit for approximately 60 min. Em-porase was then added at a rate of 100 ml per 454 kg of milk. Microbial rennet was diluted 1:40 with tap water prior to introduction. The milk was stirred for 5 min and then allowed to sit without agitation for 25-30 min until curd formation. The coagulum was cut into cubes using 9.5 mm wire cheese knives, followed by 5 min of agitation. Titratable acidity of the whey was measured at 0.12%. Cooking was started slowly with steady agitation until a peak temperature of 37.8 C was reached in 30 min. The temperature was maintained for 45 min. Periodic agitation at a medium speed was used throughout the cooking and holding period. After cooking, the curds were pushed to one side of the vat, and the whey

Date:	8-11-78	kg of Milk:	2767 kg
Lot No.:	Not indicated	% Fat:	3.6
Operator:	Dick & Ben	Color Added:	204 ml
Past. Time:	30 min	Rennet Added:	610 ml
Past. Temp:	62.8 C	Starter Added:	Frozen
Setting Temp:	32 C		(1-1/2)
Acidity:	0.16	Salt Added:	8.2 kg
Starter Acid:	Frozen	kg of Cheese:	277 kg
Highest Temp:	37.8 C	Form of Cheese:	Square
		Yield per 100#:	10%

<u>Time</u>		<u>Milk or Whey</u> <u>Acidity</u>
7:20	Adding Starter	0.16
8:20	Adding Rennet	0.16
8:55	Cutting	0.12
9:05	Cooking	N/A
10:45	Drain	N/A
11:00	Packing	N/A
1:15	Milling	0.62
1:25	Salting	N/A
1:40	Hooping	N/A
2:05	Time in Press	20.40 hr

Figure 4. Production Report for Cheddar Cheese

drained through the exit gate. When the curds were about one inch below the surface of the whey, they were trenched over the length of the vat and allowed to mat for 15 min. The curds were then cut longitudinally into slabs and turned twice at 15 min intervals. The slabs were piled atop one another in groups of two and again turned every 15 min until a titratable acidity of 0.5 to 0.6% was reached. The slabs of matted curd were then milled, salted at a level of 0.3%, and dipped into 9.1kg Wilson hoops. After dipping, the cheese was pressed, first at 1.4 kg/cm² for 30 min, and then at 2.8 kg/cm² for approximately 14 hr. The cheese blocks were packaged in Cryovac shrink bags and ripened for 102 days at 16.7 C before cutting and packaging as retail portions for this study.

Natural Mozzarella

Natural Mozzarella cheese had not previously been made at the Michigan State University Dairy Plant. The procedures followed for its manufacture were modifications of those outlined for production of part skim, low moisture Mozzarella cheese (Kosikowski, 1977). The production report for the cheese used in this study is presented in Figure 5.

Manufacture. Whole milk was standardized to approximately 2% fat using reconstituted non-fat dry milk. The milk was pasteurized for 30 min at 62.8 C and pumped into a 2,722 kg cheese vat. The temperature was adjusted to 32.2 C and a 1.5% inoculation of yogurt culture was

Date:	9-22-78	kg of Milk:	680 kg
Lot No.:	Not indicated	% Fat	2.0
Operator:	S. Ionson	Color Added	None
Past. Time:	30 min	Rennet Added:	127.5 ml
Past. Temp:	62.8 C	Starter Added:	10.2 kg
Setting Temp:	32.2 C	Salt Added:	None
Acidity:	0.16%	kg of Cheese:	59 kg
Starter Acid:	Not indicated	Form of Cheese:	Square
Highest Temp:	40.6 C	Yield per 100#	9%

<u>Time</u>		<u>Milk or Whey</u> <u>Acidity</u>
8:30	Adding Starter	N/A
9:00	Adding Rennet	N/A
9:35	Cutting	0.10
9:50	Cooking	N/A
10:30	Drain	N/A
10:45	Packing	N/A
1:45	Milling	0.67
2:00	Stretching	N/A
3:00	Hooping	N/A
12hr	Brining	---

Figure 5. Production Report for Mozzarella Cheese

added. The mixture was then agitated for 20 - 30 min. Yogurt culture was a 1:1 mixture of Streptococcus thermophilus and Lactobacillus bulgaricus. It was prepared by inoculation of one 70 ml can of frozen culture (Chr. Hansen's AY3) into approximately 32 kg of sterile whole milk followed by incubation for 3 hr at 43.9 C.

After culture inoculation, single strength microbial rennet was added at a rate of 85 ml per 454 kg of milk, stirred for 5 min and left undisturbed for approximately 30 min until formation of the coagulum. This was cut using 9.5 mm knives and the cut curd allowed to sit quietly in the whey for 15 min. Titratable acidity was 0.10% after cutting. The whey was drained and the curds allowed to mat. Matted curds were then cut into large slabs and turned every 15 min while maintaining a vat bottom temperature of 42.2 C. The turning was continued until a titratable acidity of 0.67% was attained. The slabs then were milled and portioned into equal portions for the stretching operation. Each portion of milled curd was immersed in a hot water bath (76.6 C) and agitated vigorously. After several minutes, the curd became pliable and dough-like. It was then removed from the bath and molded by hand until a soft, plastic body with a good sheen developed. This was molded into 9.1 kg Wilson hoops and pressed gently for several minutes using bricks for weight. The cheese was cooled in a water bath and placed in a 22% salt solution for 12 hr at 10 C. After brining, the cheese hoops were packaged in Cryovac shrink bags and

stored at 12.7 C for 28 days before cutting and packaging for use in this study.

Modern operations use mechanical tumblers containing hot water to mold and stretch the milled curd. This process is vastly superior to the hand method that was used in the present study. It was difficult to be completely uniform in molding between portions of milled curd. Some variation in texture occurred since the softness and textural properties of the cheese are highly dependent upon the stretching process. Localized hard spots present in the final hoops of cheese more than likely were due to insufficient molding.

Experimental Packages

All packaging materials were supplied by the American Can Company. They were received as pre-formed pouches with dimensions chosen to fit the cheese cuts being used (Figure 6). Proper sizing eliminates unnecessary flaps, wrinkles, and material waste. A short description of the different materials will be discussed in this section. More specific information on material characteristics will be covered in the Results and Discussion section.

Biaxially Oriented Polypropylene/PVDC Coating/Polyethylene Extrusion/EVA Extrusion (A). This film is a Saran coated lamination commonly used for retail cheese packaging. The material is somewhat stiffer than material D but possesses similar barrier properties.

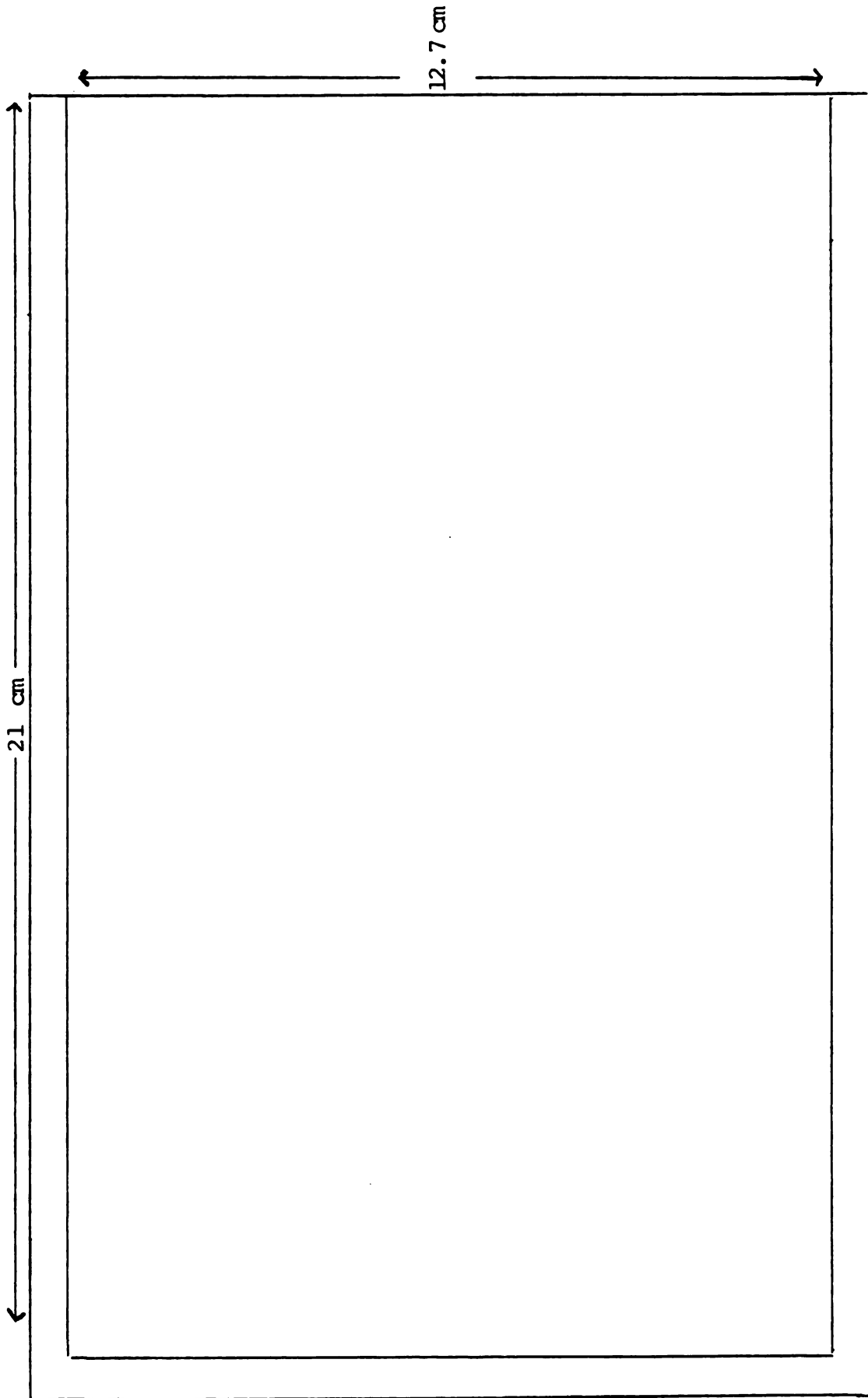


Figure 6. Experimental Pouch Dimensions - Full Scale

Polyester/EVA/Polyethylene (B). A proprietary lamination by American Can Company, this material is not presently used for cheese packaging. It is a good moisture and a fair oxygen barrier.

Low Density Polyethylene - 2.5 ml (C). This is a thin, highly flexible film with a poor oxygen barrier and good moisture barrier.

Biaxially Oriented Polyamide/PVDC Coating/Polyethylene Extrusion/EVA Extrusion (D). This is a laminated film often used in vacuum and gas flush packaging of cheese. This material has excellent barrier properties.

Polyamide-Polyolefin (E). A slightly inflexible material, this is an intermediate oxygen and good moisture barrier. It has some applications in cheese packaging.

Methods

Cutting and Packaging

The 9.1 kg hoops of experimental cheese were cut into retail portions for packaging on a Model 5 J-R Cheese-cutter (R. Howard Strasbaugh, Inc.). Cutting dimensions were approximately 3.2 cm x 14.0 cm x 9.0 cm. The pouches were then hand-filled and vacuum packaged in a Multi-vac model AGW machine. The Multi-vac is a vacuum chamber device equipped with a heat sealing impulse bar. Filled pouches were placed with the open ends laying across the lower outer support. Air evacuation proceeded automatically after

closing the lid. Following evacuation, the impulse bar heat sealed the packages. The duration of vacuum pull and impulse time can be controlled. Dial settings are related to the operation time of each function as indicated in Table 9 . Non-standardized evacuation can result in entrapped oxygen or deformed cheese. Insufficient impulse time can result in weak seals, while over heating melts material at the seal area. Both vacuum and impulse settings were standardized for each material and cheese. The settings are presented in Table 10 .

Twenty replications for each cheese type in a particular material were packaged. This provided four replications at each testing period. Due to time restrictions, only three replications were utilized.

Storage for Shelf Life Tests

The packaged cheeses were placed on perforated shelves in cold storage at the Michigan State Dairy Plant. Temperature was maintained at 4 C. The relative humidity was not controlled throughout the length of the study. Incandescent light was present 6 days per week and from 8 - 10 hr per day.

Unpackaging

At designated time periods, samples were randomly taken from storage for analytical testing. Unpackaging of the samples was performed as aseptically as possible. Pouches were generally opened from either the top or side

Table 9. Operation Times for Selected Multi-vac
Dial Settings

Vacuum Setting	Duration (sec)	Impulse Setting	Duration (sec)
3.00	14.40	2.50	1.80
5.00	30.00	3.00	2.10
8.00	52.20	3.25	2.50
10.00	57.00	5.00	3.60

Table 10. Standardized Multi-vac Dial Settings for
Experimental Materials (All Cheese Varieties)

Material	Vacuum Setting	Impulse Setting
A	7.00	2.50
B	7.00	3.25
C	7.00	2.25
D	7.00	2.50
E	7.00	3.00

seal depending upon the experimental needs of the Packaging School. After opening, samples of the cheese portions were cut for analytical testing. Prior to obtaining samples for the microbiological assay, the cheese was not touched.

Analytical Procedures

Cheese samples were unpackaged after 4, 15, 25, and 35 weeks of storage. Most of the analytical tests were performed at each of these designated times unless indicated otherwise during the discussion on individual procedures. The portioning of cheese samples for analytical testing is illustrated in Figure 7. Analytical methods carried out at the School of Packaging were designed to test the package materials for seal strength, flex-crack, oxygen barrier, and water barrier.

Measurement of Shear Force

Shear compression force of the cheese samples was measured using a Kramer Shear Press, model SP-121MP, equipped with a 3000# texturegage, a model Cl-1 standard shear compression cell, and recording device. The test cell consisted of a stationary element and moving blades. The press forced the blades in a vertical direction through the stationary element containing the cheese sample. The resistant forces of the sample caused compression of the transducer ring (texturegage) which is recorded as a peak with characteristic shape and height for that sample.

The specific procedures employed were similar to those

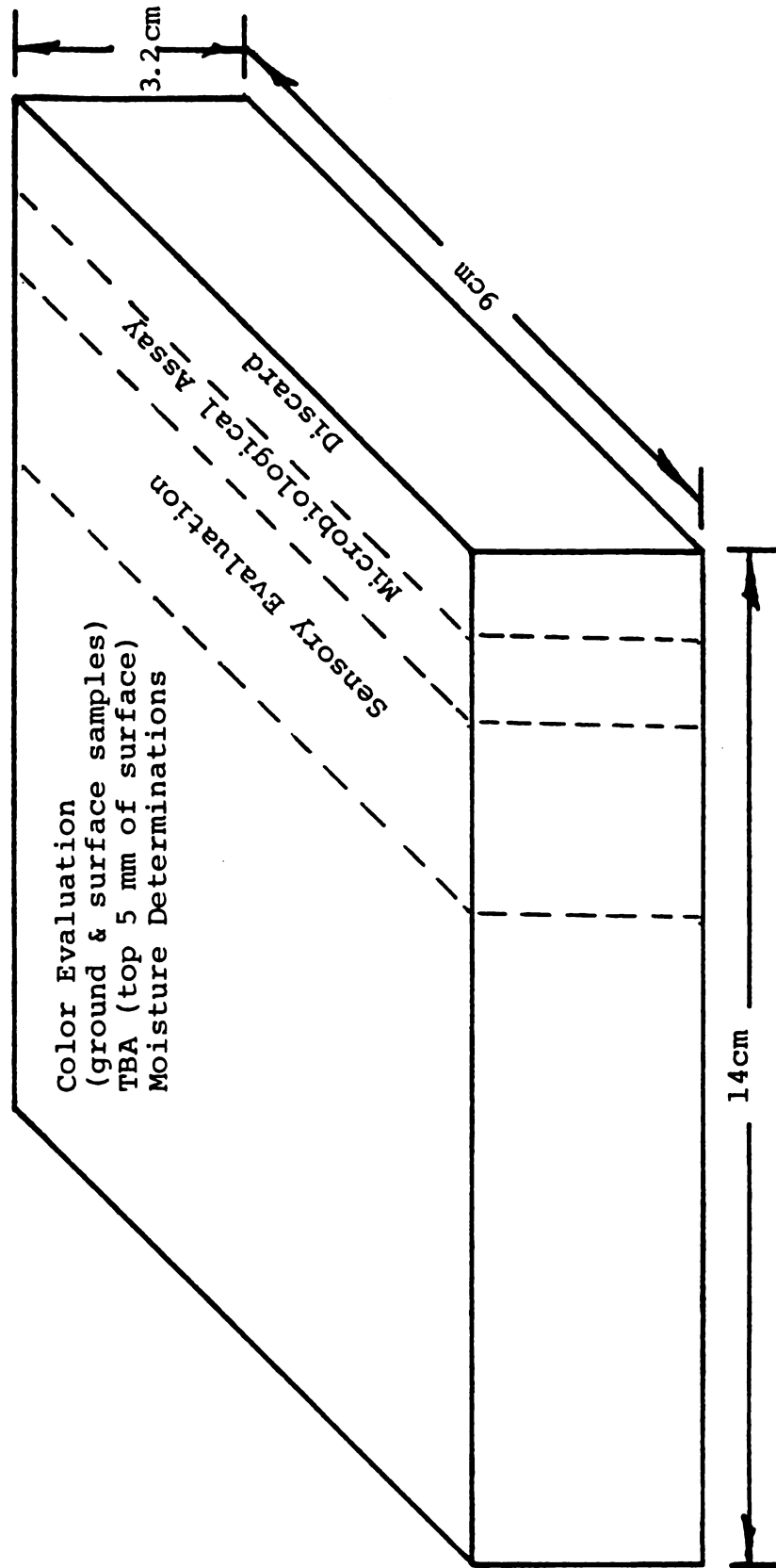


Figure 7. Portioning of Cheese Sample for Analytical Testing.

recorded by Thakur (1973) for Cheddar cheese.

- 1) Two 12 mm thick samples from each retail cheese portion were cut to fit test cell dimensions, weighed to the nearest 0.01 g, and tempered for 5 hr at 22 C.
- 2) Press range was set at 20.
- 3) Recorder pen was adjusted to zero.
- 4) Cheese sample was fitted in the stationary element of the test cell and positioned on the press.
- 5) The shear blades were attached to the texture-gage and passed through the sample.
- 6) Characteristic peak was recorded and shear compression force (# force/gram sample) calculated using the following formula:

$$\frac{(\# \text{ ring})(\text{range}/100)(\text{Max Peak ht}/100)}{\text{sample wt. in grams}}$$

Weight Loss and Moisture Content

Weight Loss. The initial weight of each packaged cheese was determined to the nearest 0.001 lb using a Hobart scale (Model 1000). Weight difference from 0 time was calculated at each designated testing interval.

Moisture Content. Initial moisture content for each cheese was determined in duplicate using an established vacuum oven technique for cheese (Method I, AOAC, 1975). The 0 time determinations were mean values determined from analysis of representative samples taken from each of the

five hoops used for a particular cheese.

Sensory Evaluation

A panel of three judges using the American Dairy Science Association score sheet for Cheddar cheese evaluated the samples at all the designated testing periods. Only one type of cheese was tested at any particular time so that treatment differences could be emphasized. In addition, a commercial natural Mozzarella was made available to the panel for reference when judging the Mozzarella samples. Evaluations were made in a clearly lit room free from extraneous odors and distractions. Flavor and body scores of 10 and 5, respectively, required no criticism. Sample forms are shown in Figure 8 and Table 11.

Microbiological Assay

Cheese samples were tested at all the designated test periods for yeast and mold count, and coliform count. Procedures used were based on the recommendations specified by the American Public Health Association in The Standard Methods for the Examination of Dairy Products (1978).

Sample Preparation. Eleven grams of cheese were aseptically cut and blended for 2 min in 99 ml of sterile 2% sodium citrate buffer (40 C). Additional dilutions were prepared by aseptically pipetting appropriate volumes of the 1:10 buffered cheese solution into dilution bottles filled with the buffer solution.

Contestant No _____

Date _____ A.D.S.A. Cheddar Cheese Score Card D.F.I.S.A.

Perfect Score	Criticism	1	2	Sample No.										Total Grades
				3	4	5	6	7	8	9	10			
FLAVOR	Contestant													
10	Score													
	Grade													
	Score													
	Criticism													
	Acid													
No	Bitter													
Criticism	Feed													
10	Fermented/Fruity													
	Flat													
	Garlic/Onion													
Normal	Heated													
Range	Moldy													
1-10	Rancid													
	Unclean													
	Whey taint													
	Sulfide													
	Yeasty													
BODY & TEXTURE	Contestant													
	Score													
	Grade													
	Score													
	Criticism													
	Corky													
No	Crumbly													
Criticism	Curdy													
5	Gassy													
	Mealy													
	Open													
	Pasty													
	Short													
	Weak													
	Total score of each sample													
TOTAL	TOTAL GRADE PER SAMPLE													
FINAL GRADE RANK														

Figure 8. Sample form of Questionnaire Used to Evaluate Cheese Samples

Table 11. Suggested Flavor and Body Scores for Samples
with Designated Defect Intensities

<u>FLAVOR:</u>				<u>BODY & TEXTURE:</u>			
	S	P	D		S	P	D
Acid	9	7	5	Corky	4	3	2
Bitter	9	7	4	Crumbly	4	3	2
Feed	9	8	6	Curdy	4	3	2
Fermented/Fruity	8	6	5	Gassy	3	2	1
Flat/Lacks Flavor	9	8	7	Mealy	4	3	2
Garlic/Onion	6	4	1	Open	4	3	2
Heated	9	8	7	Pasty	4	3	1
Moldy	7	5	3	Short	4	3	2
Rancid	6	4	1	Weak	4	3	2
Sulfide	9	7	4	Oily Surface	N/A		
Unclean	8	6	5				
Whey taint	8	6	5	S - denotes slight			
Yeasty	6	4	1	D - denotes definite			
Putrid	N/A			P - denotes pronounced			
Foreign	N/A						
Unnatural	N/A			Decolorized	N/A		

Yeast and Mold. Specified volumes of diluted samples were aseptically pipetted into sterile 100 x 15 mm petri dishes. Duplicates for each dilution were taken from the cheese solution. Approximately 10 ml of Potato Dextrose Agar acidified to a pH of $3.5 \pm .1$ with 10% tartaric acid was poured at 45C into the plates and incubated for 5 days at 22 - 24 C. For low counts, 10 ml of the diluent were distributed among 3 plates. Total colony count on the 3 plates was recorded and reported as yeast and mold per gram of product.

Presumptive Coliform. Pour plates of appropriate dilution were made using Violet Red Bile Agar. Each dish was capped with an additional 5 ml of media and incubated for 24 hr at 32 C. Typical cherry red coliforms were counted and reported as colonies per gram of product.

Color Evaluation.

A Hunterlab Color/Difference Meter, Model D25-2, was used to evaluate color changes in the cheese samples. This device decomposed color into 3 scales as indicated in Figure 9. The L coordinate values range from 0 to 100 and relate to the degree of lightness of the samples. Coordinate a_L indicates redness (positive values) and greenness (negative values). Coordinate b_L indicates yellowness (positive values) and blueness (negative values).

The sample was placed under the Hunterlab lens and the L, a_L , and b_L values recorded from the digital read-out. Initially, the duplicate readings from a finely ground sample gently packed to capacity in a petri dish were taken for

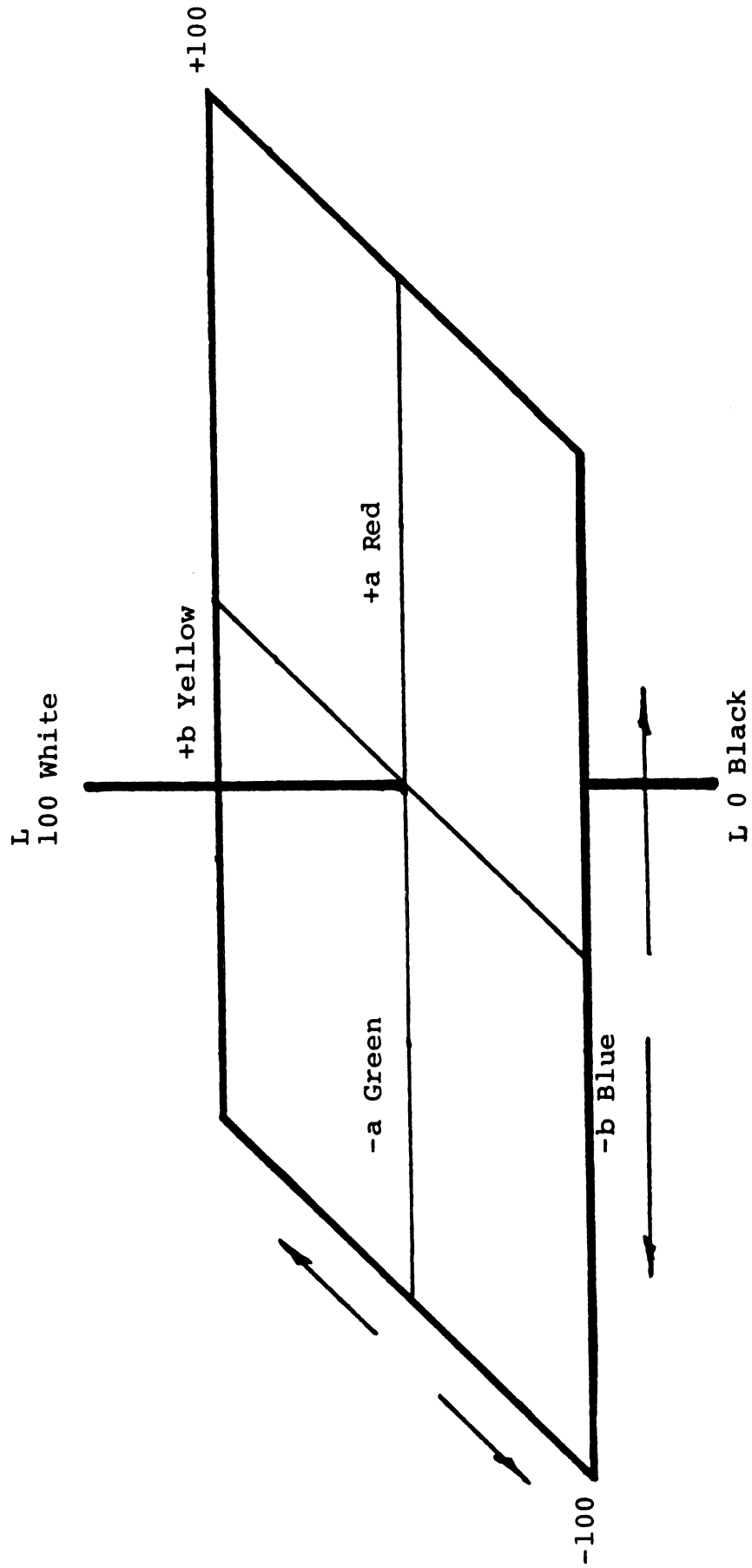


Figure 9. Hunterlab L.a.b. Opponent Color Solid

color evaluation. The dish was rotated 45° under the portal for duplication. However, the 25 and 35-wk testing periods, surface color determinations were made on unground samples when it became evident that the color differences occurring were surface related. Both broad surface areas of the cheese portion were evaluated. A white tile was used to standardize the instrument.

