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THE USE OF FILMS AS SUITABLE PACKAGING MATERIALS FOR MINIMALLY PROCESSED FOODS — A REVIEW

by

Tom C.S. Yang

August 1994

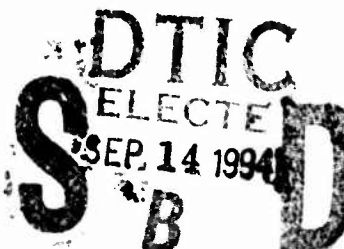
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Preface

The information in this report is based on an invited presentation at the International Symposium on the Properties of Water (ISOPW), Practicum II, Food Preservation by Moisture Control, June 19-24, 1994 at Universidad de las Americas - Puebla Cholula, Mexico.

I felt the material covered in this technical review would be beneficial to both military and the public for their packaging design for such an important food trend as minimally processed foods.

Citation of trade names in this paper does not constitute an official endorsement of the product.

THE USE OF FILMS AS SUITABLE PACKAGING MATERIALS FOR MINIMALLY PROCESSED FOODS - A REVIEW

1. INTRODUCTION

Minimally Processed Foods:

Commercially, there are many packaged fruits/vegetable salads, deli meats, entrees, and pre-cooked pastas that are not sterile yet receive only at most partial cooking or heating (e.g., microwaveable) by the consumers. These foods are usually perceived by the consumers as being fresher and closer to what would be prepared at home; consequently, they are tastier, healthier, and of higher quality. They are generally referred to as minimally processed foods, chilled foods, refrigerated foods, prepared foods, and/or convenience foods (ready-to-serve or fast foods), etc.

Since they are not sterile, Kraft General Foods (Harris, 1989) suggested a five-point safety program for chilled foods: (i) use proper and clean manufacturing practices; (ii) utilize monitored production procedures based on Hazard Analysis & Critical Control Points (HAACP) program; (iii) use Hurdle technology that applies formulation and/or packaging to control the growth of microorganisms, followed by extensive microbial testing; (iv) control distribution temperature by applying time-temperature indicators (i.e., a strip on the package that turns an irreversible color when the package has been exposed to a certain temperature) to protect against consumer and distribution abuse; design packaging to withstand a challenge protocol representative of the temperature range found in retail stores; (v) provide consumers information and instruction about how to use these types of products (e.g., "Must Be Refrigerated").

Three technologies widely used for preparing chilled foods are modified atmosphere packaging (MAP), cook-fill-chill, and sous-vide (French for "under vacuum"). MAP involves the altering of the gas content within a food package to extend the product's shelf life; cook-fill-chill processing is a technique used primarily for food service packaging and is used only for pumpable products. Cooked products are pumped at about 85°C into a plastic casing, clipped shut, and tumble-chilled to less than 4°C; sous-vide is a prep-fill-cook-chill technology in which packaged pouches or sealed trays are post-pasteurized (Cooperhouse, 1993).

Selection of Packaging Films:

In order to preserve the quality and the safety of the food, an appropriate packaging is critical. Usually, for this type of food a minimal packaging is used to display the products (i.e., refrigerated pizza); often a minimum barrier to the evaporation of volatile flavor is used. The image of freshness and the packaging of these products often contradict each other; according to Cooperhouse (1993), consumers perceive the packaged food as leftover and are reluctant to believe that longer shelf life products can actually be

fresh. A MAP salad, when served on a plate will receive a much higher rating than if served directly from the sealed container. Cooperhouse (1993) further suggests a sous-vide product, packaged in trays with peelable lids, would be better received by the consumers than a MAP product.

Many types of freshly cut vegetables suffer textural change during storage. Except for some occurrence of lignification (an enzymatically catalyzed process which toughens the plant tissue), most of the textural changes are due to moisture loss (Reineccius, 1989). By carefully controlling temperature, humidity, and package design, we can greatly retard water loss in leafy vegetables. Besides moisture loss, typical quality deteriorations of refrigerated foods include warmed-over flavor of meat products, staling of starch-based products, inter/intra-food moisture migration (which causes partial hardening and sogginess), enzymatic reactions, and vitamin loss, etc. These possibilities should all be considered when selecting and designing the packaging for this type of food.