2-Thiobarbituric Acid Test (TBA).

Oxidative rancidity was determined by a 2-thiobarbituric acid test (TBA). The specific procedure used was a variation of the distillation method reported by Tarladgis, Watts, Younathan, and Dugan (1960). The test is based upon a reaction involving the formation of a red colored complex when 2-thiobarbituric acid is heated with malonaldehyde, a by-product of oxidative rancidity. An approximately 5 mm-thick sample was cut from the outer surface of each cheese portion for analysis. Determinations were only made at 0 time and after 35 wk of storage.

- 1) A 10 g sample was blended for 1 min in 50 ml of warm, distilled water (50 C) using an Osterizer blender. Duplicates from each cheese portion were prepared.
- 2) The cheese solution was then quantitatively transferred to a 500 ml extraction flash containing 2.5 ml HCL:H₂O mixture (1:2 v/v), glass beads, and Dow-Corning antifoam. Final pH of the mixture was approximately 1.5.

- 3) The sample was distilled vigorously until 50 ml of the distillate was collected. Glas Col Model 0 mantel with type 3PN116B powerstats were used for heating the flasks. Powerstat setting was 85.
- 4) Two 5 ml portions of the distillate were placed in 2 test tubes containing 5 ml each of 2-thiobarbituric reagent (0.02 M 2-TBA in 90% re-distilled glacial acetic acid). Tubes were mixed on a Vortex Genie mixer.
- 5) The mixtures were heated in boiling water for 35 min followed by 10 min of cooling in a cold water bath (8 C).
- 6) Percent absorbance was determined at 435 nm using a Beckman DB spectrophotometer. Readings were made against a blank tube containing only TBA reagent and distilled water.

Visual Examination.

At 2 wk intervals, all samples in storage were examined visually for product or package anomalies. These would include mold and yeast contamination, color changes, pouch blow-outs, or any additional factor considered significant.

Visual mold contamination was characterized for each individual sample in terms of its quantity and location. Three classes of mold contamination were defined. These are illustrated in Figures 10 and 11. If classified as class 1, one isolated spot of mold was evident. This would usually

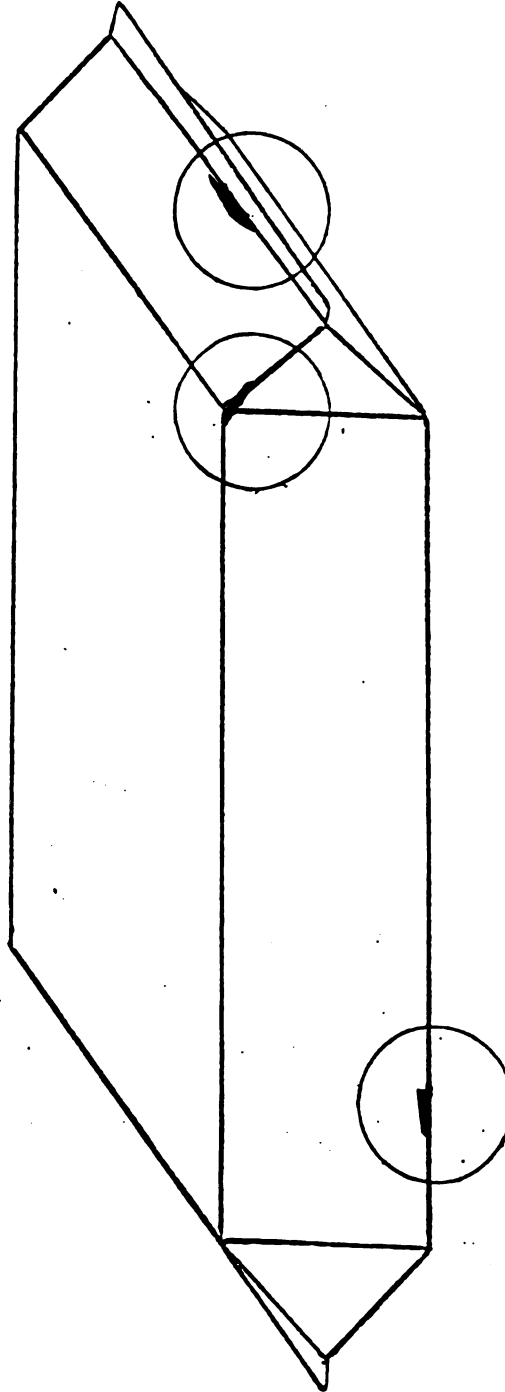


Figure 10. Graphic Depiction of Class 1 and Class 2 Visual Mold

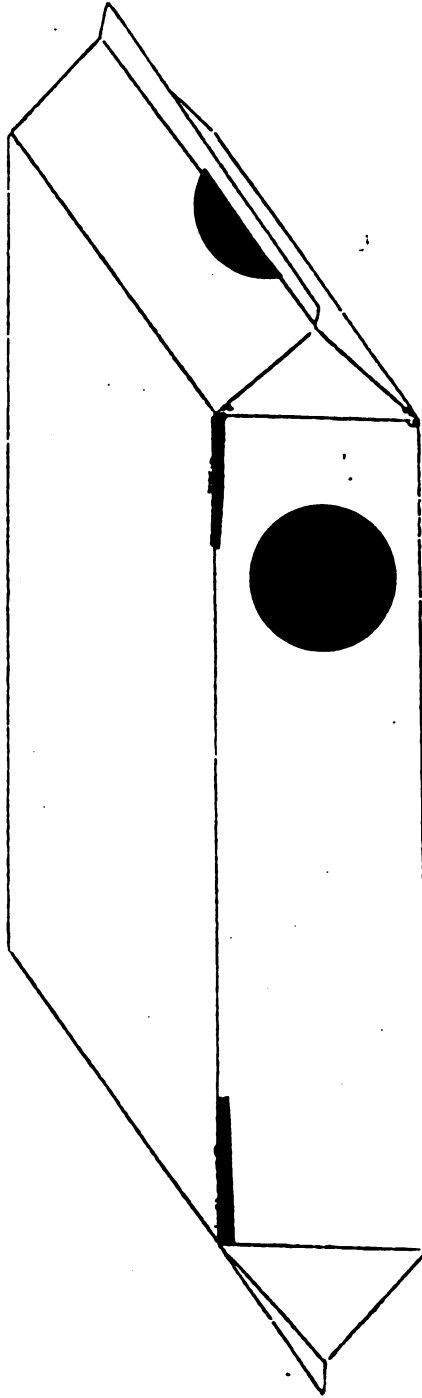


Figure 11. Graphic Depiction of Class 3 Visual Molds

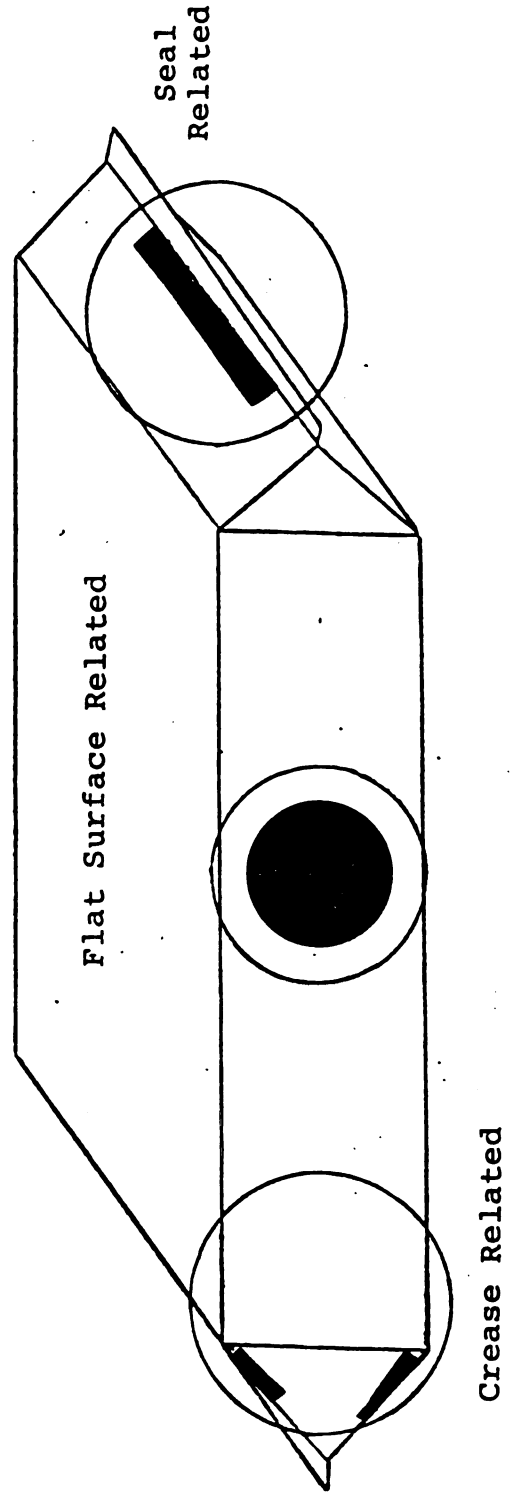


Figure 12. Graphic Depiction of Visual Mold Location

occur at the package crease or seal. Class 2 mold is indicated when more than one spot is present. Figure 10 in its entirety is a good representation of class 2 contamination. Cheese samples classified as class 3 possessed considerable mold growth as is illustrated in Figure 11. Note that the mold is not necessarily present on the flat surface of the cheese. Contamination on a sample could also be associated with the package creases, seals, flat surfaces, or any combination of these areas as is illustrated in Figure 12.

Fat Analysis.

Fat content in cheese samples was not monitored throughout the storage period. Initial determinations were made using the Rose-Gottlieb method with Mojonnier modification for cheese (Milk Industry Foundation, 1959). The steps followed were those described by Mojonnier Bros. Co. (1925) for determination of fat in cheese.

Treatment of Data

Three replications for each treatment were utilized in this study. Data collected from the visual examination, microbiological plating, and sample weighing was tabulated and/or presented graphically. Statistical treatment was not suitable for these methods. Data from the TBA test, and the sensory, color, and shear compression evaluations was analyzed by analysis of variance (Spence, Cotton, Underwood, and Duncan, 1976).

The 2-Thiobarbituric Acid test was conducted at 0 time

and after 35 wk of storage. Results were evaluated using a one-way analysis of variance between the different packaging films. Shear compression, color, and sensory data was analyzed by a two-way analysis of variance, fixed model effects. Two-way analysis of variance is designed to assess the effects of two known variables on a dependent measure. In this study, pouch type and storage time are the two controlled sources of variation. Application of two-way analysis of variance allows us to make three kinds of statements about the results: 1) the effects on the response measure of the different pouch types, independent of storage time; 2) the effects of the different storage times on the response measure independent of pouch type; and 3) the joint effects or interaction of pouch type and storage time on the response measure. Unfortunately, samples obtained for 0 time analysis were not randomly collected and are not considered representative of the total population for the various dependent measures. They will, therefore, not be included in the statistical treatment. As such, a significant pouch effect will automatically assume 4 wk of storage. Similarly, significant storage time effects are only valid from 4 to 35 wk of storage (or 25 to 35 wk for surface color data).

If a significant effect was indicated by analysis of variance, the differences between values of the dependent measure were pinpointed by use of the Tukey Honestly Significant Difference Test (Spence, Cotton, Underwood, and Duncan, 1976). This is a separate statistical method designed to

indicate statistically significant differences between groups of numbers. The method is more strict than many of the others commonly used and may result in fewer separations being made. It is possible for significant effects, as indicated by analysis of variance, to be unconfirmed by Tukey separations. Tukey separations can only be applied to one independent variable at a time and were only calculated between pouch treatments since effects of the packaging materials was the major thrust of this research project.

Both statistical tests involved three basic assumptions:

1. Subjects of the experiment must be randomly and independently drawn from their initial populations;
2. The initial populations from which treatment groups are selected must be normally distributed for the dependent measures;
3. The variances for the initial populations must be equal.

If one or two of these assumptions appear not to be satisfied, then confidence levels can be increased, and the data interpreted more conservatively. For this study, confidence levels will be maintained at 1%.

RESULTS AND DISCUSSION

Proximate Composition of Experimental Cheeses

The fat and moisture content of each experimental cheese is presented in Table 12. Two basic groups of cheese are evident according to these criteria. The first group includes the natural Cheddar and Rosano cheeses which have relatively high fat and low moisture contents. Natural Mozzarella, artificial Mozzarella, and artificial Processed American constitute the second group with higher moisture and low fat contents. Additional compositional information can be calculated from the product formulations and production sheets presented in the procedure section.

Table 12. Proximate Composition of Experimental Cheeses

Cheese Variety	% Fat (w.b.)	% Moisture (w.b.)
Natural Cheddar	32.42	35.65
Rosano	32.00	38.63
Artificial Mozzarella	19.40	50.83
Artificial Processed American	21.65	47.58
Natural Mozzarella	16.39	46.24

Visual Examination

The quantity and location of mold development on cheese samples was the predominant factor recorded during the visual examinations. Other phenomenon observed on cheese samples during storage included color difference, crystal formation, gas evolution and package failures.

Color bleaching occurred in natural Cheddar and Rosano cheeses packed in films B and E after approximately 22 wk of storage. The phenomenon appeared to be surface related and more intense on the light-exposed surface of each portion. More specific examination of the color changes will be provided in a later section.

Both artificial products developed white crystals on the surfaces of cheese portions. The crystals were larger, more abundant, and appeared whiter on artificial Mozzarella samples. First appearance was after approximately 5 wk of storage for the artificial Mozzarella cheese samples. Crystal formation on the Processed American analog was first observed after about 20 wk of storage and did not develop further with time. Development of crystals was not dependent upon the packaging film used. The crystals may be calcium or sodium salts of either the citrate or gluconate ions present in the artificial Processed American and artificial Mozzarella cheeses, respectively.

After approximately 16 wk of storage, materials A and D were not tightly gripping natural Mozzarella cheese samples. This "loosening" continued until some of the

packages were mildly distended, hypothetically due to gas production. This phenomenon did not occur in films B and E. We assume the gas to be carbon dioxide which developed as a result of extended storage. It is possible that carbon dioxide permeabilities for films B and E were greater. Available carbon dioxide would thus slowly diffuse through the film and into the environment.

Periodically, packaging films would no longer adhere to the cheese samples. This generally occurred as a result of extensive seal leakage or complete seal failure. Both top, bottom, and side seals were observed to be responsible for the leaks. Except for material C, package failure of this type was minimal and seldom occurred. However, bursting of the side seal commonly occurred with film C. Table 13 presents the extent of package failure for material C for each cheese variety.

Table 13. Extent of Seal Rupture and Total Package Failure for Cheese Samples Packaged in Film C

Cheese Variety	% Total Samples	Storage Time (wk)
Natural Cheddar	80	5
Artificial Mozzarella	0	-
Rosano	30	3
Artificial Processed American	40	less than 10
Natural Mozzarella	20	less than 10

After approximately 15 wk of storage, the artificial Processed American samples developed a fluid exudate which lined the inside of the packaging films. This was associated with off flavors and odors in the latter part of storage. Different package materials did not noticeably affect its development.

Visible mold was extensive for some materials and cheese varieties. Figures 13 through 22 illustrate both the quantity and location of mold for each cheese stored in films A, B, D, and E. Since samples were randomly taken at periodic intervals for analytical testing, data from the visual examination obtained after the 25-wk testing period is not presented due to a limited sample size.

Samples packaged in film C are not included in the graphics due to early and extensive mold development. This will be further elucidated in this discussion. The artificial Processed American cheese is also not included in the graphics. This variety did not show visual mold throughout storage. We postulate that the fluid exudate lining the inside of the pouch prevented oxygen contact with the cheese. However, no concrete evidence has been collected to support this hypothesis.

Mold development suggests that oxygen is not being totally excluded from beneath the packaging film. Various sources of oxygen can be postulated:

1. From the outside environment by active diffusion through the material, or entry via pinholes and/or seal leaks;

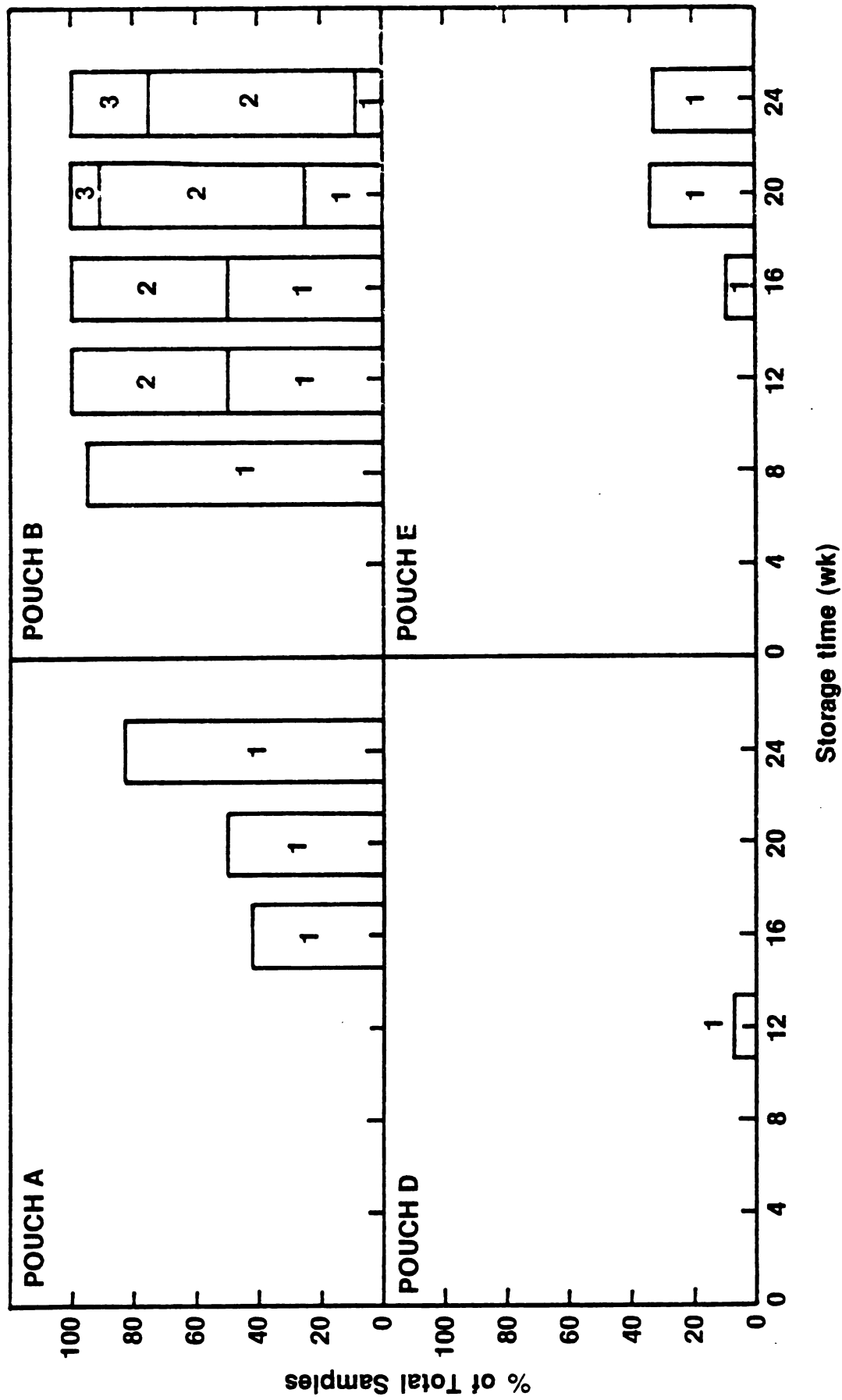


Figure 13. Quantity and Class of Visual Mold on Natural Cheddar Cheese Packaged in Experimental Pouches

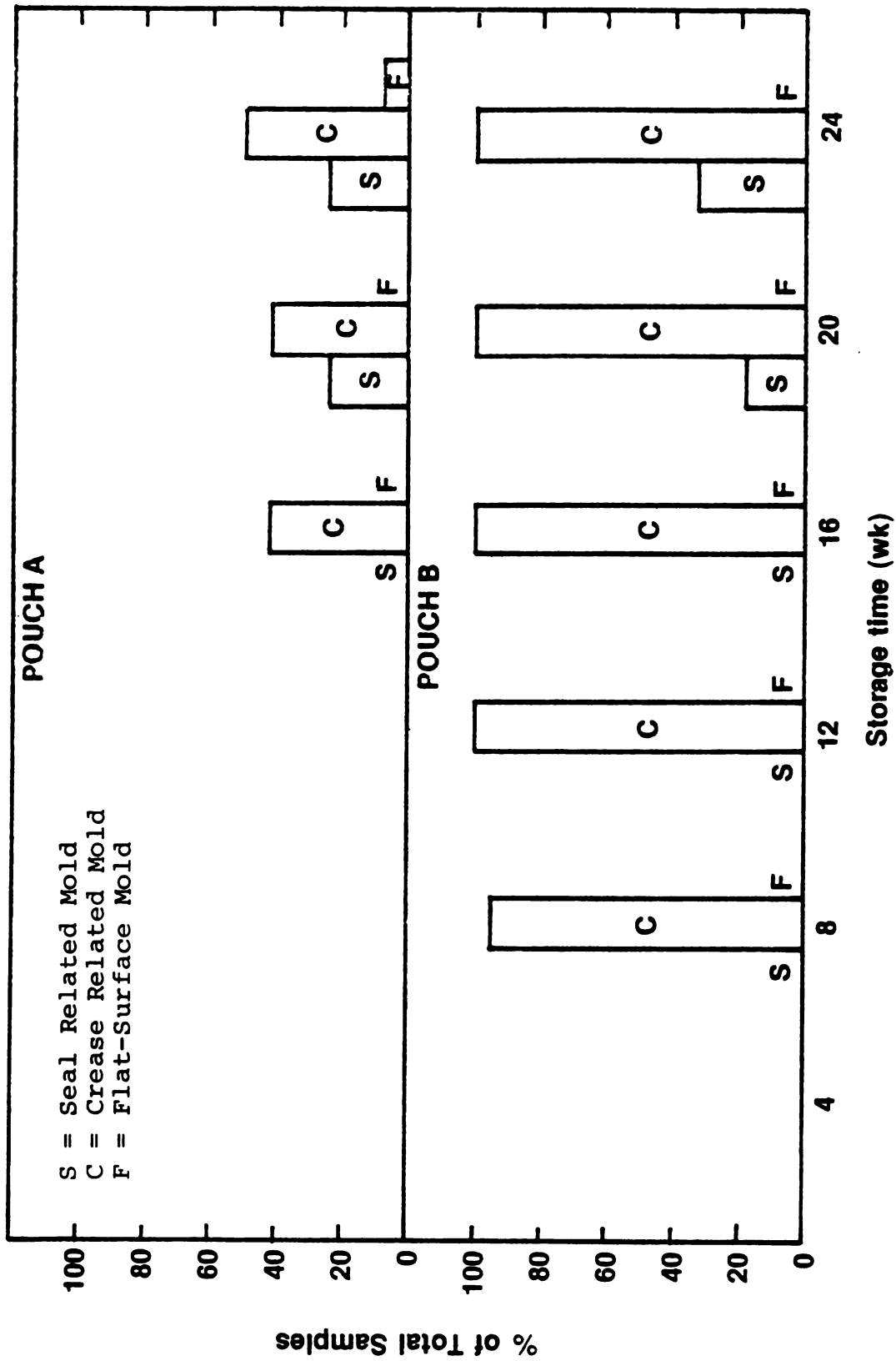


Figure 14. Location of Visual Mold on Natural Cheddar Packaged in Experimental Pouches A and B.

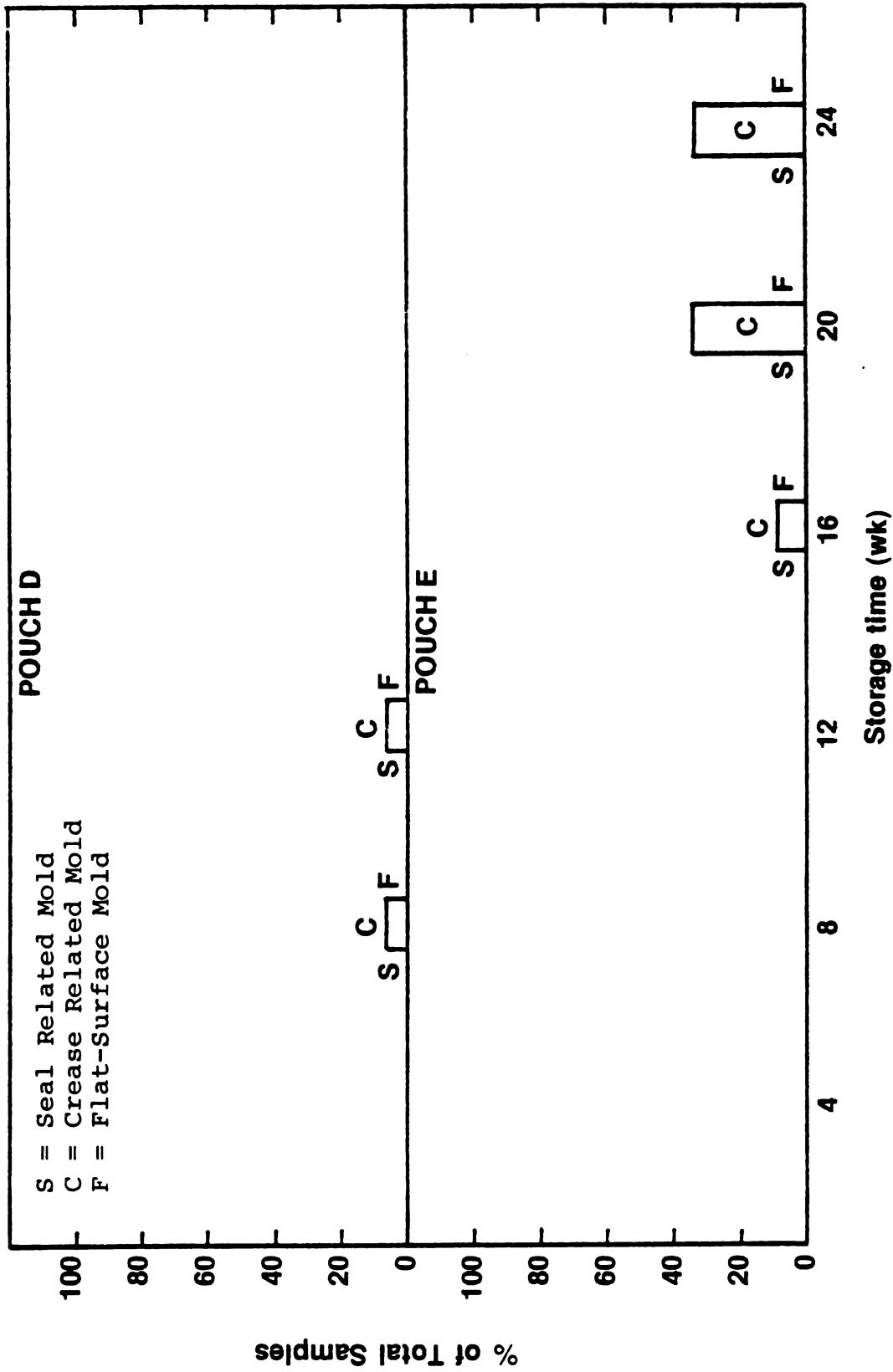


Figure 15. Location of Visual Mold on Natural Cheddar Cheese Packaged in Experimental Pouches D and E.

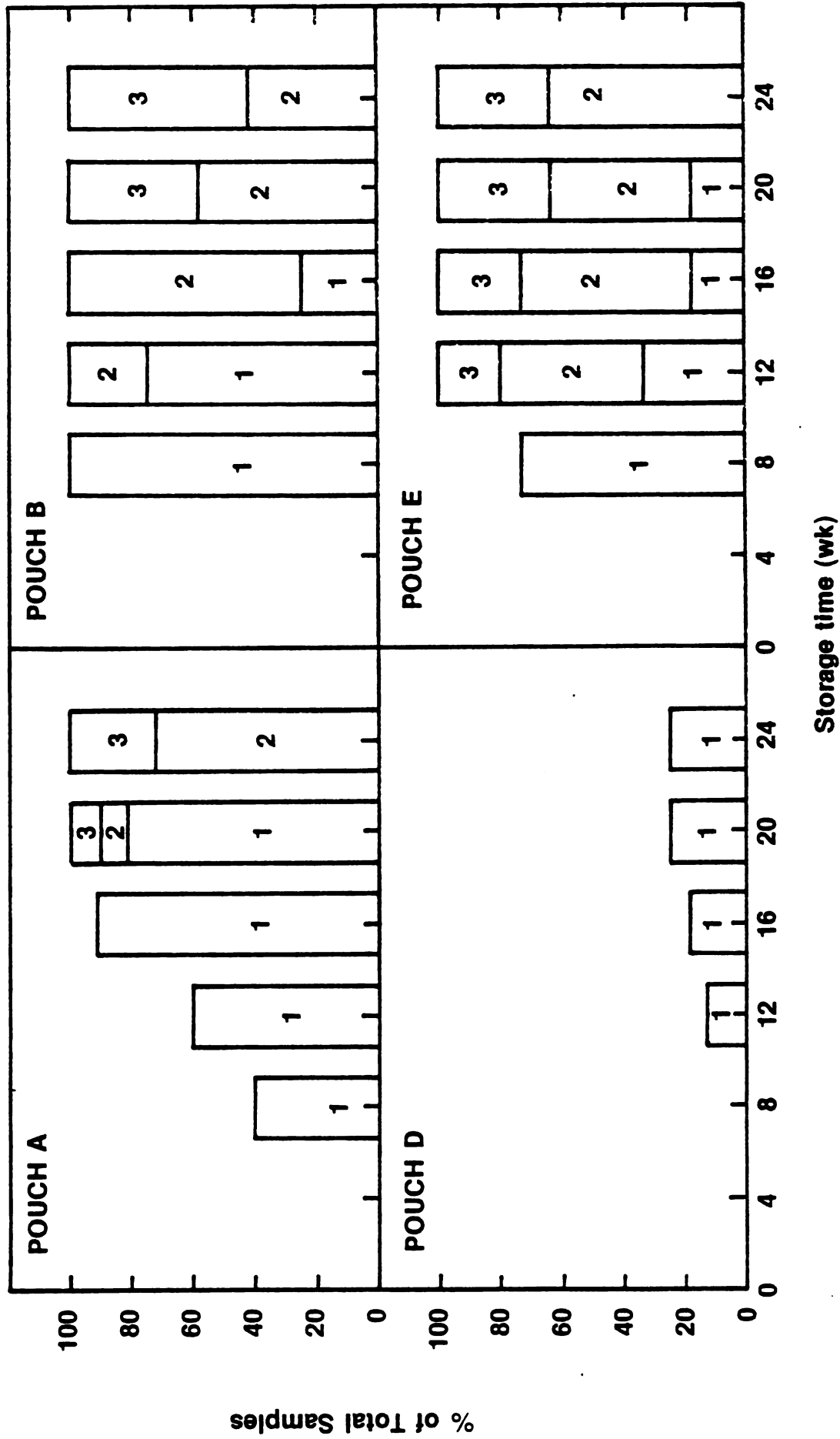


Figure 16. Quantity and Class of Visual Mold on Artificial Mozzarella Cheese Packaged In Experimental Pouches.

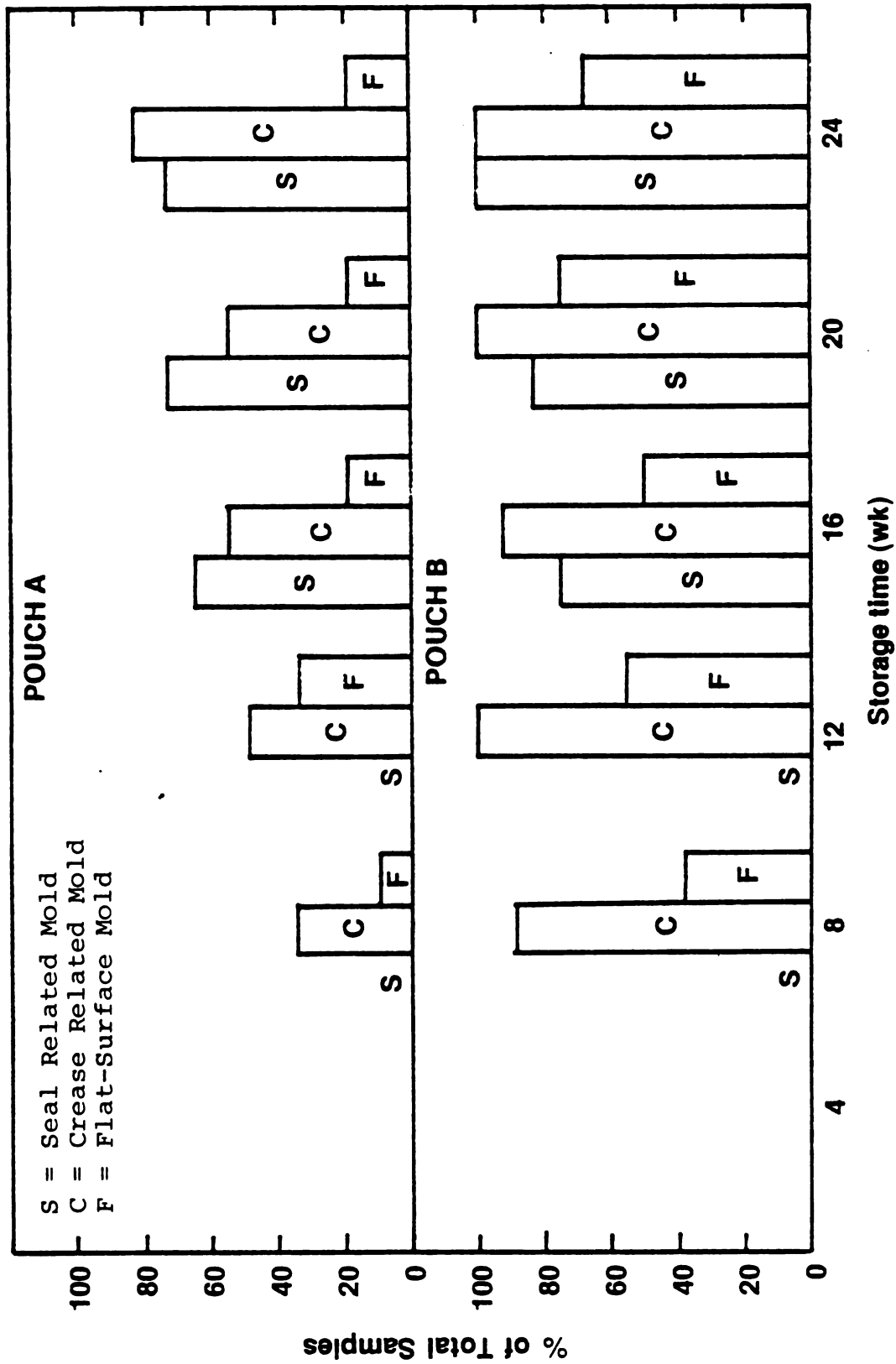


Figure 17. Location of Visual Mold on Artificial Mozzarella Cheese Packaged in Experimental Pouches A and B.

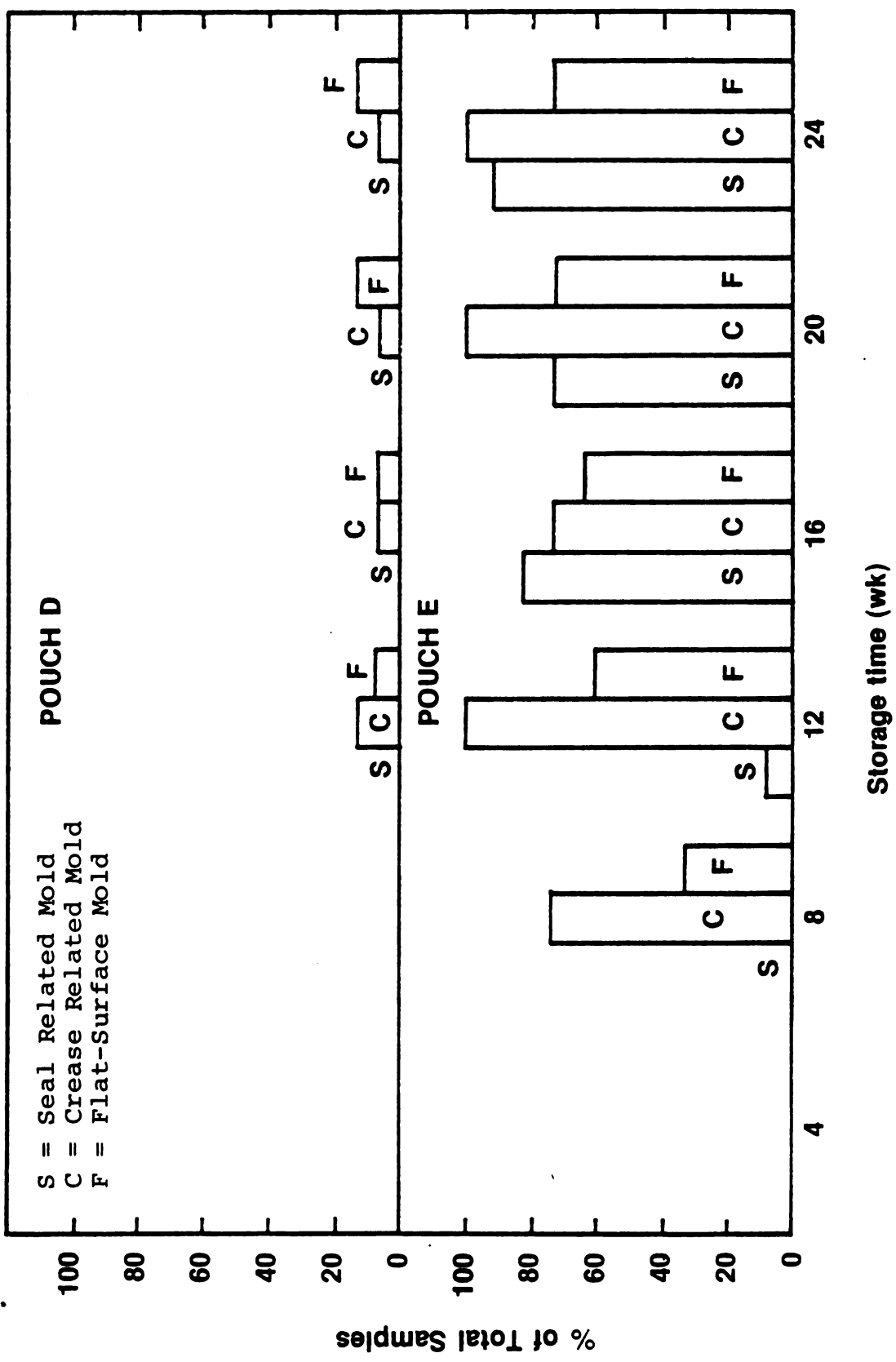


Figure 18. Location of Visual Mold on Artificial Mozzarella Cheese Packaged in Experimental Pouches D and E.

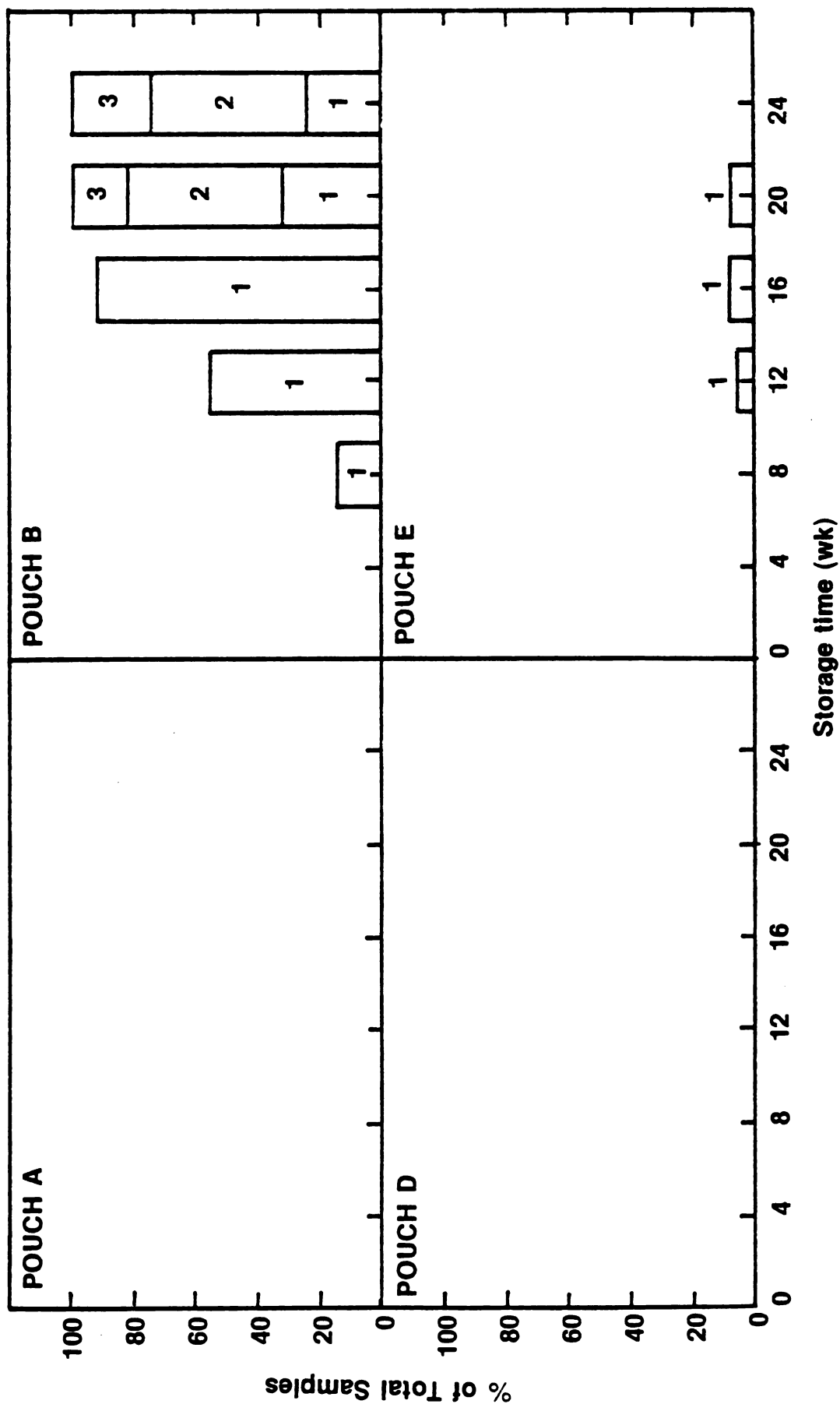


Figure 19. Quantity and Class of Visual Mold on Rosano Cheese Packaged in Experimental Pouches.

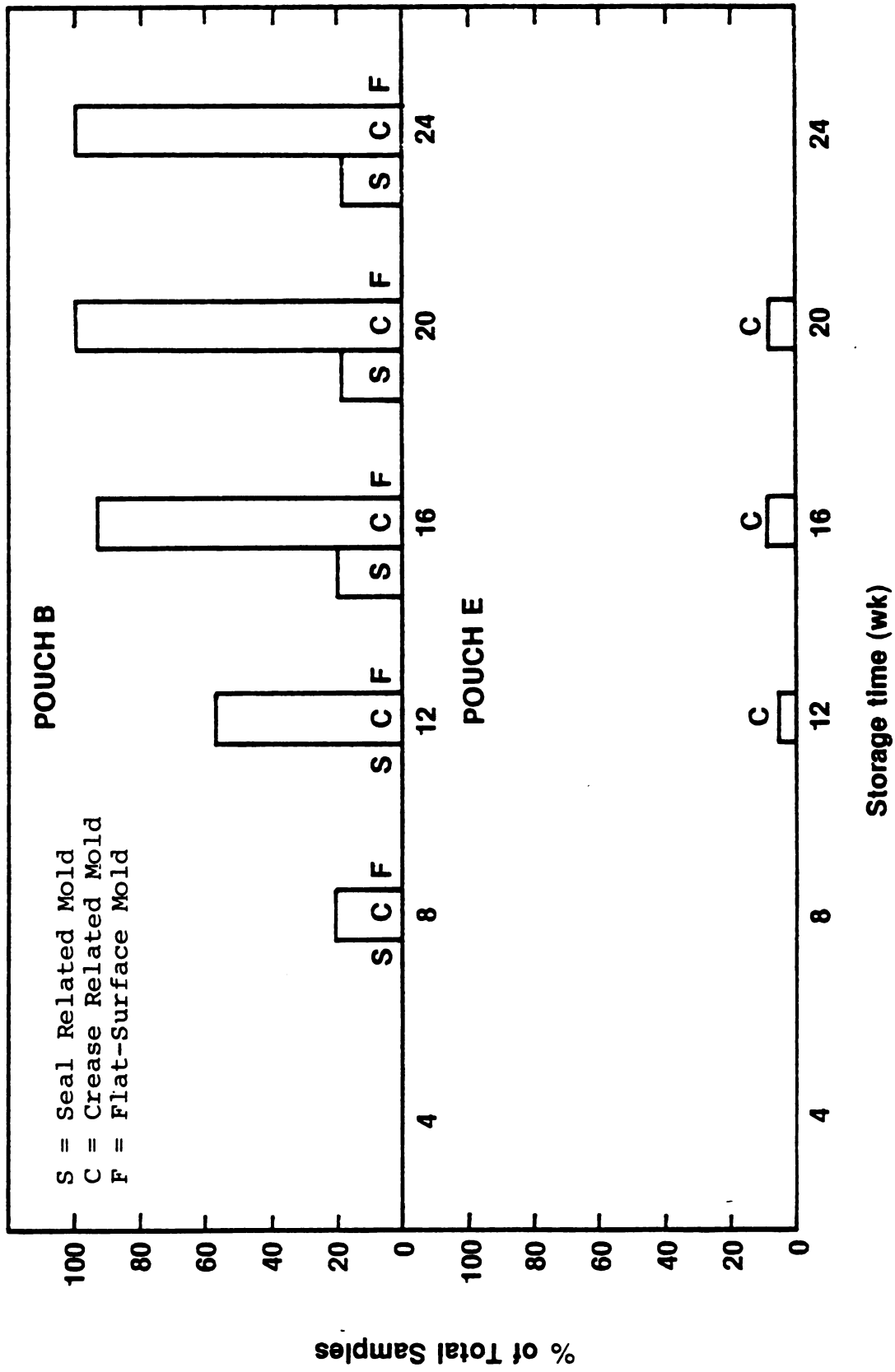


Figure 20. Location of Visual Mold on Rosano Cheese Packaged in Experimental Pouches B and E.

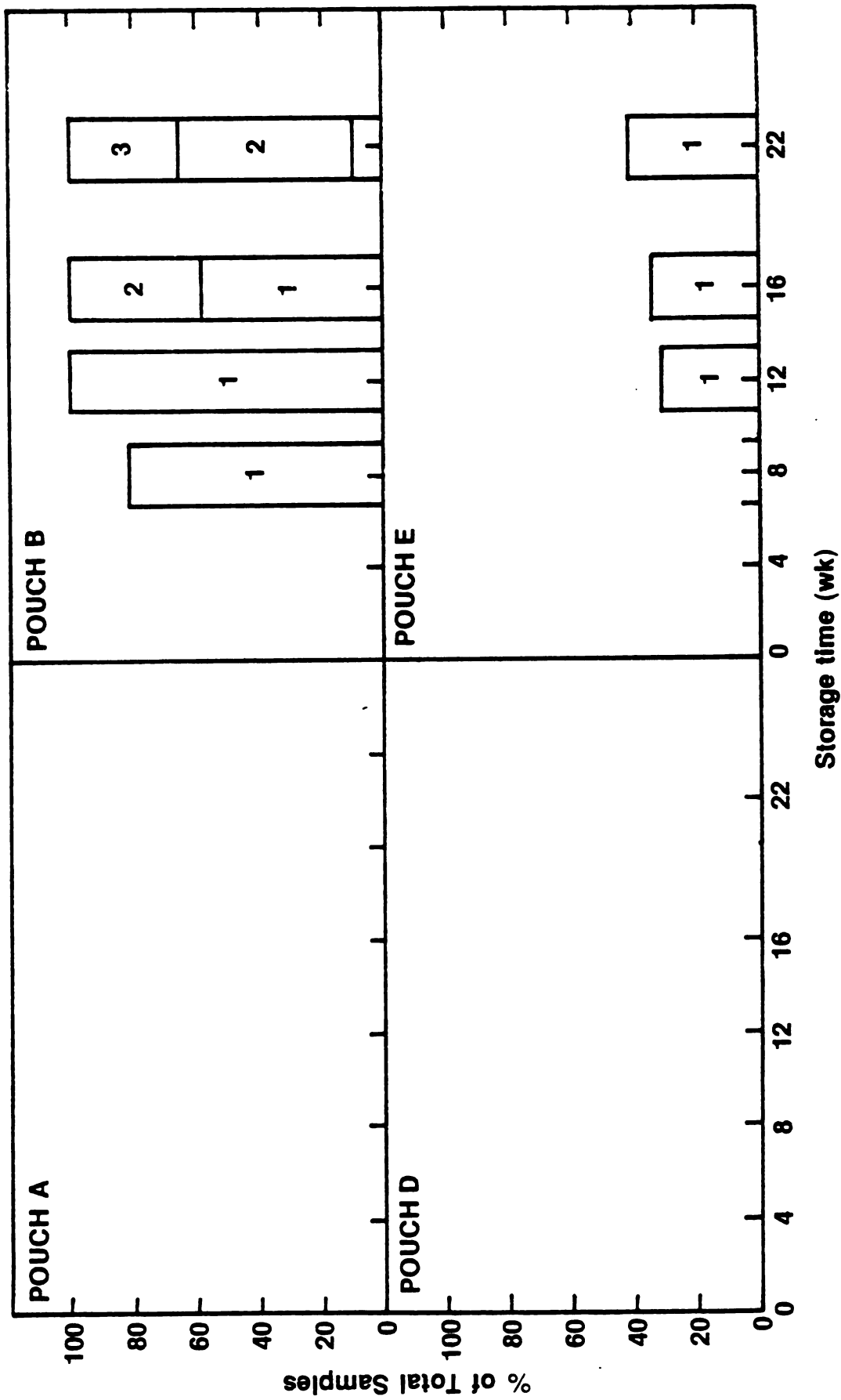


Figure 21. Quantity and Class of Visual Mold on Natural Mozzarella Cheese Packaged in Experimental Pouches.