It is important to consider what level of packaging films are acceptable at the least expensive basis. The traditional ambient testing of individual films is time consuming and rarely permits a real-life scenario; instead, a mathematical/computer modeling including all key variables is currently being used (Mannapperuma and Singh, 1990; Erickson, 1993). The model will predict how much oxygen and moisture, etc. permeate the package and what effects these elements will have on shelf life. By altering packaging material data, the packaging designer can learn just what components, and at what proportion, are required for optimal quality. By using gas chromatography and mass spectroscopy to determine the precise composition of a package material, we can reveal information about whether flavor volatiles are being scalped from the food product by the material, or whether the material is releasing components onto the food products. Also, we can use sensory analyses to trace odor and flavor problems to complement those results obtained with instrumentation.

Potential degradation of food quality in the packaging also can occur in multiserving containers where problems ranging from staling to contamination could occur if the packaging does not reseal properly. Devices such as resealable plastic lids and reclosable zippers should be considered.

Resistive susceptors are an integral part of microwave food packages designed to enhance browning and crisping. They are made by depositing thin films of aluminum or stainless steel particles on a polyester substrate layer that is in turn laminated to paperboard. The susceptors absorb the incident microwave radiation and emit heat sufficient to raise the surface temperature above 205°C within 3-5 min (Shukla, 1991). In microwave foods, one concern is that current susceptor materials could leach into the food products as the food is heated. An alternative is to have a metalized paper susceptor, which uses starch-based adhesives as opposed to synthetic glues.

Key-Fresh Foods (West Chester, PA) introduced its Fresh Buffet,

which is packaged with a clear dome that allows consumers to see the products and for more air flow around stacked cartons. The product also uses a time-temperature indicator for at-home quality check. The box is uniquely designed in parallelogram shape for enhanced graphic display. Under well-designed display temperature and illumination, the product looks appealing to consumers. Fresh Valley Produce (Salinas, CA) and Fresh Hold vegetable packaging (Hercules, Henderson, KY) use a gas-permeable "lung label," which is applied over vent holes in the dome and enables the packaged produce to breathe at reduced respiration rates. This item extends the shelf life of fresh fruits and vegetables 1.5 to 3 times longer than conventional packaging. The label, made of polypropylene (PP), is applied onto a polyvinylchloride (PVC) lid, which is less permeable to oxygen and carbon dioxide. The labels can be customized based on the types of produce, form, weight, package volume, and surface area. Plexus (Aldine Technologies, NY), a heat-sealable cellulosic/polymeric material, can absorb gas quickly and hold moisture while allowing rapid gas transfer.

Stewart et al. (1992) introduced a temperature-responsive, gas-permeable film (i.e., Intelimer; Landec Corp., Menlo Park, CA). The semipermeable film exhibits large changes in gas permeation in response to small temperature changes. It belongs to a family of materials known as Side Chain Crystallizable (SCC) polymers, which exhibit abrupt thermal transitions associated with the side chain rather than the polymer backbone. The film can match or exceed the increasing respiration rates of fresh produce caused by temperature fluctuation. By using computer simulations for time and condition changes, a variety of gas selectivities, P-10 values (i.e., permeability over a 10°C range below and above the side chain transition), and permeability can be designed into these films to meet specific needs.

MAP Films:

To devise suitable MAP systems for particular commodities, it is necessary to tailor the permeability of the film to package design (e.g., pillow pack or rigid tray overwrap) and to the rate of tissue respiration. For example, there are no sufficiently permeable films as yet for produce with very high rates of respiration (e.g., sweet corn, cauliflower, leeks, etc.) However, using an overwrapped rigid PVC tray with a micro-perforated PVC film tends to preserve leeks longer (Nash, 1988). Another example is a 1-3% oxygen, 5-6% carbon dioxide atmosphere with 35µm low density polyethylene (LDPE) film that will double the shelf life (i.e., up to 14 days) at 4°C for shredded lettuce (Ballantyne et al., 1988).