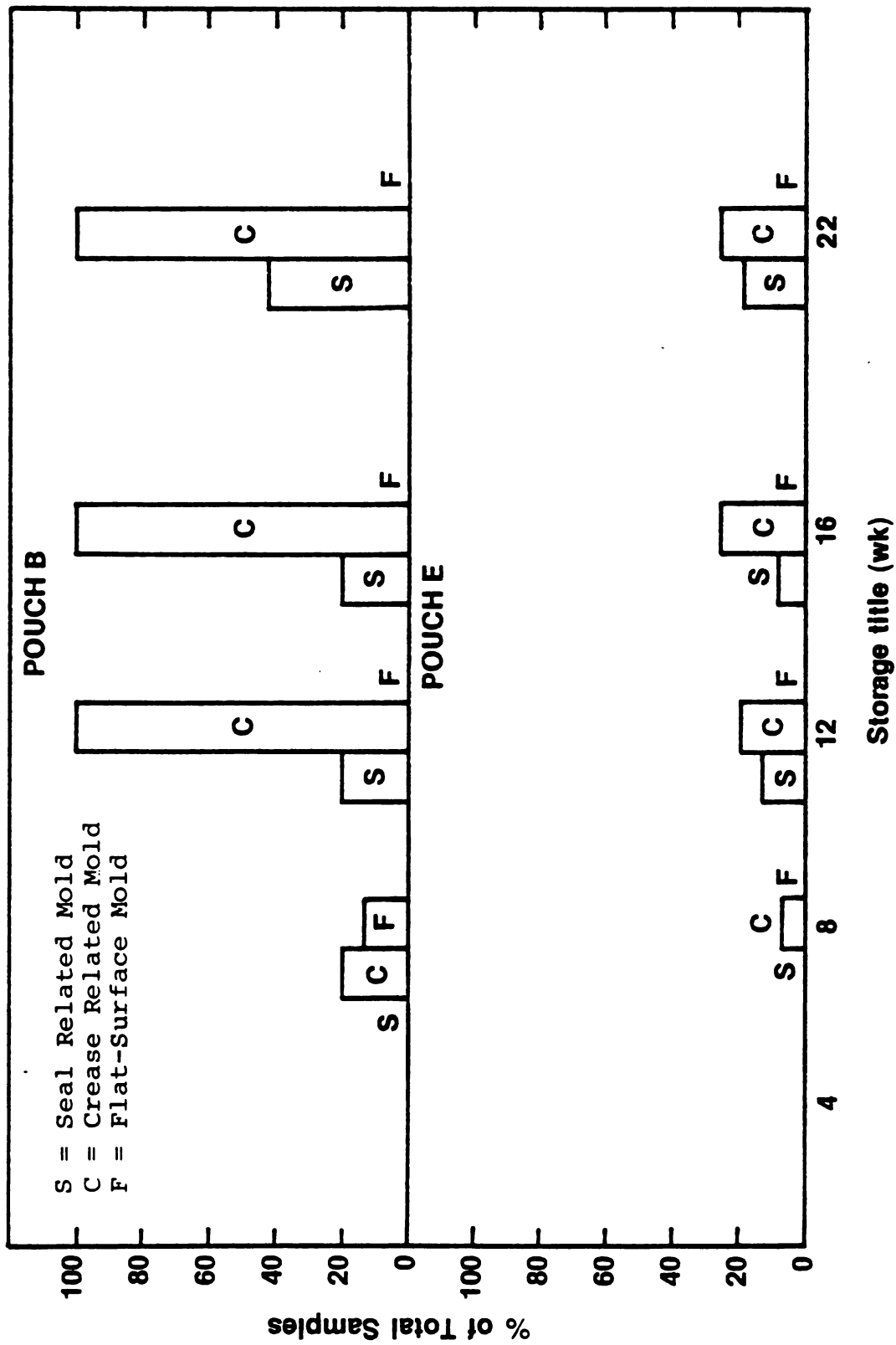


Figure 22. Location of Visual Mold on Natural Mozzarella Cheese Packaged in Experimental Pouches B and E.

2. Entrapped beneath the package film during packaging;
3. Diffused within the cheese body.

Extensive class 3 mold was observed on all polyethylene packed cheese after only 5 wk of storage. Mold predominated on the flat portions of the cheese samples and at package creases and wrinkles. Oxygen permeating through the pouch material is postulated to have been the major source of oxygen allowing mold development on the cheese samples. Table 14 presents oxygen barriers for all the experimental materials at two different environmental conditions and after 25 wk of contact with cheese for materials A, B, D, and E. The permeation rates of oxygen for material C are well above the optima suggested by Pearson and Scott (1978) and Sacharow and Griffin (1970). The extensive mold development completely eliminated the C film as a viable cheese packaging material for long-term storage. As a result, polyethylene packaged samples were not tested after the 4-wk testing period. Only the plate count data for these samples will be presented in this discussion.

Samples packaged in B films also displayed considerable mold growth with 100% of natural Cheddar, natural Mozzarella and artificial Mozzarella samples showing visual mold after 12 wk of storage. The Mozzarella analog had a higher percentage of class 3 mold than any of the other varieties (Figure 16), while mold on Rosano samples developed more slowly with 100% of the total samples showing contamination after 20 wk of storage (Figure 19). The location of the contamination along with the evidence obtained by the School of Packaging suggests the probable cause for

Table 14. Oxygen Permeability and Ranking for Experimental Pouches (cc/100 in²/24 hr)*

0 Time			
Pouch Type	23 C -- 0% RH	Pouch Type	23 C -- 100% RH
D	0.430	D	0.587
A	0.498	A	0.594
E	2.170	B	5.160
B	4.940	E	6.270
C	298.000	C	297.000

After 25 Weeks of Cheese Contact		
Cheese	Pouch Type	23 C -- 100% RH
Natural Cheddar	A	0.655
	D	0.766
	B	5.030
	E	7.520
Artificial Processed American	A	0.523
	D	0.694
	B	5.320
	E	6.080
Rosano	A	0.708
	D	0.890
	B	5.510
	E	6.190

*From Lockhart and Koning (1979).

the major portion of this mold.

Data collected by the School of Packaging showed extensive flex cracking in the B films after 4 wk of storage. Flex cracking only occurred on the inner ply in contact with cheese and was associated with stress points in the package. Table 15 and Figure 23 indicate both the location and extent of cracking for the B materials.

All of the natural Cheddar, artificial Mozzarella, Rosano, and natural Mozzarella cheeses packaged in film B contained crease related mold. We speculate that the flex cracked areas on the material allowed greater access of oxygen beneath the packaging film resulting in the observed mold development.

Data collected by the School of Packaging does not show increased oxygen permeation rates for material B samples containing flex cracked areas. However, material samples for testing were not isolated solely to flex cracked portions (Figure 24). Localized decreases in oxygen barrier properties at cracked areas may have been too small for disclosure by these methods.

The soft and compressible nature of Rosano samples may have reduced material flex cracking and thus explain its lower rate of mold development. However, this has not been confirmed by data from the School of Packaging.

Mold growth in crease related areas was still evident even in the absence of flex cracking and on cheeses packaged in materials with excellent barrier characteristics (A and

Table 15. Location and Extent of Flex-Cracking on Material B.*

Sample	Corner	Ear	Length	End
<u>4 Weeks</u>				
Natural Cheddar	2	1	2	0
Artificial Mozzarella	2	1	2	0
Artificial Processed American	2	1	1	0
Rosano	2	1	1	0
Natural Mozzarella	2	1	1	0
<u>15 Weeks</u>				
Natural Cheddar	2	1	2	0
Artificial Mozzarella	2	1	2	0
Artificial Processed American	2	1	2	0
Rosano	2	1	2	0
Natural Mozzarella	2	1	2	0

*0 = No Flex-Crack
 1 = Isolated Flex-Crack
 2 = Closely Spaced Flex-Crack
 From Lockhart and Koning (1979)

Table 15. (cont'd.)

Sample	Corner	Ear	Length	End
		<u>35 Weeks</u>		
Natural Cheddar	2	1	2	0
Artificial Mozzarella	2	1	2	0
Artificial Processed American	2	1	2	0
Rosano	2	1	2	0
Natural Mozzarella	2	1	2	0

*0 = No Flex-Crack
 1 = Isolated Flex-Crack
 2 = Closely Spaced Flex-Crack
 From Lockhart and Koning (1979)

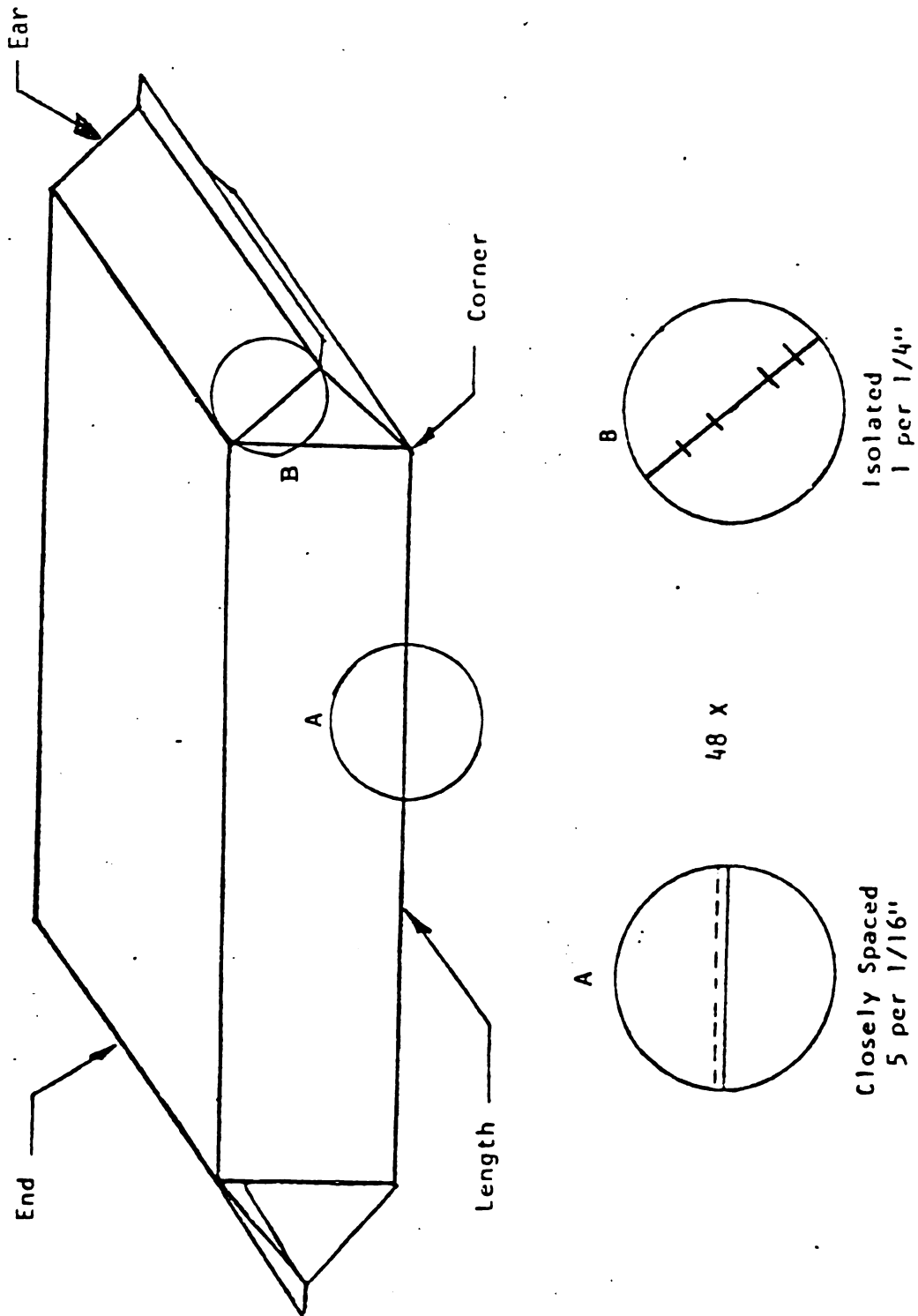
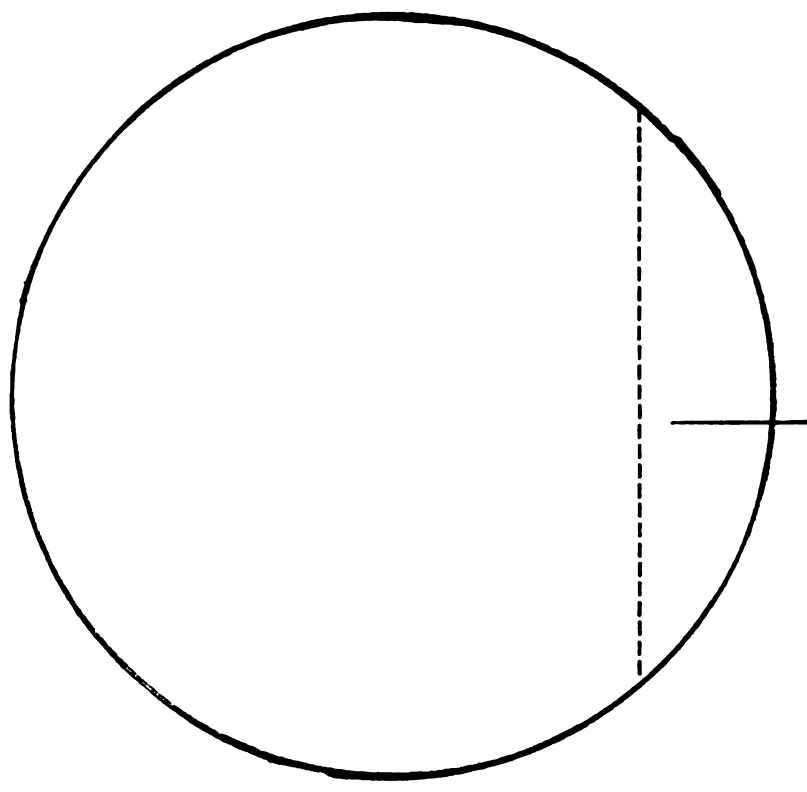


Figure 23. Location and Extent of Flex-Crack on Material B (from Lockhart and Koning (1979))



Approximately 3 in of
closely spaced flex-
cracking along length of
test sample.

Figure 24. Oxygen Barrier Test Specimen for Film B After
25 Wk Contact with Cheese. (From Lockhart & Koning)

D). No flex cracking was observed in materials A, E, or D by the School of Packaging. However, after 24 wk of storage, 81% and 30% of the natural Cheddar portions packaged in films A and E, respectively, showed class 1 mold (Figure 13). Fifty per cent of the natural Cheddar samples packaged in pouch A and 33% of those packaged in film E showed crease related mold following 24 wk of storage (Figures 14 and 15). Both natural Mozzarella and Rosano samples packaged in material A were completely free from visual mold. Rosano cheese portions in film E had only minimal class 1 mold development, all of which was crease related (Figures 19 and 20). Mold contamination on samples in material D was minimal for all cheese varieties.

We hypothesize that gas entrapment during packaging was the major source of oxygen responsible for mold development in these crease related areas. Gas entrapment may have also contributed to mold growth on B packaged samples. The superior flexural characteristics evident in film D may have resulted in a closer adherence between the cheese and material, thus reducing the incidence of oxygen entrapment.

The natural Mozzarella portions packaged in film A did not show mold growth, hypothetically due to the extensive gas produced and subsequent "blowing" of the pouch. As indicated earlier, high concentrations of carbon dioxide have been shown to inhibit mold development (Volodin and Shiler, 1977). Lack of visual mold on Rosano portions packaged in films A and E could be a result of gas production by Propionibacterium shermanii, but more likely

is related to the extreme softness of the cheese variety with product filling the creases and corners of the package.

Up to this point, we have not discussed the presence of mold on the artificial Mozzarella variety packaged in films A, D, and E. The results for this cheese variety are more difficult to interpret and require additional explanation. Significant contamination was evident on artificial Mozzarella samples packaged in films A and E. Development was most extensive on those samples packaged in film E with 100% showing class 2 and 3 mold after 24 wk of storage (Figure 16). A similar but slower rate of development was evident on samples packaged in material A. Pouch D provided the most protection against mold growth with twenty-five percent of the total samples being affected following 24 wk of storage. The contamination was observed to occur in creases, seals, and on the flat surface of the artificial Mozzarella cheese samples. Only the artificial Mozzarella samples contained surface related mold in pouch materials other than C (Figures 18 and 19).

The surface mold occurring on the artificial Mozzarella samples had the following characteristics:

1. The surface mold was only associated with irregular hills and valleys on the narrow surface of the cheese portion;
2. Present on samples packaged in Film A;
3. Minimal on samples in pouch D;
4. Greatest for samples in pouches B and E.

The irregular areas were formed while dipping hot cheese from the process cheese kettle and are restricted to only one narrow side of the individual cheese portions. We speculate that oxygen was entrapped at those areas during packaging. Use of film D reduced the incidence of entrapment due to its superior flexural properties. The fact that the extent of mold was greater on samples packaged in films with less than optimum oxygen barrier (B and E) and also seemed to increase in intensity with time, suggests that oxygen permeating through the materials also contributed to the mold development.

We could also postulate that the artificial Mozzarella cheese had a lower reducing potential since it did not contain living cultures. Thus, all of the entrapped or permeated oxygen would be available for mold growth. This would corroborate evidence reported by Dolby (1966) for natural Cheddar cheese. The artificial Mozzarella cheese does, in fact, exhibit more mold contamination than the other cheese varieties in the same package treatments. However, reducing potential of the experimental cheeses was not measured and the effect of this variable is unknown. Further, the filled and natural cheeses had been ripened for several weeks prior to packaging for this study, and as such, microbial populations would have been greatly reduced and the contributions of reducing potential to oxygen utilization relatively negligible (Dolby, 1966).

Two observations tend to discount dissolved gas as a

significant contributor of oxygen beneath the film wrapper. The presence of oxygen beneath the film should not be affected by the packaging material if its source is from within the cheese body. Secondly, oxygen diffusing from within the cheese would accumulate beneath the film wrapper and initiate mold growth on the flat portions of the cheese cuts. All of the mold development in natural Cheddar, Rosano, and natural Mozzarella cheeses occurred in creases or at seals. Additionally, no surface mold was evident on the broad portions of the artificial Mozzarella samples.

Mold associated with seals was not as plentiful as that associated with package creases and wrinkles. Mold resulting from seal leaks was most common on the artificial Mozzarella variety and occurred predominantly on those samples packaged in materials A, B, and E. Thirty-two percent of the natural Cheddar samples had seal related contamination following 24 wk of storage in films A and B, respectively (Figure 14). Rosano cheese samples only developed mold growth at seal areas when packaged in pouch B with approximately 18% of the samples affected after 24 wk of storage (Figure 20). Natural Mozzarella samples showed seal related contamination in films B and E with 42% and 18% of the samples contaminated after 24 wk of storage, respectively (Figure 22).

Wrinkles in the seal area seem to be related to the presence of visual mold. Prevention of wrinkles in the seal during packaging requires that the material lay flat across

the impulse bar and be free from crimping. This was a greater problem with more inflexible materials (A, B, and E).

Microbiological Assays

The results from plate counts of yeasts, molds, and coliforms are presented in Tables 16 and 17. Initial coliform counts per gram of cheese were quite high for the Rosano and artificial Mozzarella cheeses. As expected, however, colonies rapidly decreased throughout storage. After 15 wk of storage, no coliform colonies were detected on artificial Mozzarella, natural Mozzarella, and artificial Processed American cheeses, and very low counts on the natural Cheddar samples. Coliform counts of less than 1 per gram of cheese were observed for the Rosano samples after 25 wk of storage. No clear relationship was indicated between the coliform counts and type of packaging material utilized.

The nature of yeast and mold contamination on the samples affects the interpretation of the data. As indicated by the results from the visual examination, most of the mold contamination occurred in pouch creases and seals, and as such, was a localized phenomenon. Samples for plate counts were always taken from the same area of the cheese portion and did not accurately represent the true incidence of mold on the sample. For this reason, much of the present data is difficult to interpret since occasional high counts are

Table 16. Presumptive Coliform Counts for Cheeses Stored
In Experimental Pouches (Counts/g Cheese)

Pouch Type	Storage Time (Wk)				
	0	4	15	25	35
<u>Natural Cheddar</u>					
A	29	3	5	<1	<1
B	29	2	3	<1	<1
C	29	31	--	--	--
D	29	2	<1	<1	<1
E	29	150	<1	<1	<1
<u>Artificial Mozzarella</u>					
A	250	160	<1	<1	--
B	250	300	<1	<1	--
C	250	250	--	--	--
D	250	80	<1	<1	--
E	250	47	<1	<1	--
<u>Artificial Processed American</u>					
A	39	<1	<1	--	--
B	39	<1	<1	--	--
C	39	<1	--	--	--
D	39	<1	<1	--	--
E	39	<1	<1	--	--
<u>Rosano</u>					
A	8200	720	130	<1	--
B	8200	110000	340	<1	--
C	8200	2200	--	--	--
D	8200	2800	150	<1	--
E	8200	470	230	<1	--
<u>Natural Mozzarella</u>					
A	21	6	<1	--	--
B	21	<1	<1	--	--

Table 16. (cont'd.)

Pouch Type	0	<u>Storage Time (Wk)</u>		25	35
		4	15		
<u>Natural Mozzarella</u>					
C	21	3	<1	--	--
D	21	<1	<1	--	--
E	21	<1	<1	--	--

Table 17. Yeast and Mold Counts for Cheeses Stored in
Experimental Pouches (log counts/g Cheese)

Pouch Type	0	4	Storage Time (Wk)		35
			15	25	
<u>Natural Cheddar</u>					
A	2.08	1.50	2.23	2.71	1.08
B	2.08	2.66*	3.25*	2.78	3.15*
C	2.08	3.94	--	--	--
D	2.08	1.38	0.99	0.23	0.00
E	2.08	2.00	4.81*	3.49*	3.43*
<u>Artificial Mozzarella</u>					
A	0.54	3.04*	2.46*	3.51*	2.61
B	0.54	4.04*	3.23*	4.46*	3.63*
C	0.54	4.43	--	--	--
D	0.54	1.40*	1.45	2.49*	2.76*
E	0.54	3.36*	3.32*	4.18*	3.00*
<u>Artificial Processed American</u>					
A	0.00	3.82*	4.11*	3.88	3.04*
B	0.00	3.86*	5.41*	4.20*	3.96*
C	0.00	5.32	--	--	--
D	0.00	3.60*	3.04*	2.65*	2.76*
E	0.00	4.26*	4.45*	3.20*	3.93*
<u>Rosano</u>					
A	0.95	0.90	0.00	0.00	0.00
B	0.95	0.36	4.28*	1.92	2.67
C	0.95	5.04	--	--	--
D	0.95	0.00	0.00	0.08	0.00
<u>Natural Mozzarella</u>					
A	0.18	0.00	0.00	0.89	1.08
B	0.18	4.15*	4.15*	4.38*	3.00

*Greater than 90% yeast

Table 17. (cont'd.)

Pouch Type	0	<u>Storage Time (Wk)</u>			
		4	15	25	35
<u>Natural Mozzarella</u>					
C	0.18	6.04	--	--	--
D	0.18	0.00	0.00	0.50	0.00
E	0.18	0.00	1.68	0.50	3.95*

*Greater than 90% yeast

interspersed with intermediate and low values. Another misleading factor is the high yeast counts present in the artificial Processed American and to a lesser extent, the artificial Mozzarella samples. Extensive yeast contamination was evident on cheese portions packaged in materials that did not show excessive visual mold. Samples in D films contained more than 90% yeasts throughout most of the storage of the artificial Mozzarella and artificial Processed American cheeses. Almost all of the microbiological counts in the artificial Processed American samples were attributed to yeast growth. Yeast counts in the natural and filled cheeses were associated to a greater extent with samples containing significant visual mold contamination.

Despite the irregularities, it is evident from the data that the D film offered the greatest protection from mold contamination followed by films A, E, B, and C.

Weight Loss During Storage

It was assumed that any significant loss of weight from the samples would reflect permeation of water vapor through the packaging films or seal leaks. The water vapor barriers for the experimental pouches were determined by the School of Packaging and are presented in Table 18. As indicated, temperature, relative humidity, and cheese contact can alter the water barrier properties of the experimental films. The most pertinent figures for permeability are those representing conditions of storage for this study. Water vapor transmission rates for all

Table 18. Water Vapor Transmission Rates and Ranking
for Experimental Pouches (g/100in²/24 hr)*

<u>Test Conditions</u>						
Cheese Variety	Storage Chamber (4 C)		25 C - 50% RH		38 C - 85% RH	
<u>0 Time</u>						
All Cheeses	D	0.0030	D	0.0120	B	0.1800
	B	0.0078	A/B	0.0300	A	0.2600
	A	0.0110	C/E	0.1200	D	0.3300
	C	0.0204			C	0.8500
	E	0.0250			E	0.9700
<u>After 25 Wk of Cheese Contact</u>						
Natural Cheddar	A	0.000				
	B/D	0.0024				
	C	0.0220				
	E	0.0270				
Artificial Mozzarella	A/D	0.00				
	B	0.0094				
	C	0.0200				
	E	0.0230				
Rosano	D	0.00				
	A/B	0.0024				
	C	0.0200				
	E	0.0290				
Artificial Processed American	D	0.00				
	A/B	0.0024				
	C	0.0140				
	E	0.0270				
Natural Mozzarella	A	0.0000				
	B	0.0024				
	D	0.0025				
	E	0.0260				
	C	0.0270				

*From Lockhart and Koning (1979)

of the experimental materials were well below the 1 g/100 in²/ 24 hr maximum recommended by Pearson and Scott (1978) for cheese packaging films.

Weight loss data for package treatments A, B, D, and E are graphically presented in Figures 25 through 29.

The vast majority of samples lost weight; occasional weight gains probably resulted from experimental error. A slight weight loss generally was evident after 4 wk of storage. The cheese weight did not significantly change throughout the remainder of the study. The sudden loss in weight after packaging is believed to result from higher initial weights caused by dew which had formed on the newly packaged cheeses. There were no weight loss measurements in excess of 1%, and we conclude that all of the pouch materials are successfully retarding moisture loss from the cheese portions.

Textural Changes During the Storage Period

Textural characteristics in cheese are multifaceted and as such were not clearly indicated by the shear compression data collected in this study. A brief subjective evaluation of the initial textural properties of the different cheese varieties is necessary and will have significance in the interpretation of data presented in other sections.

Rosano cheese had a highly compressible and rubbery body. This contrasted with the typical firmness of body

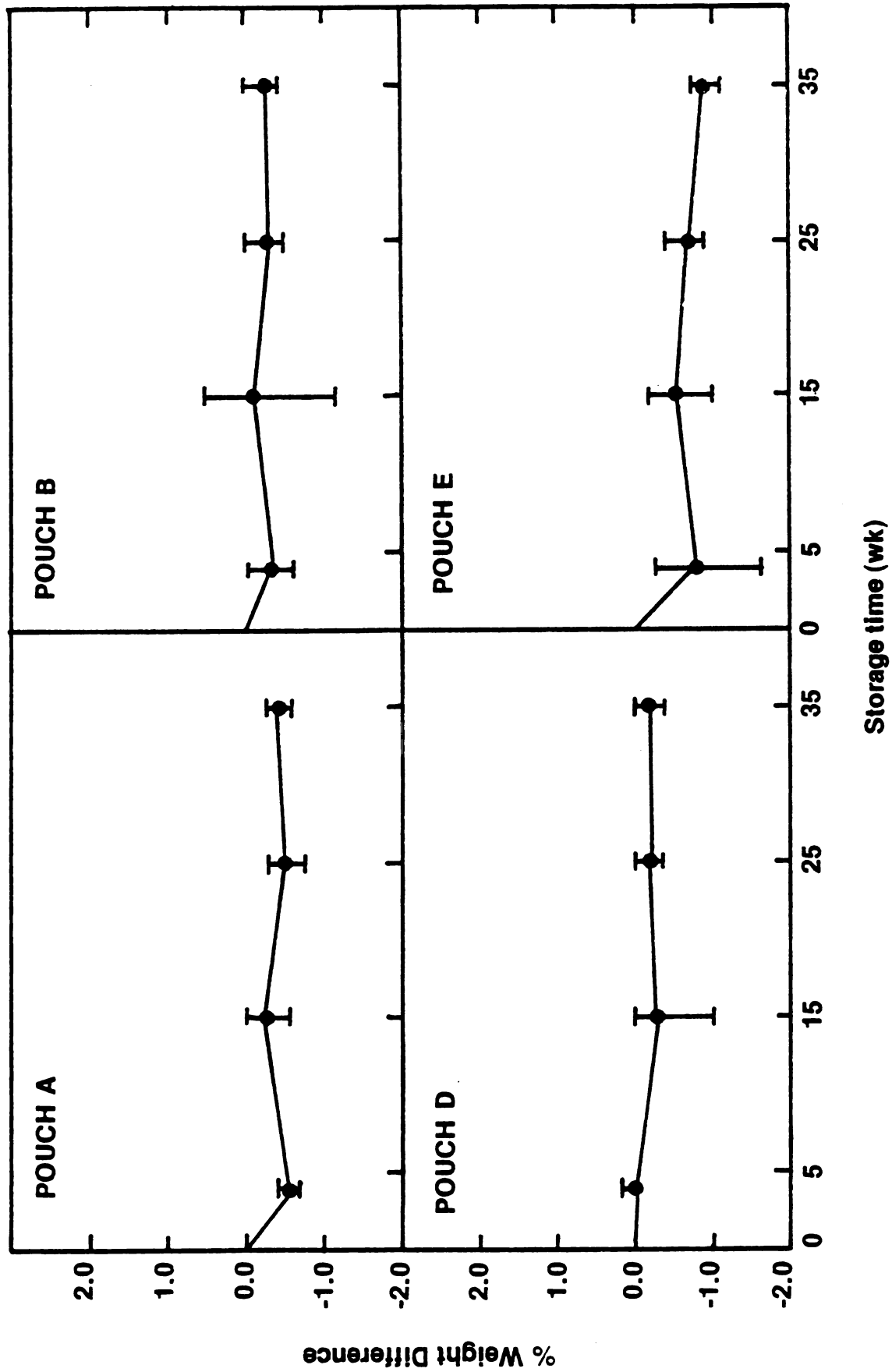


Figure 25. Percent Weight Losses Observed for Natural Cheddar Cheese Stored in Experimental Pouches (Mean Values and Range).

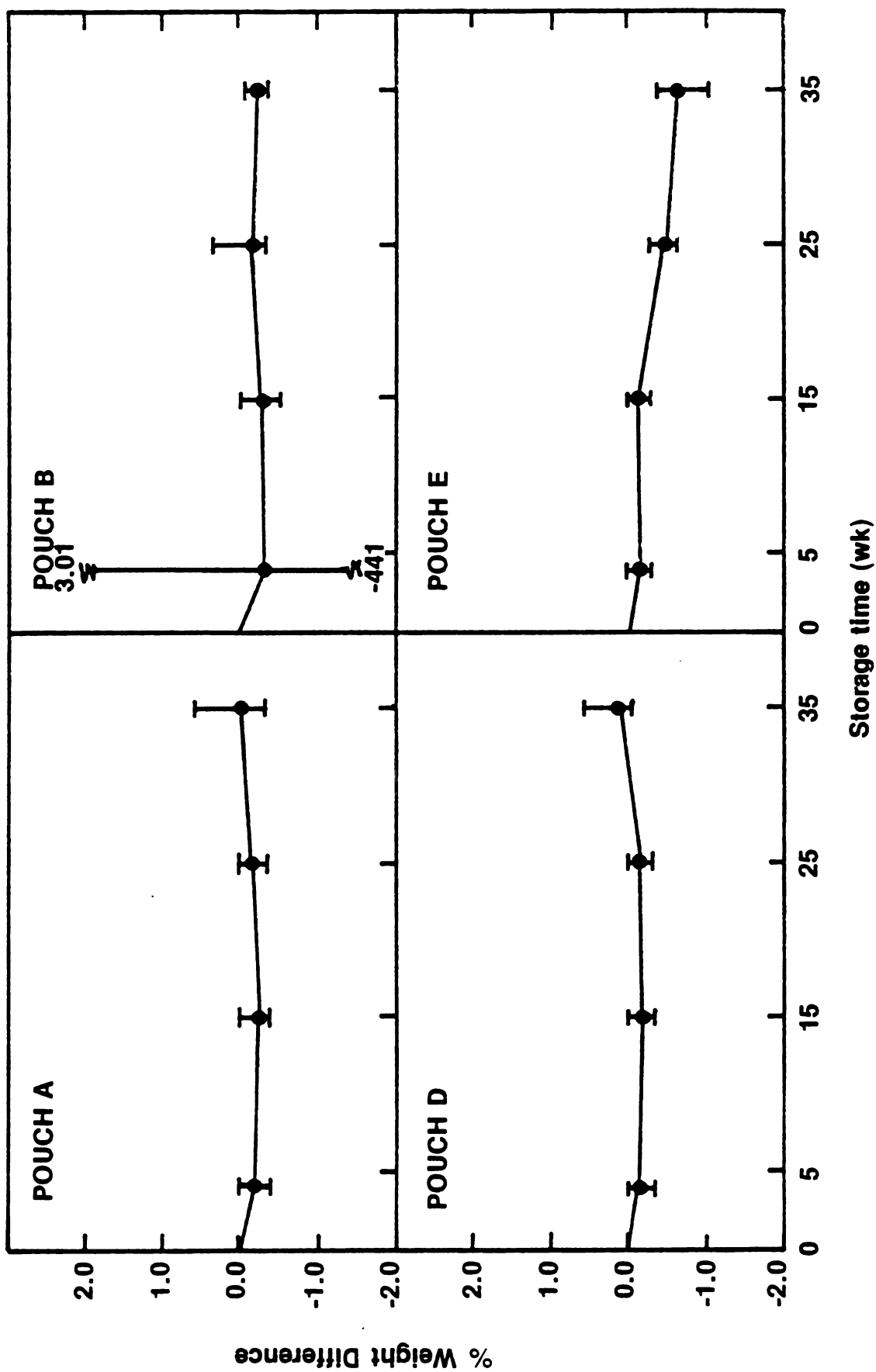


Figure 26. Percent Weight Losses Observed for Artificial Mozzarella Cheese Stored in Experimental Pouches (Mean Values and Range).

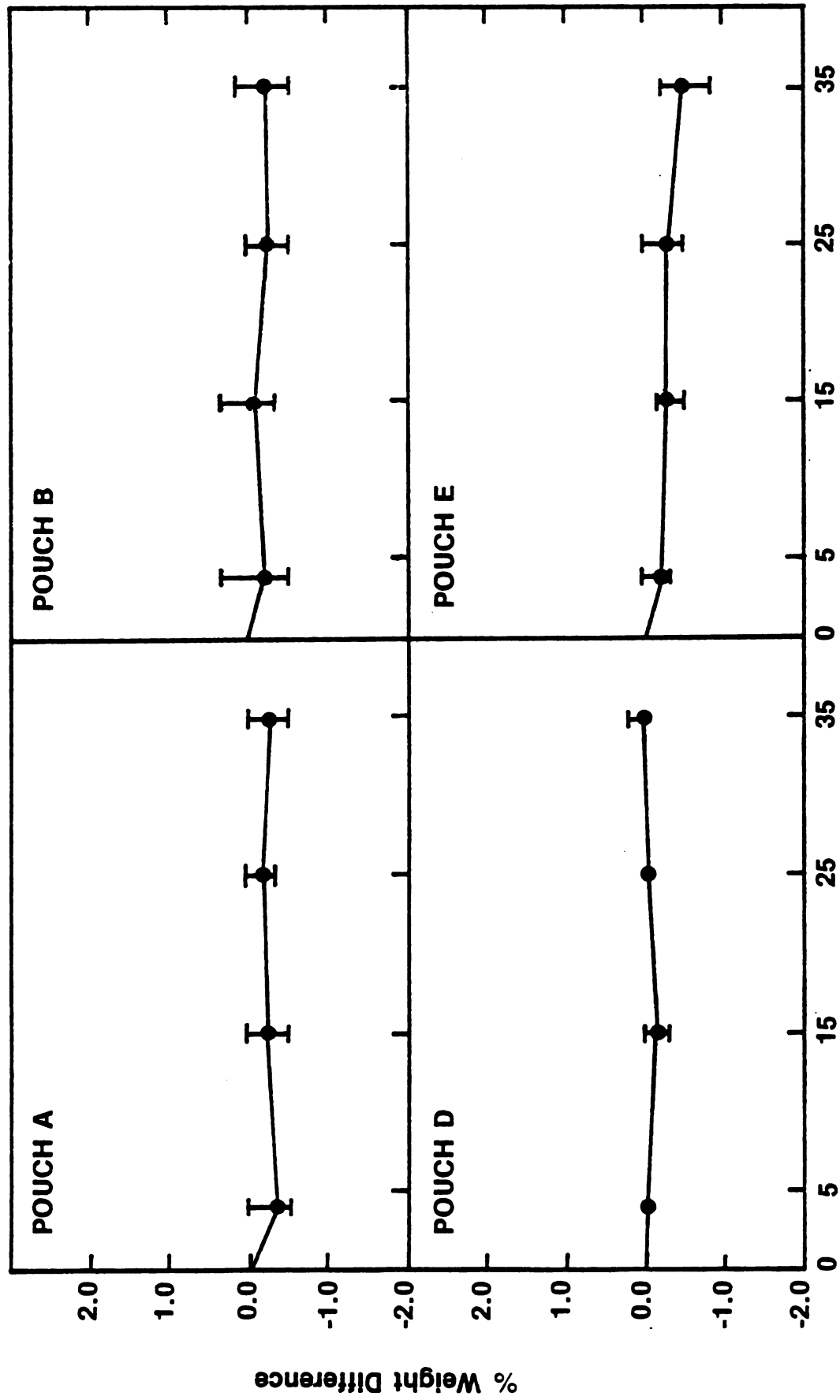
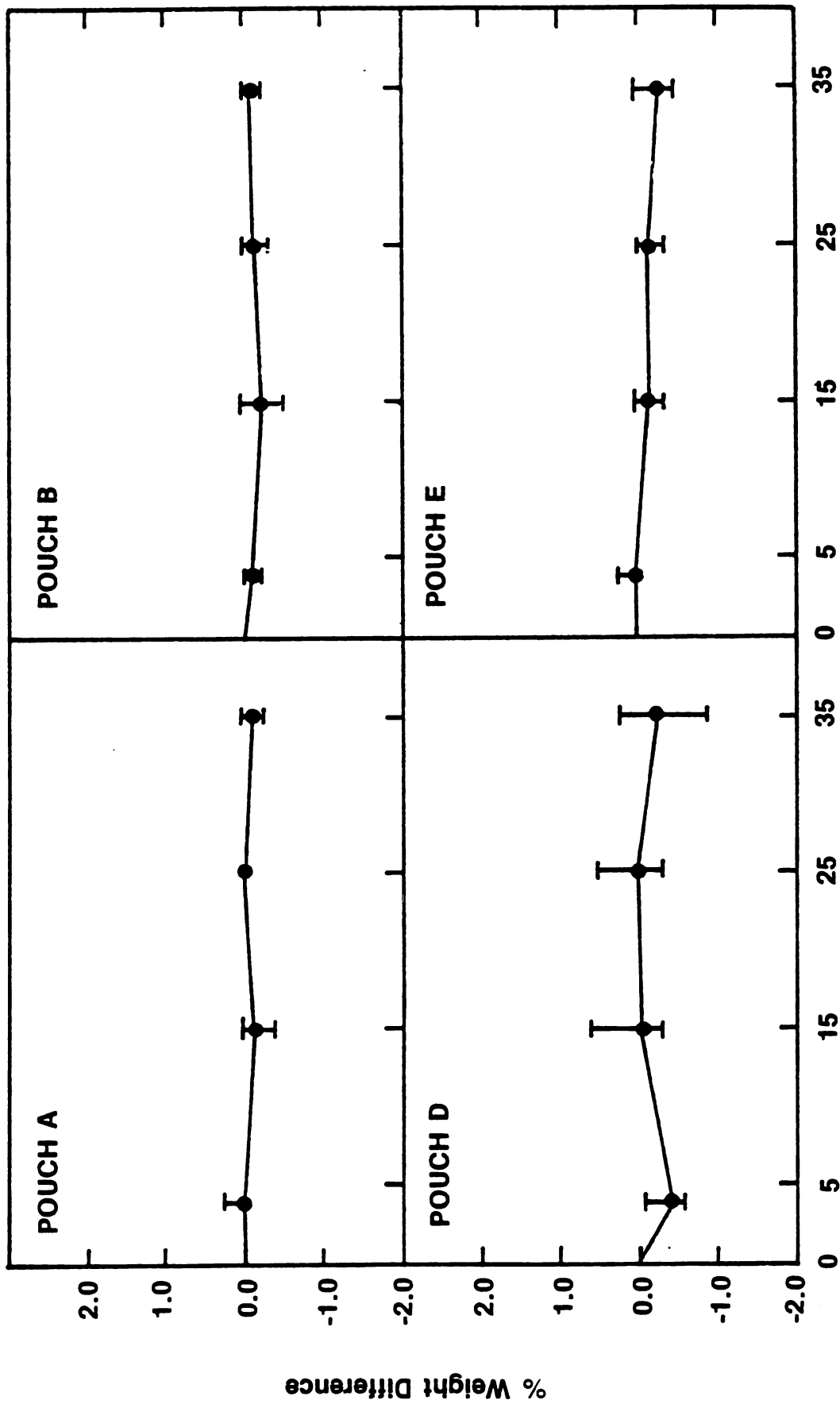


Figure 27. Percent Weight Losses Observed for Artificial Processed American Cheese Stored in Experimental Pouches (Mean Values and Range).



Storage time (wk)

Figure 28. Percent Weight Losses Observed for Rosano Cheese Stored in Experimental Pouches (Mean Values and Range).

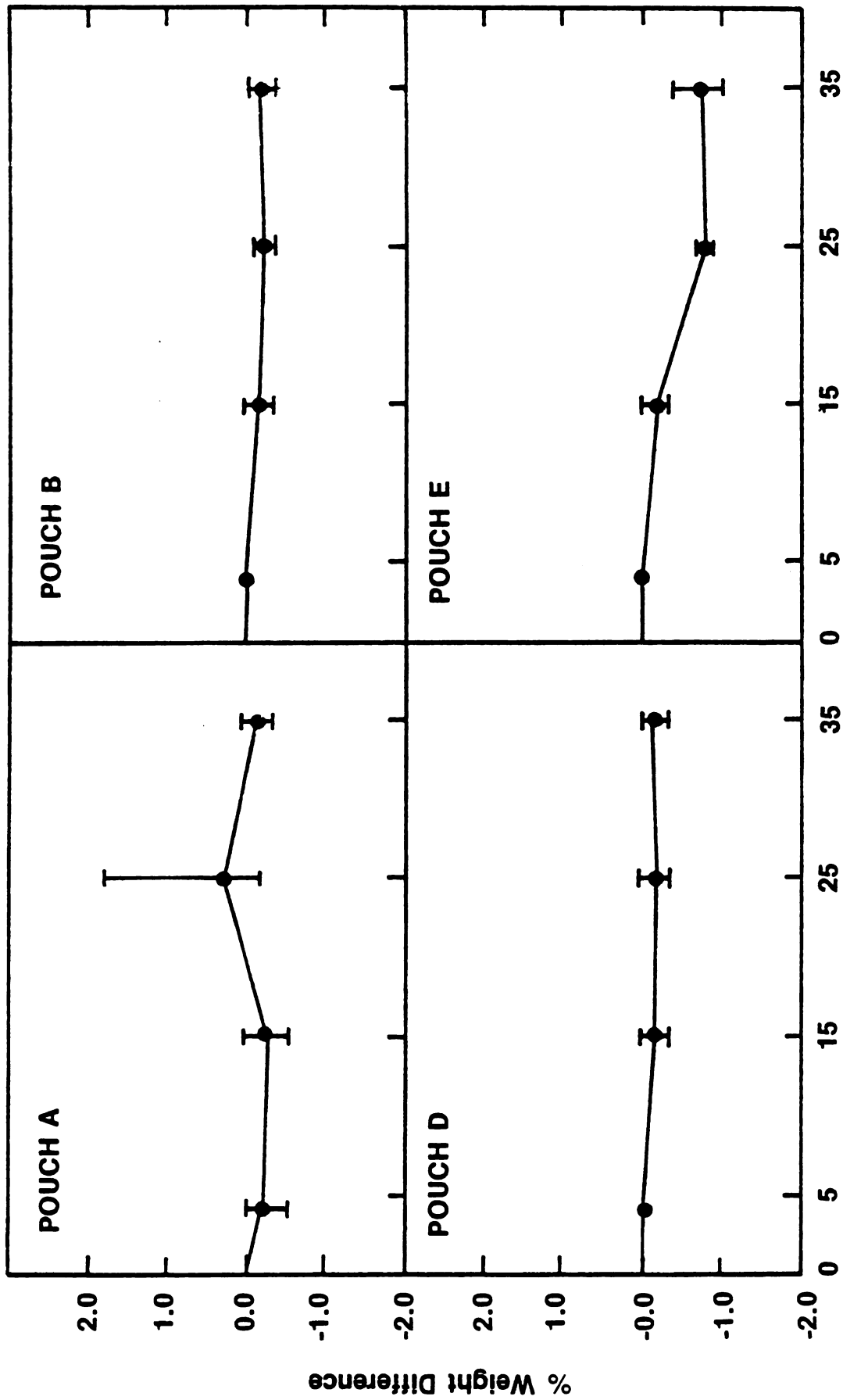


Figure 29. Percent Weight Losses Observed for Natural Mozzarella Cheese Stored in Experimental Pouches (Mean Values and Range).

found in the natural Cheddar cheese despite similar shear compression values between these two varieties (Figures 30 and 33). Both substitute cheeses were of intermediate compressibility and firmness while the natural Mozzarella was initially quite hard and shear resistant.

The absence of moisture loss from the cheese portions eliminates the possibility of textural changes caused by sample dehydration. Examination of Table 19 indicates that statistically significant textural changes occurred in the artificial Mozzarella, artificial Processed American, Rosano, and natural Mozzarella samples. Neither storage duration nor packaging material had any effect on the shear compression values of the natural Cheddar samples.

The artificial Mozzarella samples showed statistically significant differences throughout storage regardless of packaging material. An interaction effect between pouch material and storage time was also indicated. This interaction effect was not confirmed by the Tukey separations, however, and is not considered valid. Therefore, different pouch materials did not have any effect on the shear compression values in artificial Mozzarella samples. The textural changes which occurred throughout storage for all artificial Mozzarella cheese samples are graphically illustrated in Figure 31. Increasing shear force values after 4 wk of storage and until 25 wk were evident. After 25 wk, a softening of the cheese samples ensued until the end of storage. There was also some evidence of initial decreases

Table 19. Analysis of Variance of Shear Compression Data for Cheese Stored in Experimental Pouches ($p \leq .01$) *

Source of Variation	df	Mean Squares
<u>Natural Cheddar</u>		
Storage Time	3	0.212
Pouches	3	0.144
Interaction	9	0.161
Error	32	0.094
<u>Artificial Mozzarella</u>		
Storage Time	3	0.253*
Pouches	3	0.008
Interaction	9	0.103*
Error	32	0.020
<u>Artificial Processed American</u>		
Storage Time	3	0.740*
Pouches	3	0.027
Interaction	9	0.030
Error	32	0.022
<u>Rosano Cheese</u>		
Storage Time	3	4.137*
Pouches	3	0.850*
Interaction	9	0.220
Error	32	0.074
<u>Natural Mozzarella</u>		
Storage Time	3	5.777*
Pouches	3	0.203
Interaction	9	0.279
Error	32	0.162

*denotes significance

Table 20. Mean Shear Compression Force Values and Tukey Separations for Cheeses Stored in Experimental Pouches ($p \leq 0.01$)*

Pouch Type	0	4	<u>Storage Time (wk)</u>		35
			15	25	
<u>Artificial Mozzarella</u>					
A	2.78	2.52a	2.75a	2.94a	2.81a
B	2.78	2.44a	3.04a	2.76a	2.67a
D	2.78	2.74a	2.78a	2.90a	2.68a
E	2.78	2.59a	2.98a	2.86a	2.72a
<u>Rosano</u>					
A	2.64	2.64a	2.74a	1.83a	2.05a
B	2.64	2.93a	2.30a	1.83a	1.73a
D	2.64	2.80a	2.19a	1.77a	1.67a
E	2.64	3.33a	2.53a	2.85b	1.87a

*similar letters within columns denote no significant difference

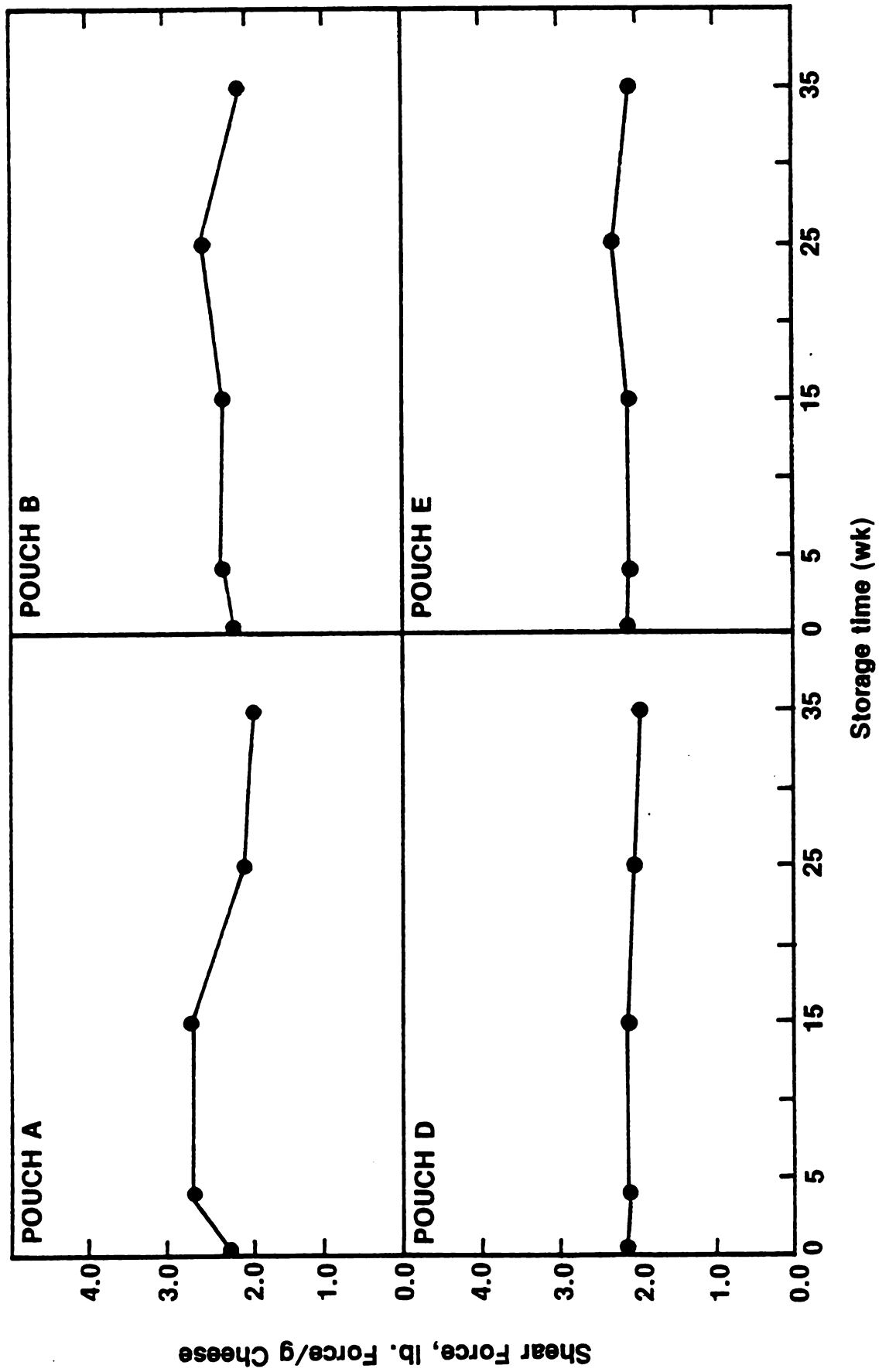


Figure 30, Changes in Shear Compression Force in Natural Cheddar Cheese Stored in Experimental Pouches (Mean Values).

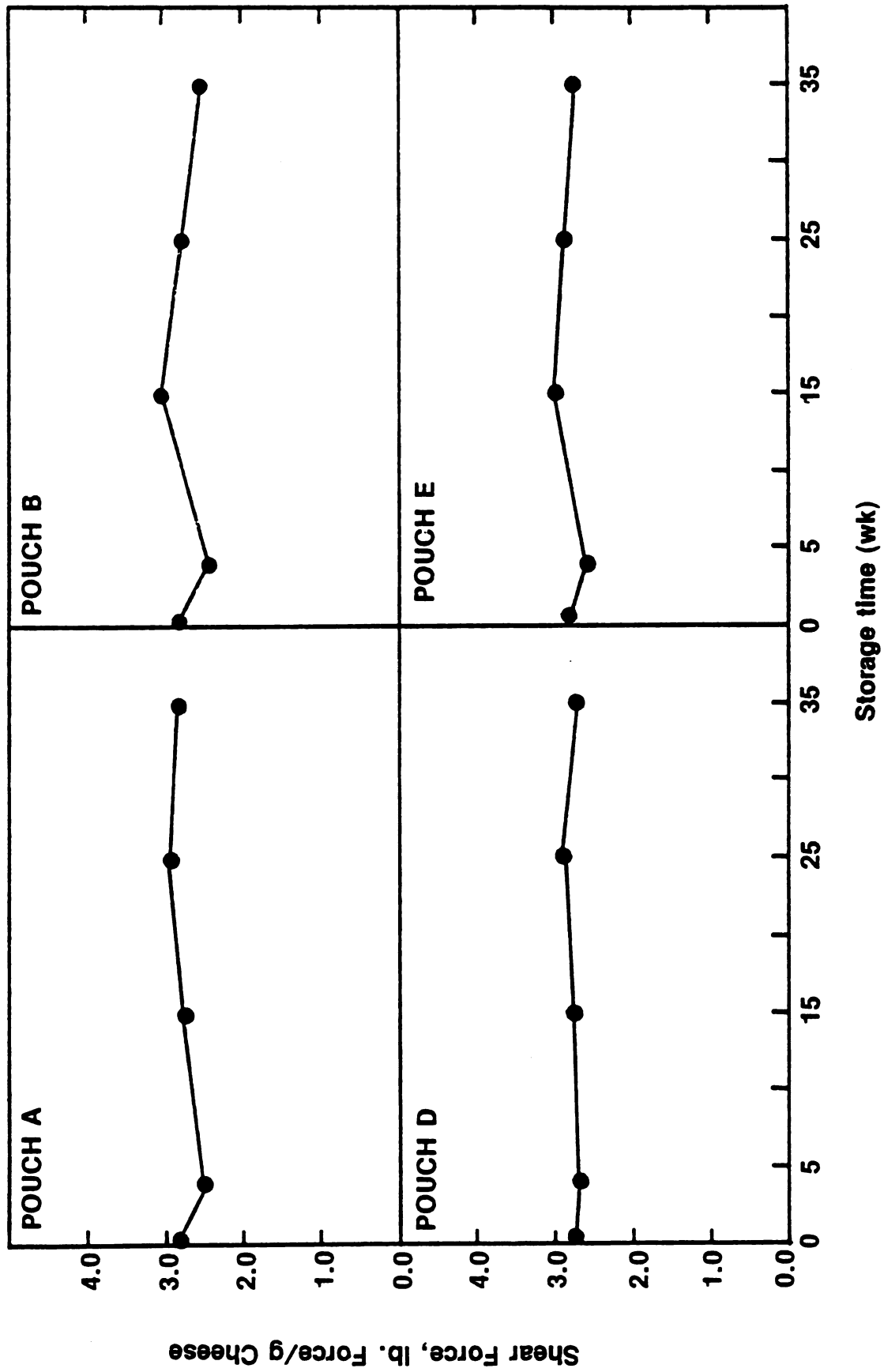


Figure 31. Changes in Shear Compression Force in Artificial Mozzarella Cheese Stored in Experimental Pouches (Mean Values).

in shear compression values between 0 and 4 wk of storage. However, this effect is not included in the analysis of variance.

The use of different packaging materials was found to have no effect on the shear compression force in the artificial Processed American samples. However, the shear force values did gradually increase through storage. This "toughening" may have been caused by the exudation of a fluid from the cheese body. This became visually apparent after approximately 15 wk of storage (Figure 32).

Significance for both main effects is indicated by analysis of variance for the Rosano samples. Tukey separations between the mean value of the package treatments indicated large shear compression values for samples packaged in film E after approximately 25 wk of storage (Table 20). However, at the time of unpackaging, it was evident that two of the three replicates were originally taken from outside corners of the 20-lb Rosano hoops. Examination of other Rosano hoops revealed similar "toughness" in these locations. Therefore, lack of complete randomization and/or non-normally distributed shear compression values in Rosano cheese hoops were probably responsible for the statistically significant variation.

Shear compression values invariably decreased throughout storage regardless of packaging material for the Rosano cheese (Figure 33). Natural Mozzarella also displayed lower shear force values during storage without regard to the packaging material (Figure 34). The softening of both

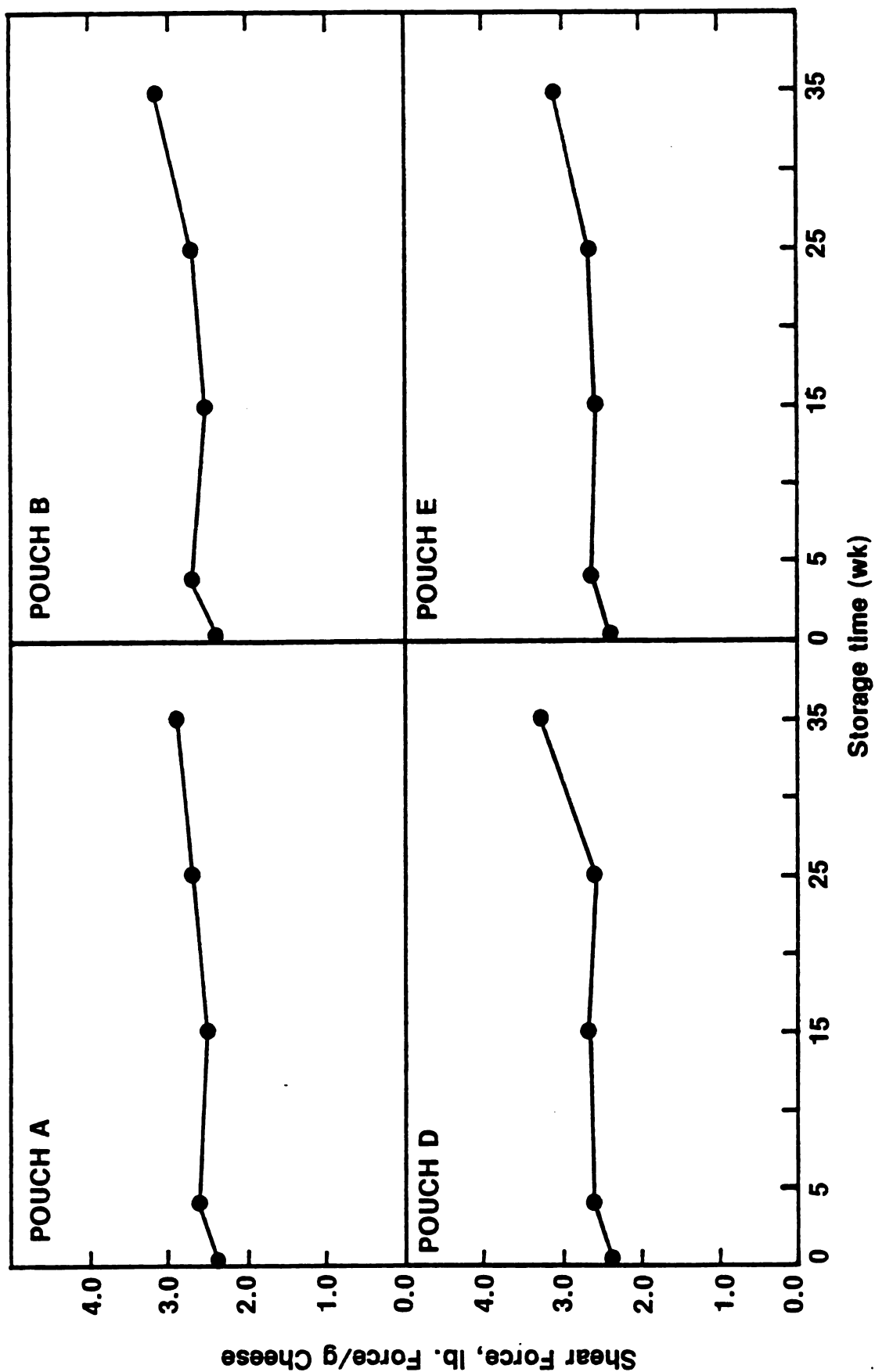


Figure 32. Changes in Shear Compression Force in Artificial Processed American Cheese Stored in Experimental Pouches (Mean Values).

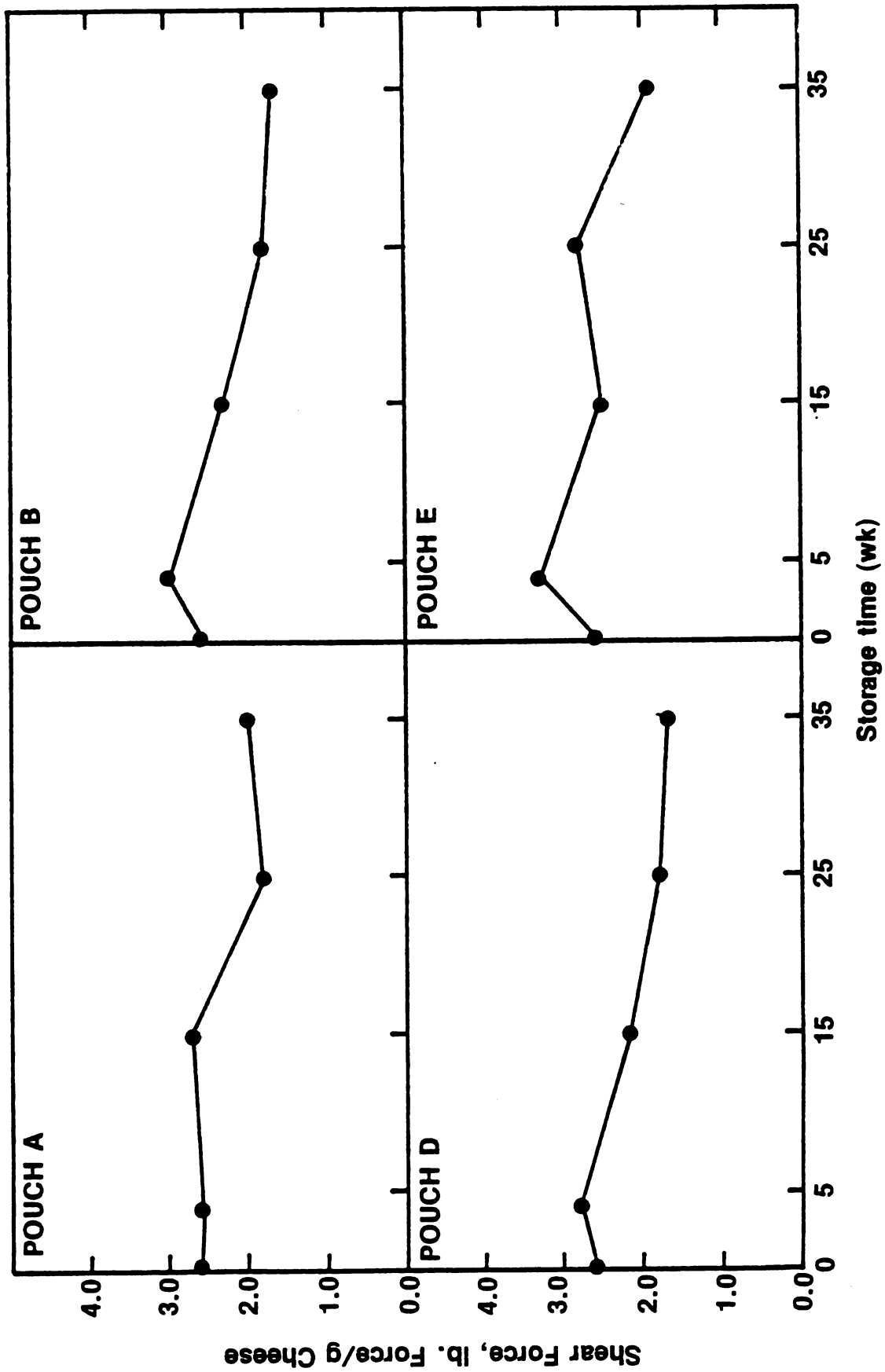


Figure 33. Changes in Shear Compression Force in Rosano Cheese Stored in Experimental Pouches (Mean Values).

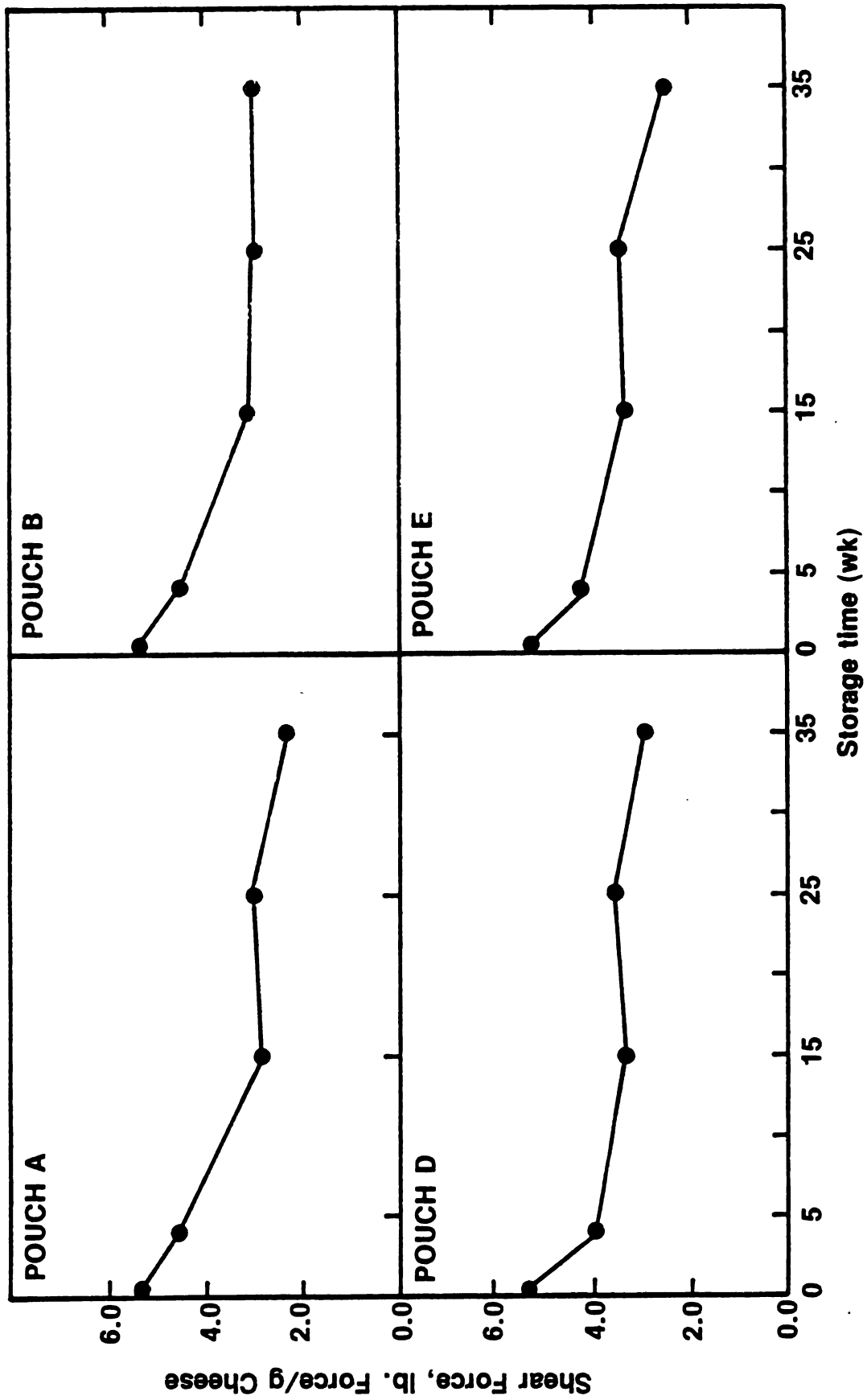


Figure 34. Changes in Shear Compression Force in Natural Mozzarella Cheese Stored in Experimental Pouches (Mean Values).

Rosano and natural Mozzarella is attributed to proteolytic action occurring during the long-term storage.

To summarize, changes in shear force were not associated with the use of different packaging films. Significant differences which did occur may be attributed to intrinsic ripening effects within the cheese varieties causing textural changes during storage.

Color Evaluation

Samples for color evaluation were initially obtained by grinding a large portion of the cheese portion in a Waring blender and packing the ground cheeses to capacity in a petri dish. Two problems were encountered using this method:

1. The color changes which occurred were surface related and not accurately represented by this method, and
2. Prolonged ripening resulted in textural changes which made even grinding impossible for the natural and filled cheeses.

Lack of a uniform grind greatly altered the color coordinate values obtained from the HunterLab for the filled and natural cheeses. Ground sample values for the two substitute cheeses are believed to be accurate and will be included in the statistical treatment and discussion. Emphasis, however, will be placed upon the values obtained from the cheese surfaces, which are considered very reliable.

Unfortunately, color coordinate values were not taken on the cheese surfaces at 0 time. Figures for the ground samples at 0 time have been included in the tabulation for comparison.

Analysis of variance for the color coordinate values is presented in Tables 21 and 22. Mean values and Tukey separations for the artificial Mozzarella and artificial Processed American cheeses are presented in Tables 23 and 24, respectively. Table 25 contains the surface data for the natural Cheddar, Rosano, and natural Mozzarella cheese varieties.

Artificial Mozzarella samples packaged in different materials showed no statistically significant differences in color coordinate values due to the packaging film. This is further confirmed by Tukey separations. However, significant differences for the ground samples of artificial Mozzarella were indicated between test periods. Tukey separations were not calculated, but the average values indicate increasing L values, decreasing a_L values, and decreasing b_L values from 0 time to approximately 25 wk of storage. Higher Hunter L values reflect a general increase in the whiteness of the samples. White crystal formation probably explains the changing L values. Decreasing a and b color coordinate values reflect increasing greenness and blueness, probably resulting from mold development on the cheeses.

Table 21. Analysis of Variance of HunterLab Color Coordinate Data for Artificial Mozzarella and Artificial Processed American Cheeses Stored in Experimental Pouches - Ground Samples ($P \leq 0.01$)

Source of Variation	df	L Coordinate Mean Squares	a Coordinate Mean Squares	b Coordinate Mean Squares
<u>Artificial Mozzarella</u>				
Storage Time	3	98.683*	0.332*	0.997*
Pouch Type	3	0.737	0.019	0.191
Interaction	9	0.402	0.020	0.075
Error	32	0.259	0.008	0.091
<u>Artificial Processed American</u>				
Storage Time	3	14.410*	1.653*	3.253*
Pouch Type	3	0.793	0.297	0.103
Interaction	9	0.428	0.043	0.098
Error	32	0.180	0.083	0.092

*denotes significant difference

Table 22. Analysis of Variance of HunterLab Color Coordinate Data for Cheeses Stored in Experimental Pouches - Surface Samples ($p \leq 0.01$)*

Source of Variation	df	L Coordinate Mean Squares	a Coordinate Mean Squares	b Coordinate Mean Squares
Storage Time	1	2.568*	0.271	0.175
Pouch Type	3	10.251*	40.437*	44.357*
Interaction	3	.340	0.326	0.202
Error	16	.273	0.540	0.414
Storage Time	--	--	Artificial Mozzarella --	--
Pouch Type	3	0.430	0.054	0.032
Interaction	--	--	--	--
Error	8	0.321	0.030	0.034
Storage Time	1	Artificial Processed American 2.160*	0.007	0.193
Pouch Type	3	0.165	0.062	0.890
Interaction	3	-.157	0.052	0.149
Error	16	0.163	0.058	0.359

*denotes significant difference

Table 22. (cont'd.)

Source of Variation	df	L Coordinate Mean Squares	<u>Rosano</u>	a Coordinate Mean Squares	b Coordinate Mean Squares
Storage Time	1	0.510		0.076	0.683
Pouch Type	3	1.622*		1.287*	25.480*
Interaction	3	0.073		0.120	0.843
Error	16	0.279		0.078	0.299
Storage Time	1	1.021	<u>Natural Mozzarella</u>	0.018	0.007
Pouch Type	3	0.657		0.224	0.244
Interaction	3	0.317		0.086	0.141
Error	16	0.435		0.099	0.141

*denotes significant difference

Table 23. Mean Color Coordinate Values and Tukey Separations for Artificial Mozzarella Cheese Stored in Experimental Pouches ($P \leq 0.01$)*

Pouch Type	0	4	Storage Time (wk)			25	35	SURFACE
			15	25	35			
			GROUND					
L Coordinate Values								
A	81.35	81.13a	84.83a	87.03a	86.57a	--		86.03a
B	81.35	80.93a	84.73a	86.82a	85.47a	--		86.48a
D	81.35	80.60a	85.52a	87.73a	86.35a	--		86.52a
E	81.35	81.10a	84.68a	87.22a	86.57a	--		85.73a
a Coordinate Values								
A	-1.50	-1.62a	01.20a	-1.32a	-1.18a	--		-0.34a
B	-1.50	-1.60a	01.13a	-1.27a	-1.47a	--		-0.48a
D	-1.50	-1.47a	-1.15a	-1.22a	-1.27a	--		-0.64a
E	-1.50	-1.48a	-1.12a	-1.20a	-1.38a	--		-0.64a
b Coordinate Values								
A	13.15	13.30a	12.53a	12.50a	12.73a	--		9.18a
B	13.15	12.87a	12.74a	12.35a	12.47a	--		9.37a
D	13.15	12.88a	12.50a	12.22a	12.60a	--		9.30a
E	13.15	12.82a	12.75a	12.03a	12.30a	--		9.42a
*like letters within columns denote no significant difference								

*like letters within columns denote no significant difference

Table 24. Mean Color Coordinate Values and Tukey Separations for Artificial Processed American Cheese Stored in Experimental Pouches ($p \leq 0.01$) *

Pouch Type	0	4	Storage Time (Wk)				25	SURFACE
			15	25	35	35		
			GROUND					
<u>L Coordinate Values</u>								
A	75.75	74.30a	76.13a	76.57a	76.55a	73.63a	74.38a	
B	75.75	74.23a	75.78a	76.16a	76.45ab	73.83a	74.32a	
D	75.75	74.33a	75.40a	76.68a	76.65a	73.87a	74.85a	
E	75.75	73.42a	75.77a	76.62a	75.37b	74.07a	74.35a	
<u>a Coordinate Values</u>								
A	10.45	10.33a	9.83a	9.88a	9.70a	10.53a	10.42a	
B	10.45	10.75a	10.00a	10.17a	9.83a	10.20a	10.37a	
D	10.45	10.62a	10.18a	10.13a	9.83a	10.37a	10.12a	
E	10.45	11.00a	10.07a	10.37a	9.82a	10.30a	10.37a	
<u>b Coordinate Values</u>								
A	27.50	25.97a	25.72a	25.22a	24.87a	22.48a	22.72a	
B	27.50	25.86a	25.30a	25.76a	24.87a	22.43a	22.58a	
D	27.50	25.97a	25.30a	25.38a	24.62a	22.23a	21.63a	
E	27.50	26.42a	25.38a	25.55a	24.78a	22.83a	22.65a	

*Like letters within columns denote no significant difference

Color coordinate values for artificial Processed American samples did not significantly differ as a result of the packaging material utilized. Statistically significant differences between storage times were evident in the L , a_L , and b_L coordinates for the ground samples, but only in the L coordinate of the surface samples. Examination of Table 24 indicates rising L values throughout storage in the ground samples and from 25 - 35 wk in the surface samples. Additionally, a_L and b_L coordinate figures decreased as storage time increased for the ground samples. The same trend is evident in the artificial Mozzarella portions and may be a result of crystal formation.

Surface color values for the Rosano and natural Cheddar cheese samples reveal interesting results. As indicated earlier, color fading was visually evident on these two cheeses after approximately 22 wk of storage. This color fading is characterized by lower L coordinate values and decreased a_L and b_L values. The largest color fading occurred for samples of natural Cheddar packaged in film B. Samples in film E showed similar changes in color coordinate values, but only the b_L coordinate was confirmed statistically (Table 25).

Natural Cheddar samples packaged in materials A and D did not appear to change color throughout storage. Surface color for these samples compared favorably with Cheddar cheeses from other batches and did not differ markedly from sample interiors.

Rosano samples packaged in material B had low a_L and b_L coordinate values after 25 and 35 wk in storage. Once again, only the b_L values were significantly lower for Rosano samples packaged in pouch E.

We cannot presently explain the lack of change in L coordinate values for Rosano samples which were visibly faded when packaged in pouch B, nor the peculiar lack of change in the L and a_L coordinate values for natural Cheddar and Rosano samples packaged in material E. The higher oxygen permeabilities of films B and E (Table 14) suggests that the fading phenomenon is a result of oxidation of annatto dye. The oxygen requirements for oxidation are not as great as those needed for the development of mold (Whitehead, 1958). As such, lack of surface mold on the color faded surfaces of samples packaged in films B and E is not surprising. Riddet, Whitehead, Robertson, and Harkness (1961) reported a tallowy flavor associated with discoloration in ripening hoops of Cheddar cheese. The incidence of tallowy and oxidative flavor defects in the samples will be discussed in the next section.

Light exposure appears to hasten color fading. Greater bleaching was visually evident on samples closer to the light source. The large amount of fading in natural Cheddar samples may be due to their close proximity to the light. Lack of fading in the artificial Processed American samples may be due to the fluid exudate lining the inside of the packaging films. Its presence may have stopped oxygen contact with the cheese portions and thus inhibited bleaching.

Table 25. Mean Color Coordinate Values and Tukey Separations for Natural Cheddar, Rosano, and Natural Mozzarella Cheeses Stored in Experimental Pouches ($p \leq 0.01$) -- Surface Readings*

Pouch Type	0	Storage Time (Wk)			0	25	35	0	25	35
		NATURAL	CHEDDAR	ROSANO						
L Coordinate Values										
A	66.80	71.07a	71.30a	78.95	80.03a	79.67a	83.85	80.43a	79.73a	
B	66.80	73.30b	74.47b	78.95	80.85a	80.70a	83.85	79.72a	79.97a	
D	66.80	70.67a	71.62a	78.95	81.02a	80.45a	83.85	79.55a	79.10a	
E	66.80	71.43a	71.70a	78.45	79.91	79.82a	83.85	80.32a	79.57a	
A	14.15	15.72a	15.93a	<u>a_LCoordinate Values</u>			-2.80	-0.75a	-0.92a	
B	14.15	10.73b	10.55b	3.10	3.82b	3.32b	-2.80	-0.97a	-1.27a	
D	14.15	16.43a	16.38a	3.10	4.22a	4.25a	-2.80	-0.57a	-0.60a	
E	14.15	13.57a	14.43a	3.10	4.57a	4.43a	-2.80	-1.10a	-1.15a	
<u>b_LCoordinate Values</u>										
A	--	30.87a	30.65ac	29.20	26.30a	26.30a	23.60	25.60a	25.33a	
B	--	25.47b	24.97b	29.20	22.30b	21.15b	23.60	25.07a	25.47b	
D	--	31.33a	31.02a	29.20	26.22a	25.48a	23.60	25.18a	25.15a	
E	--	28.62c	28.97c	29.20	24.53c	25.07c	23.60	25.10a	24.87a	

*0 time from ground sample

Sensory Analysis

Sensory data collected during this study is statistically analyzed in Tables 26, 32, and 33. To observe the trends, the data is also graphically presented in Figures 35 through 39. In addition, sensory criticisms made by the judges have been tabulated and are presented on Tables 27 to 31.

Flavor and body scores for artificial Mozzarella, artificial Processed American, Rosano, and natural Mozzarella changed during storage regardless of the packaging material utilized (Table 26). Only the flavor scores differed significantly between storage times in the natural Cheddar cheese samples. The differences are related to inherent characteristics of the individual cheese varieties and their examination is not the major thrust of this research project. However, a short description of the sensory trends for each cheese variety will be discussed. Tukey separations were not calculated between the mean values of samples with different storage times, but major trends can be ascertained by examination of Figures 35 through 39.

For Rosano cheese samples, the most obvious feature is the decreasing flavor scores throughout storage (Figure 35). After 35 wk of storage, flavor defects of unnatural and bitter type were unanimously cited for all cheese samples, regardless of packaging material (Table 27). The body scores also dropped after high scores at the 4-wk testing period. Pasty body was cited as the predominant body

Table 26. Analysis of Variance of Flavor and Texture Scores
for Cheeses Stored in Experimental Pouches ($p \leq 0.01$)

Source of Variation	df	Flavor Mean Squares	Body Mean Squares
<u>Natural Cheddar</u>			
Storage Time	3	2.213*	0.204
Pouches	3	1.193*	0.041
Interaction	9	0.444	0.105
Error	32	0.216	0.159
<u>Artificial Mozzarella</u>			
Storage Time	3	1.130*	2.373*
Pouches	3	0.249	0.006
Interaction	9	0.351*	0.070*
Error	32	0.114	0.018
<u>Artificial Processed American</u>			
Storage Time	3	2.167*	1.590*
Pouches	3	0.144	0.110
Interaction	9	0.128	0.067
Error	32	0.069	0.042
<u>Rosano</u>			
Storage Time	3	11.900*	1.890*
Pouches	3	0.913*	0.337*
Interaction	9	0.452*	0.204*
Error	32	0.076	0.058
<u>Natural Mozzarella</u>			
Storage Time	3	10.907*	3.893*
Pouches	3	0.012	0.099
Interaction	9	0.100	0.100*
Error	32	0.345	0.029

*denotes significant difference

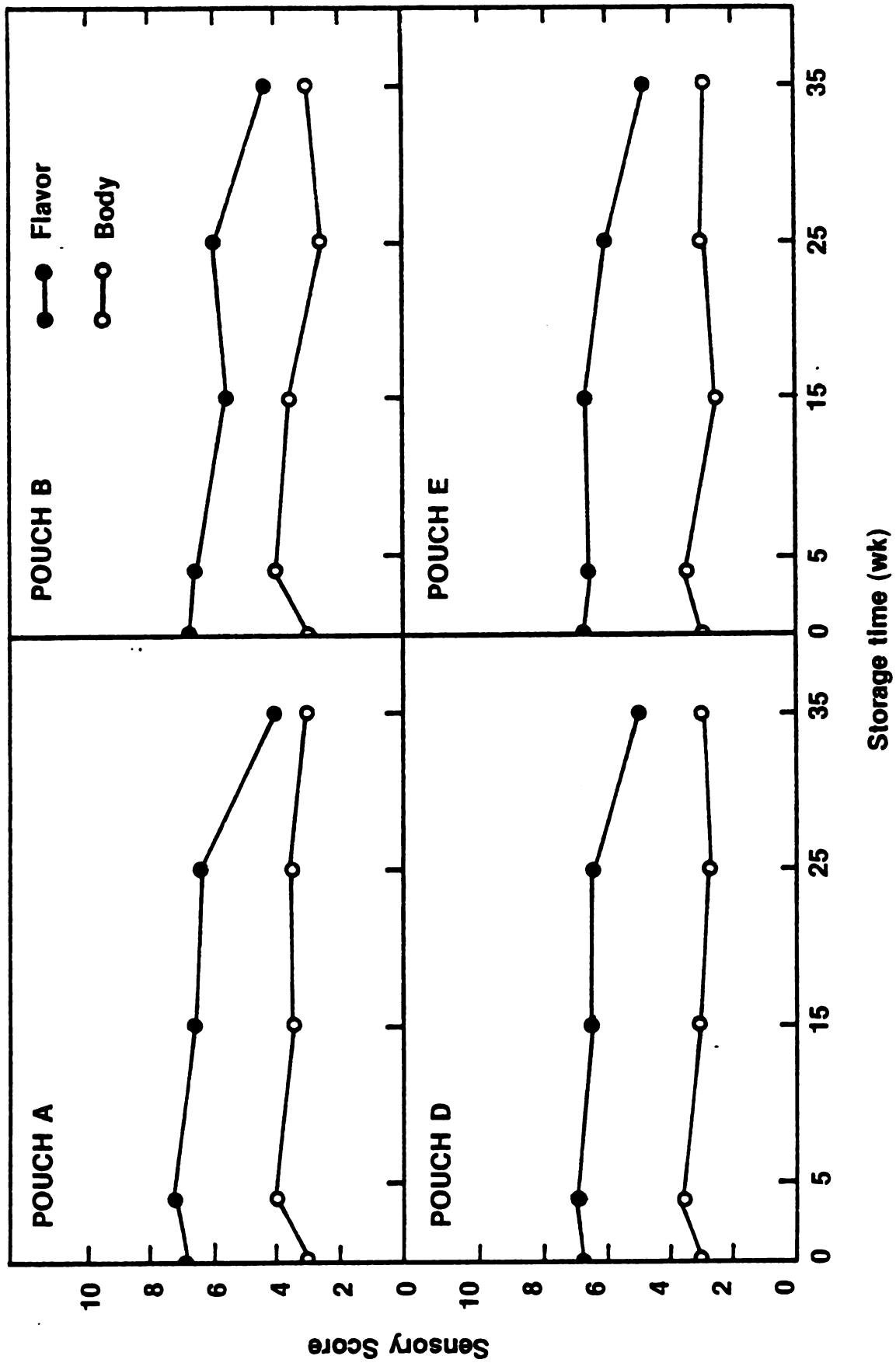


Figure 35. Flavor and Body Scores for Rosano Cheese Stored in Experimental Pouches (Mean Values).

Table 27. Sensory Criticisms for Rosano Cheese Stored in Experimental Pouches as
% of Total Possible Comments for Each Defect*

		Storage Time (Wk)									
		4					15				

	Storage Time (Wk)							
	25				35			
	<u>Pouch Type</u>							
	A	B	D	E	A	B	D	E
<u>Flavor Comments</u>								
Unnatural Foreign	33	33	33	67	100	100	100	100
Oily								
Unclean Fruity	33	44	11	44				
Bitter	11				100	100	100	100
Flat	67	67	67	67				
Moldy								
Heated								
<u>Body Comments</u>								
Mealy		22						
Pasty		11	33		100	100	100	100
Corky	22	33	22	67				
Curdy				22				
Gassy								
Open								
Short								
Weak	89	100	100	67				
Crumbly								
Decolorized		22						

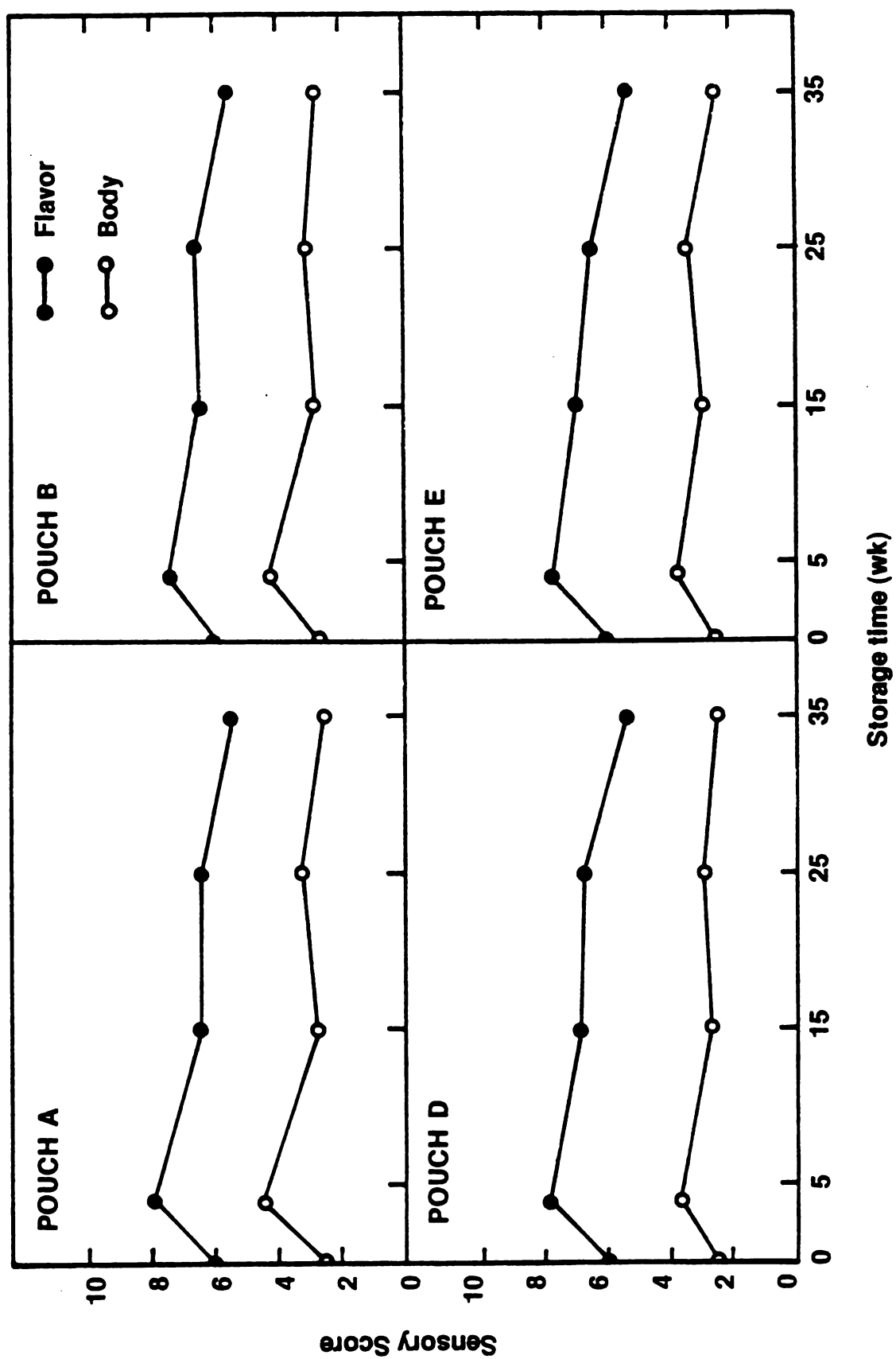


Figure 36. Flavor and Body Scores for Natural Mozzarella Cheese Stored in Experimental Pouches (Mean Values).

Table 28. Sensory Criticisms for Natural Mozzarella Cheese Stored in Experimental Pouches as % of Total Possible Comments for Each Defect*

	Storage Time (Wk)											
	0					4					15	
	Pouch Type											
Flavor Comments	A	B	C	D	E	A	B	D	E			
Rancid												
Flat	11	67	56	33	56	67	67	33	33			
Fruity							22		22			
Unclean							22		22			
Bitter												
Unnatural	11											
Moldy			11									
Heated		22	11	22		33	33	67	67			
Lacks Flavor		33	33	33	33							
Whey Taint									11			
Acid								22				
Nutty												
Foreign												
Body Comments												
Mealy												
Weak				22	22		11	22				
Rubbery												
Corky	11	33	33	33	33	33	22	11	22			
Curdy	11	33	33	44	33	67	67	67	67			
Gassy			22	11	11							
Short												
Soft						33	33	33	33			

* Three replications x three judges = nine total comments

Table 28. (cont'd.)

	Storage Time (Wk)				
	25			35	
	<u>Pouch Type</u>				
	A	B	D	E	
<u>Flavor Comments</u>					
Rancid					
Flat	33	33	67	67	11
Fruity	33	33	33		56
Unclean	11				22
Bitter					11
Unnatural					11
Moldy					
Heated					
Lacks Flavor					
Whey Taint					
Acid					
Nutty	33	33	33	33	
Foreign	33	33			

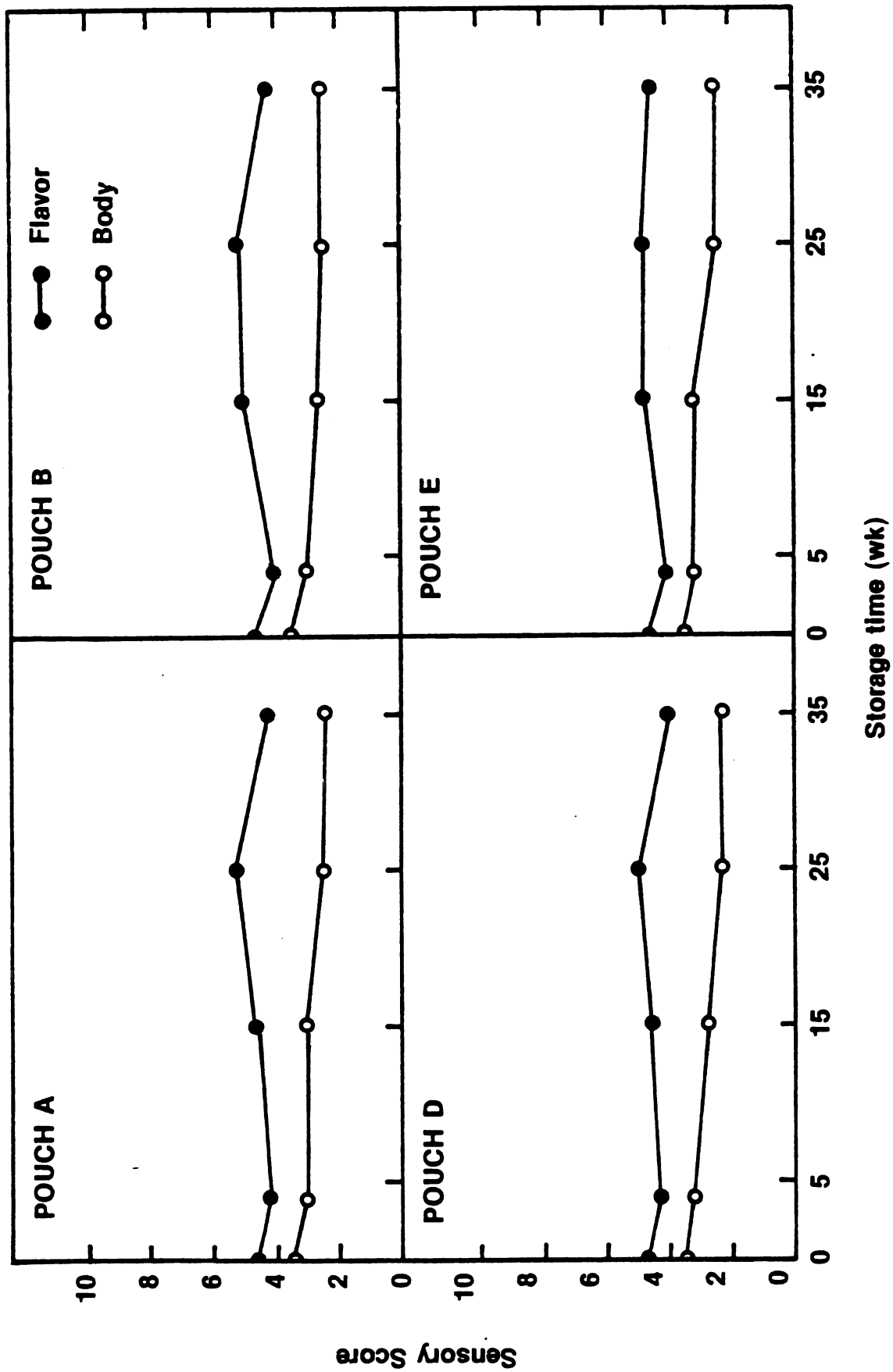


Figure 37. Flavor and Body Scores for Artificial Processed American Cheese Stored in Experimental Pouches (Mean Values).

Table 29. Sensory Criticisms for Artificial Processed American Cheese Stored in Experimental Pouches as % of Total Possible Comments for Each Defect*

	Storage Time (Wk)														
	0					4					15				
Flavor Comments															
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Rancid															
Unnatural	11	33	33	33	33						67	67	67	67	67
Foreign	11	33	33	33	33										
Putrid Odor															
Bitter															11
Acid															
Flat												33		11	
Unclean	11						11					33			22
Fruity	11											22			
Heated															
Body Comments															
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Corky	11								22	33		11		22	
Crumbly											11				
Mealy		67	56	33	33				33	33	67	67	67	67	67
Curdy		33	33	33	33				33	33	22	11	11	33	33
Weak	11	22									67	67	67	67	67
Pasty															
Short											22	22	11		
Oily Surface															
Gassy	11														
Open												11			11

*Three replications x three judges = nine total comments

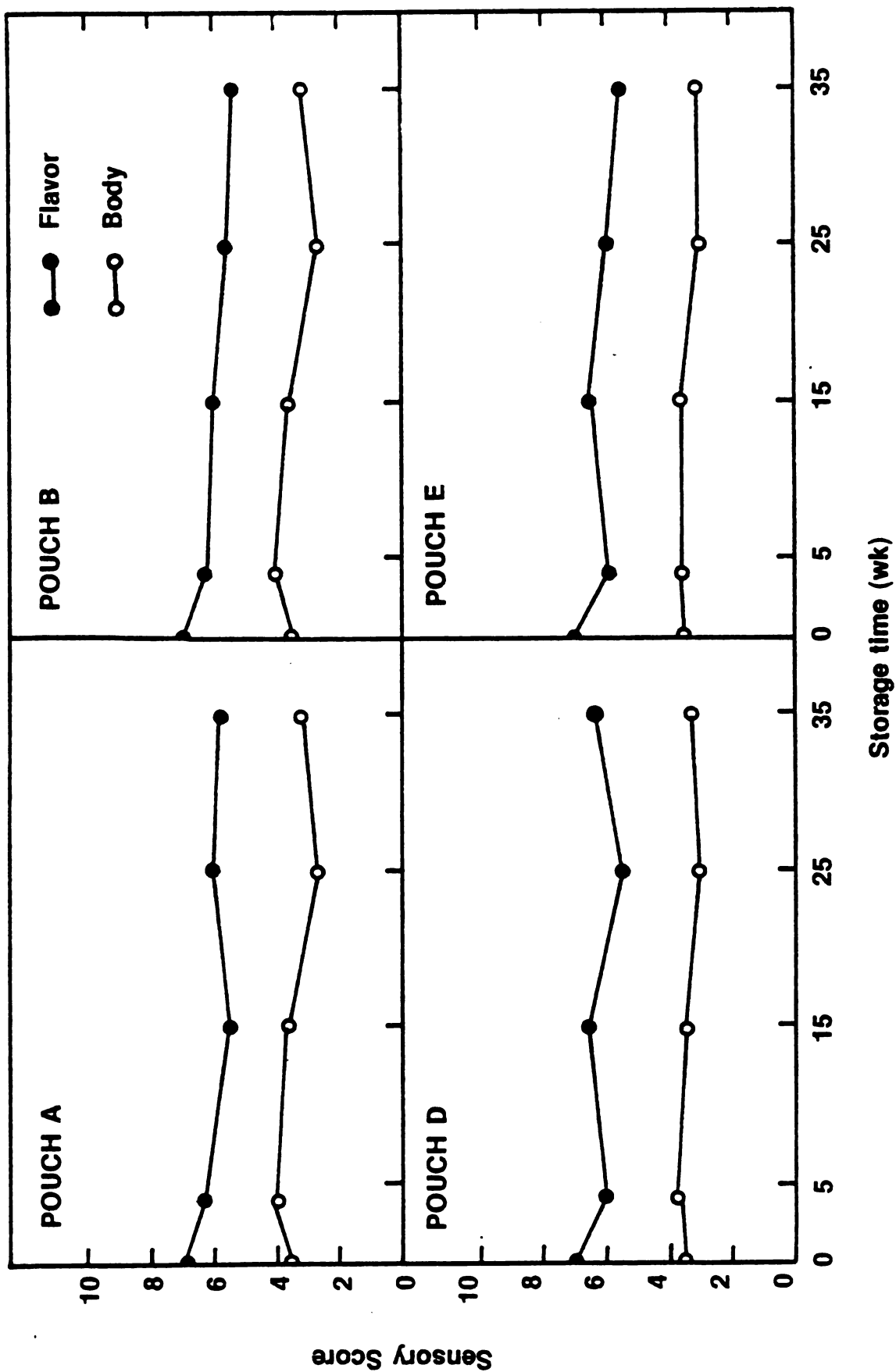


Figure 38. Flavor and Body Scores for Artificial Mozzarella Cheese Stored in Experimental Pouches (Mean Values).

Table 30. Sensory Criticisms for Artificial Mozzarella Cheese Stored in Experimental Pouches as % of Total Possible Comments for Each Defect*

		Storage Time (Wk)									
		4				15					
		A		B		C		D		E	
Flavor Comments		A		B		C		D		E	
Unnatural		33	33	33	33	33	33	67	67	67	67
Foreign	22	22	22	22	11						
Flat						33	33		11		33
Fruity								33	33	33	33
Unclean		11						33	33	22	
Bitter				11	22	11		11			
Sulfide											
Body Comments		A		B		C		D		E	
Corky	11	33	11					22	22	33	22
Crumbly	11				33	11				11	
Short			22						33	33	33
Weak		33	33	33	33	56	56		44	33	33
Pasty									44	33	
Mealy											
Curdy	11										

*Three replications x three judges = nine total comments

Table 30. (cont'd.)

		<u>Storage Time (Wk)</u>									
		25					35				
		<u>Pouch Type</u>									
	<u>Flavor Comments</u>	A	B	D	E	A	B	D	E		
	Unnatural	67	67	67	67	67	67	67	67	67	
	Foreign										
	Flat		33	33	33			22	33	33	
	Fruity	33	33	33	33						
	Unclean	33	33	33	33		11				
	Bitter					67	44	33	33	33	
	Sulfide	33	33	33	33						
	<u>Body Comments</u>										
	Corky	33	33	33	33	33	33	33	33	33	
	Crumbly	33	33	33	33						
	Short	67	67	33	33	33	33	33	33	33	
	Weak					33	33	33	33	11	
	Pasty										
	Mealy	33	33	67	33	33	33	33	33	33	
	Curdy	33	33			33	33	33	33	33	

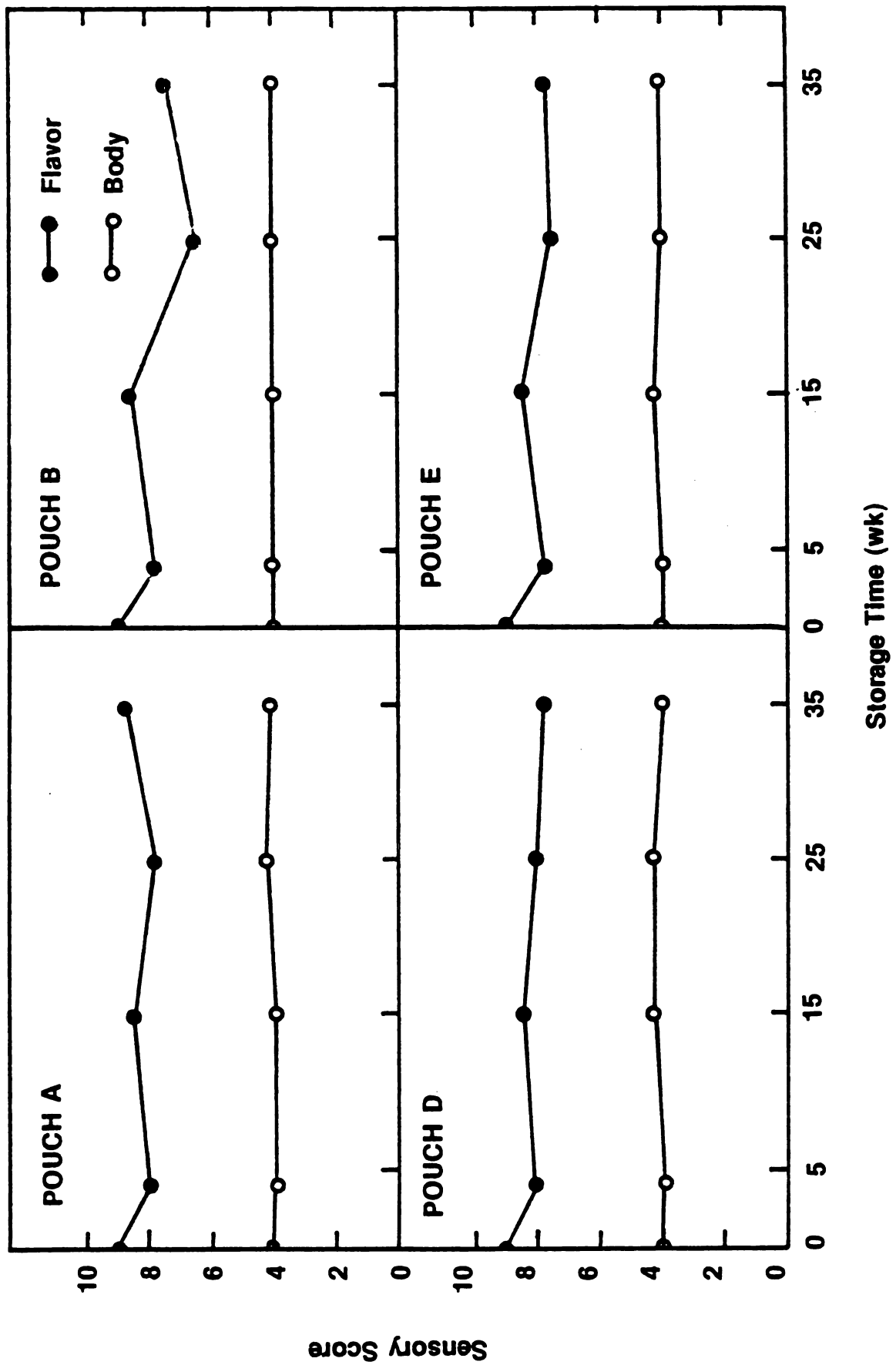


Figure 39, Flavor and Body Scores for Natural Cheddar Cheese Stored in Experimental Pouches (Mean Values).

defect at 35 wk of storage. The apparent rise in body scores immediately after packaging cannot be analyzed statistically as previously indicated. However, it may indicate a gradual improvement in the body and texture of Rosano before the onset of deterioration.

Length of storage also significantly lowered the flavor and body scores of natural Mozzarella samples regardless of the packaging treatment (Table 26). Figure 36 indicates large decreases in both flavor and body scores from 4 until 35 wk of storage regardless of packaging treatment. The initial rise in quality after packaging and until 4 wk probably reflects desirable flavor and body development as a result of cheese ripening. Rancid, fruity, and unclean flavor defects increased or developed at 35 wk of storage (Table 28). Body defects which increased in the latter part of storage include: mealy, weak, rubbery, and gassy.

Both flavor and body scores changed significantly during storage in artificial Processed American portions regardless of the packaging material utilized. Flavor scores improved from 4 until approximately 25 wk of storage and then dropped (Figure 37). Predominant flavor defects which increased after 25 wk of storage were bitter, fruity, putrid, and heated (Table 29). Body scores also decreased throughout storage but without any initial rise. Mealy, weak, short, and oily surface were commonly cited defects which either developed or increased after 35 wk of storage.

Table 32. Mean Flavor Scores and Tukey Separations for
Cheeses Stored in Experimental Pouches ($p \leq 0.01$) *

Pouch Type	0	4	<u>Storage Time (Wk)</u>		35
			15	25	
<u>Natural Cheddar</u>					
A	9.00	8.11a	8.56a	7.78ab	8.78a
B	9.00	7.72a	8.59a	6.76b	7.34b
D	9.00	8.00a	8.56a	8.11a	7.72b
E	9.00	7.67a	8.55a	7.56ab	7.72b
<u>Artificial Mozzarella</u>					
A	6.83	6.33a	5.56a	6.00a	5.78ab
B	6.83	6.33a	5.55a	6.11a	5.33a
D	6.83	5.75a	5.56a	6.67a	6.23b
E	6.83	6.25a	6.11a	6.56a	5.67ab
<u>Rosano</u>					
A	6.75	7.33a	6.67a	6.44a	4.00a
B	6.75	6.56b	5.67b	6.00a	4.33ab
D	6.75	7.00ab	6.50a	6.33a	5.00b
E	6.75	6.61ab	6.67a	6.00a	4.83ab

*like letters within columns denote no significant difference

Well-defined trends in sensory scores as a function of storage time were not present for the artificial Mozzarella and natural Cheddar cheese samples (Figures 38 and 39 , respectively). The difference indicated by analysis of variance may only represent non-uniform judging from one test period to the next.

Statistically different flavor scores between package treatments are evident in natural Cheddar, artificial Mozzarella, and Rosano cheeses (Table 26). Both the artificial Processed American and natural Mozzarella cheese varieties do not show any differences in flavor scores which could be attributed to the packaging films utilized.

The graphic illustrations in the Figures do not clearly define sensory differences between cheese samples packaged in the various packaging materials. However, Tukey separations were calculated to elucidate the sensory differences between treatments. Data presented in Table 32 for natural Cheddar cheese samples packaged in different materials shows significantly lower flavor scores for portions packaged in film B tested at the 25-wk storage period, with an average flavor score of 6.67. These samples were criticized as rancid, oxidized, and decolorized (Table 31). Cheeses packaged in pouch E were also criticized as oxidized and rancid but with less frequency than B packed cheese portions. After 35 wk of storage, higher scores were evident for cheeses packaged in film A. Flavor scores for natural Cheddar samples packed in B films improved slightly from those tested at 25 wk and were not significantly lower

than cheese packaged in films D and E. However, treatments B and E did exhibit the lowest flavor values and were still criticized as oxidized and rancid.

Significant separations between Rosano flavor scores are evident in samples at the 4-, 15-, and 35-wk testing period (Table 32). Samples packaged in film B had consistently low flavor scores after 4 and 15 wk of storage. They also displayed low ranking at 25 wk of storage, although statistically significant differences were not indicated. At 25 wk, 22% of the B packaged samples were criticized for color fading (Table 27). Tukey separations between mean values for portions packaged in film E for 4 wk do not indicate any statistically significant differences from portions packaged in the high ranking A and D pouches although lower scores are evident.

The quality of Rosano cheese had deteriorated greatly by 35 wk of storage making accurate judging difficult. We felt that significant separations at this time were a result of judging error and do not reflect effects of the packaging treatments.

An interaction effect between storage time and packaging film was also indicated by analysis of variance for artificial Mozzarella samples. At the 35-wk testing period, samples in film B were ranked last and had significantly lower scores relative to D packaged portions (high ranking).

Consistently low scores for natural Cheddar, Rosano, and artificial Mozzarella cheese portions packaged in film

B were probably a result of fat oxidation since oxygen barrier properties are lower for this material relative to films A and D (Table 14).

Incidence of oxidation coincides with color fading in the Rosano and natural Cheddar cheeses. This corroborates studies by Riddet, Whitehead, Robertson and Harkness (1961), who observed tallowy discoloration with increased atmospheric contact. Lower flavor scores for Rosano samples packaged in film B appeared after only 4 wk of storage. This may reflect increased sensitivity of the polyunsaturated corn oil to oxidation.

Flavor problems associated with cheese samples packaged in pouch E were not as evident. As shown in Table 14, at high relative humidity and after cheese contact, oxygen barrier properties for film E are less than those calculated for the B material. With lower barrier characteristics, more pronounced effects would be anticipated. Lack of more conclusive sensory data could result from a number of contributing factors. Light was not strictly controlled throughout storage. The significant influence of light on the development of off flavors in cheese was discussed earlier in reference to studies conducted by Kristoffersen, Stussi, and Gould (1975). Samples were placed on shelves of variable height and uncontrolled distance from the light source. The lower shelves were also shaded in part by other samples positioned above them. The catalytic effects of light on initiation and propagation of oxidative

deterioration could have greatly influenced the results obtained. In addition, light absorbance characteristics of the experimental package materials was not assessed. Material E may have had greater light-absorbing capacity. Sampling methods may also have confused the results. Personal evaluation of decolorized cheese surfaces by the author clearly indicated tallowy flavors. The samples presented to the judges were not cut to isolate outer surfaces of the retail portion. The most intense flavor defects would be concentrated in these outer portions and be highly diluted in thick cuts.

The synthetic nature of the filled cheese and Mozzarella analog may have masked off flavors resulting from oxidative deterioration. It is important to remember that the judges were not highly experienced in judging synthetic and filled cheeses. Finally, oxygen barrier characteristics for the films were not assessed in relationship to the conditions of storage. Material ranking in terms of oxygen barrier may change under the conditions utilized in this study.

The absence of oxidative defects on the natural Mozzarella samples may reflect a lower partial pressure of oxygen in the package headspace due to the evolution of gas observed in this cheese variety.

Oxygen contact with the artificial Processed American cheese samples may have been prevented by the fluid lining the inner films. As indicated earlier, this is also postulated to be responsible for the lack of visual mold

Table 33. Mean Body Scores and Tukey Separations for Cheeses Stored in Experimental Pouches ($P \leq 0.01$)

Pouch Type	0	Storage Time (Wk)			35
		4	15	25	
<u>Artificial Mozzarella</u>					
A	3.50	3.83ab	3.67a	2.67a	3.33a
B	3.50	4.08a	3.67a	2.67a	3.22a
D	3.50	3.83ab	3.56a	3.00a	3.33a
E	3.50	3.67b	3.67a	3.00a	3.33a
<u>Rosano</u>					
A	3.00	3.94ab	3.33a	3.44a	3.00a
B	3.00	4.00b	3.50a	2.67b	3.00a
D	3.00	3.78a	3.17a	2.78bc	3.00a
E	3.00	3.56a	2.58a	3.00c	3.00a
<u>Natural Mozzarella</u>					
A	2.50	4.33a	2.89a	3.33a	2.56a
B	2.50	3.72b	2.78a	3.22a	2.78a
D	2.50	3.89ab	2.89a	3.11a	2.50a
E	2.50	3.78b	3.00a	3.44a	2.61a

*like letters within columns denote no significant difference

and color change on the samples.

Statistically different body scores developed in artificial Mozzarella, Rosano, and natural Mozzarella samples. Both interaction and package treatments were indicated as the cause of variation (Table 26). Tukey separations for the mean body scores of the cheeses are presented in Table 33. The significant differences exhibited for the three cheese varieties do not fit any predictable trends or patterns which can be related to characteristics of the individual packaging materials. We postulate that the differences are a result of judging error, incomplete sample randomization at the time of packaging, or non-normality of textural characteristics within the initial populations of cheese.

TBA Values

Fat oxidation was measured chemically using the TBA test. TBA values are expressed as optical density or absorbancy. Higher values indicate increased oxidation. Samples from cheese surfaces were tested after 35 wk of storage. One-way analysis of variance of the TBA data is presented in Table 34. Mean TBA values and Tukey separations are presented in Table 35.

Only the natural Cheddar cheese samples showed significant differences in absorbance as a result of pouch treatment. Examination of Table 35 shows significantly higher absorbance for natural Cheddar samples packaged in material B. Mean absorbance values for artificial

Table 34. Analysis of Variance of TBA Data for Cheeses Stored in Experimental Pouches ($p \leq 0.01$) *

Source of Variation	df	Mean Squares
<u>Natural Cheddar</u>		
Pouches	3	0.001034*
Error	8	0.000011
<u>Artificial Mozzarella</u>		
Pouches	3	0.000229
Error	8	0.000097
<u>Artificial Processed American</u>		
Pouches	3	0.000016
Error	8	0.000023
<u>Rosano</u>		
Pouches	3	0.000060
Error	8	0.000022
<u>Natural Mozzarella</u>		
Pouches	3	0.000145
Error	8	0.000107

*Denotes significant difference

Table 35. Mean TBA Values and Tukey Separations for Cheeses Stored in Experimental Pouches ($P \leq 0.01$)*

Pouch Type	Storage Time (Wk)	
	0	35
<u>Natural Cheddar</u>		
A	0.0655	0.0606a
B	0.0655	0.0957b
D	0.0655	0.0576a
E	0.0655	0.0578a
<u>Artificial Mozzarella</u>		
A	0.0650	0.0918a
B	0.0650	0.0860a
D	0.0650	0.0753a
E	0.0650	0.0735a
<u>Artificial Processed American</u>		
A	0.0612	0.0527a
B	0.0612	0.0550a
D	0.0612	0.0531a
E	0.0612	0.0578a
<u>Rosano</u>		
A	0.0668	0.0617a
B	0.0668	0.0642a
D	0.0668	0.0539a
E	0.0668	0.0581a

*Similar letters within columns denote no significant difference.

Table 35. (cont'd.)

Pouch Type	<u>Storage Time (Wk)</u>	
	0	35
	<u>Natural Mozzarella</u>	
A	0.0680	0.0770a
B	0.0680	0.0830a
D	0.0680	0.0682a
E	0.0680	0.0828a

*Similar letters within columns denote no significant difference.

Mozzarella, Rosano, and natural Mozzarella samples are not significantly different between pouch treatments.

The data from the TBA analysis corroborates in part the information derived from the color and sensory evaluations with higher absorbance associated with decolorization and lower flavor scores for natural Cheddar cheese samples packaged in the B film. Oxidative deterioration of the natural Cheddar samples packaged in film E as evidenced by decolorization and occasionally low flavor scores was not confirmed by the TBA test. Also, previously discussed evidence of oxidation in the artificial Mozzarella and Rosano samples packaged in film B was not confirmed by the TBA data.

SUMMARY AND CONCLUSIONS

Natural Cheddar, artificial Mozzarella, natural Mozzarella, artificial Processed American, and Rosano "filled" varieties of cheese were vacuum packaged in biaxially oriented polypropylene/PVDC coating/polyethylene extrusion/EVA extrusion (A), polyester/EVA/polyethylene (B), low density polyethylene (2.5 mil) (C), biaxially oriented polyamide/PVDC coating/polyethylene extrusion/EVA extrusion (D), and polyamide polyolefin (E). Physical and chemical changes occurring in the cheese samples and packaging films were measured at intervals through 35 wk of storage at 4 C by personnel at the Department of Food Science and School of Packaging, respectively.

Weight Loss

No significant weight losses were observed throughout storage for samples packaged in the experimental pouches. This suggests that the water vapor barriers for all package treatments were adequately preventing cheese dehydration. Of the five materials utilized, film E was shown to have the lowest barrier at storage conditions (4 C) with a water vapor transmission rate of $0.025\text{g}/100\text{ in}^2/24\text{ hr}$ (Table 18). The evidence suggests that permeation rates could be increased beyond this without significant loss of water from the cheese. However, the minimum barrier requirements for

preventing cheese dehydration cannot be assessed from the available data.

Shear Compression Force

Changes in shear compression force were not associated with the use of different packaging films. Significant differences which occurred are attributed to intrinsic ripening effects within the cheese varieties causing textural changes throughout storage.

Mold Development

Package treatments did influence the extent of mold development on cheese samples. The development of mold was believed to be related to the presence of oxygen beneath the packaging film. Variables which affected the presence of oxygen were:

1. Barrier properties of the films
2. Incidence of flex-crack or pinholing
3. Extent of air entrapment
4. Gas production by the cheese
5. Wrinkles at the seal area

Only samples packaged in film C showed visual mold on the flat cheese portions dissociated from package seals, creases, and irregular areas on the sample surface. This suggests that oxygen for mold growth diffused through the material and was not entrapped during packaging. The oxygen permeation rate of material C was found to be 297cc/100 in²/

24 hr at 23 C in 100% RH (Table 14). This greatly exceeds the $lcc/100 \text{ in}^2/24 \text{ hr}$ maximum recommended by Pearson and Scott (1978) for cheese packaging materials. Barrier properties for all other materials are considered adequate for control of mold growth.

Visual mold associated with package creases was extensive on cheese samples packaged in material B. Natural Cheddar and artificial Mozzarella cheese varieties were the most contaminated with 100% of the samples affected by 8 wk of storage. All natural Mozzarella and Rosano cheese samples were contaminated after 12 and 16 wk of storage, respectively. The cause of mold is attributed to increased oxygen permeation at flex-cracked areas found to be present at stress points on the B material.

Most of the mold development on natural Cheddar and artificial Mozzarella cheese samples packaged in pouches A, D, and E was either crease related (natural Cheddar and artificial Mozzarella) or associated with irregular hills and valleys on the cheese surfaces (artificial Mozzarella). Mold associated with irregular surfaces was also evident on artificial Mozzarella samples packaged in film B. In general, contamination was more plentiful on the artificial Mozzarella samples and developed after approximately 8 to 12 wk of storage. The presence of mold on the natural Cheddar cheese was first observed after approximately 16 wk of storage. We speculate that gas entrapment during packaging was the major source of oxygen causing mold development in these areas. Only minimal mold growth was evident on

samples packaged in film D. The superior flexural characteristics of this material may have improved contact between the cheese body and the material, thus reducing the incidence of oxygen entrapment. Natural Mozzarella and Rosano samples showed only minimal amounts of crease related mold in film E after approximately 12 wk of storage and none at all in film A. Absence of mold in the natural Mozzarella cheese is hypothetically due to extensive gas evolution from the product which reduced the partial pressure of oxygen beneath the packaging film. Limited visual mold observed on Rosano portions may be a result of the extreme softness of the cheese, with product filling package creases and wrinkles.

Visual mold at the seal area seems to be related to the presence of wrinkles. Prevention of wrinkles in the seal during packaging requires that the material lie flat across the impulse bar and be free from crimping. This was a greater problem with more inflexible materials (A, B, and E).

No visual mold was observed on any of the artificial Processed American cheese samples throughout the entire 35-wk storage period. We speculate that fluid exudate lining the inner pouch material prevented oxygen contact with the cheese, thereby inhibiting mold development. The exudate was first observed after approximately 15 wk of storage.

Of the five cheese varieties used in the study, the artificial Mozzarella was the most contaminated with visual mold. This may be a result of decreased reducing power.

However, redox potentials were not measured, and the effect of this variable is unknown. The predominance of contamination on the artificial Mozzarella cheese samples contradicts published claims of its superior mold resistance. We believe that the method of packaging is responsible for the disparity. Hot pouring of cheese directly into packaging materials may minimize mold development by eliminating post-manufacture contamination. The use of sorbates may also be a factor contributing to improved shelf stability of artificial cheeses.

Color Evaluation

Color was evaluated by visual examination and using a Hunterlab meter. Surface bleaching was first observed on natural Cheddar and Rosano cheeses packaged in materials B and E after 22 wk of storage. This was confirmed at the 25-wk testing period with objective data from the Hunterlab. The fading was most intense on the natural Cheddar samples packaged in film B. Experimental pouches A and D successfully retarded any bleaching throughout the storage period. Decolorization is attributed to the increased oxidation permeabilities of films B and E (Table 14) resulting in oxidation of annatto dye. Oxidation permeabilities for B and E films at 23 C and 100% RH were found to be 5.160 and 6.270 cc/100 in²/24 hr, respectively. The values changed slightly after cheese contact, but the ranking did not. Greater color fading associated with B films and natural Cheddar samples cannot be explained but may reflect the influence of

light on oxidative deterioration. The quantity of light exposure subjected to the samples was uncontrolled. Also, the light absorbance properties of the different films were not assessed, and the effects of these variables remain unknown. Also, barrier properties at the condition of storage (4 C) were not ascertained.

Sensory Evaluation

Body and flavor scores for many of the cheese samples changed significantly throughout storage regardless of packaging treatment.

Natural Cheddar samples packaged in film B were given significantly lower flavor scores relative to the highest ranking treatment at the 25-wk testing period. Film B and film E packaged natural Cheddar samples were also criticized as oxidized and rancid at the 25- and 35-wk testing period. Similar results for Rosano cheese were observed with lower flavor scores given B package samples at the 4-, 15-, and 25-wk testing periods. Artificial Mozzarella samples packaged in film B were given significantly lower flavor scores at the 35-wk testing period relative to the highest scoring treatment.

We speculate that the flavor defects resulted from fat oxidation occurring at the cheese surfaces and were associated with decolorized areas on the natural Cheddar and Rosano cheeses. Lack of more conclusive evidence of flavor defects in E packaged samples may be explained in part by the sources of error previously discussed in the color evaluation section

of this Summary. In addition, samples for sensory testing were not cut to isolate cheese surfaces where the greatest sensory defects would be anticipated. Lack of sensory defects resulting from pouch treatment in natural Mozzarella cheese is attributed to the gas evolution of the product. Inhibition of oxygen contact with the artificial Processed American cheese due to the presence of a fluid exudate is believed to be responsible for lack of pouch-related sensory defects.

TBA Values

TBA values, defined as optical density or absorbency, were significantly higher for natural Cheddar samples packaged in material B. Higher absorbency indicates greater oxidation, thereby corroborating, in part, information obtained from the color and sensory evaluations.

Overview

The major quality problem occurring in the packaged cheeses during the earlier stages of storage was mold development. Mold resulting from oxygen diffusion through the films was easily controlled through the use of materials with only moderate oxygen barriers (B and E). Mold resulting from seal leaks, entrapped oxygen, and material flex-crack was far more extensive. The first two problems may be alleviated by the use of more flexible materials.

Oxidative deterioration occurred primarily as a result of oxygen permeating through materials. Films with

intermediate oxygen barriers (B and E) were not able to inhibit flavor defects and/or decolorization, both of which are postulated to be the result of oxidation.

Other important variables which influence cheese packaging requirements are the cheese variety and packaging method. Extensive gas evolution by cheese appears to reduce the concentration of oxygen beneath the film and thus inhibit mold development and oxidative defects. Barrier properties may be relaxed with these cheese varieties. Cheese with very soft and compressible texture may adhere more closely to the packaging film, with product filling package creases and wrinkles. We speculate that this reduces the incidence of oxygen entrapment. No conclusive evidence is presently available which indicates any major differences in the packaging requirements of natural, filled, and synthetic cheeses. Hot pouring of artificial cheese into package materials and/or the addition of sorbates may improve resistance of mold.

The packaging method employed for this study involved the use of a chamber evacuation device and hand-filled cheese pouches. Information resulting from and hypotheses promulgated as a result of this study may not be applicable when other cheese packaging systems are used (e.g. shrink film, gas flush, thermoform methods).

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