Packaged baked goods stored in a carbon-dioxide-rich atmosphere (150 cubic feet/min) for up to 15 days have softer texture than air-stored samples. Since the complex changes contributing to staling are initiated immediately after baking (Kulp and Ponte, 1981), Knorr (1987) conducted a study to compare the compressibility of baked goods after carbon dioxide atmosphere processing and

storage. He reported that carbon dioxide significantly decreased compressibility of French bread, white bread, and lean-formula baked goods compared to air-stored samples. Fermentation and enriched white bread dough under carbon dioxide modified atmosphere also resulted in softer breads than air-processed samples, especially when no relative humidity control (e.g., 95%) was maintained during storage. Carbon dioxide storage tends to retain more water activity in foods.

A MAP packaging system developed in New Zealand for fresh meats combines the benefit of extended refrigerated storage life with the natural tenderizing process associated with the aging of meat (Anon., 1989). Retail cuts are packed in thermoformed PVC tray with nylon/PE lids or expanded polystyrene trays with film overwraps. Prime cuts are covered with an absorbent wrap. The trays or wraps then are placed in foil bags, each open bag is placed in a corrugated box, and the box is placed in a vacuum chamber. The bag is evacuated of air, injected with a predetermined amount of carbon dioxide, and sealed. By using this technique, refrigerated lamb has more than a 16-week shelf life while pork and poultry have up to 10-week shelf life.

The quality and safety of MAP foods are reduced by time-temperature abuse. Expiration date coding and temperature abuse indicators are in use; but neither are fail-safe nor without possible negative ramification since the time-temperature indicator (TTI) application might imply that the product is no longer fresh. The TTI will be more suitable for semi- or nonperishable foods to track their time-temperature history as well as to predict the remaining shelf life as it was reported by Wright et al. (1991).

The plastic and flexible packaging used for MAP is typically processed by multilayered coextrusion or lamination. Trays with lids are the dominant form, followed by bags. According to Anthony (1989), a smart material is being developed wherein the initial gas environment would be maintained much longer. It is a tray with a vented lid. A permeable film is affixed over the holes and controls the rate that oxygen enters the package and carbon dioxide exits. The respiration of the produce is therefore controlled at a favorable atmosphere. Developing such a smart film is not an easy task since it needs to be tailored for the type of produce, the produce's state of maturity, temperature, humidity, etc. The variety of films used in the MAP package is increasing, ranging from economical PE, PP, polystyrene, and PVC for bulk packaging to more expensive ones such as ethylene vinyl alcohol (EVOH), polyvinylidene chloride (PVDC) and nylon for barrier or other speciality functions.

Initial gas concentrations, their transmission rates, area/volume of the package, the volume of product, absorption characteristics of the product, temperature as well as other parameters dictate the combination of materials that make up a package.

Packaging Films for MAP/VSP:

Generally, the MAP package uses relatively impermeable film and gas mixtures that are tailored to suit specific products.

For example, meat is packed in a mixture of 75% oxygen and 25% of carbon dioxide to ensure the red color of the meat and to inhibit microbial growth. Vacuum skin packaging (VSP) provides an alternative system for centralized packaging of meat and offal. Barrier films such as those used in MAP are used, but a vacuum is drawn leaving anaerobic conditions within the pack. The system usually provides longer refrigerated shelf life for meat and offal than does MAP. However, VSP meat is a dull purplish color rather than a bright red color that the consumer expects. In this case, MAP and VSP can work together to form a packaging with superior properties. Trigon Packaging (Redmond, WA) produces a skin package for a meat product in which the product is a "breathable" coextruded film based on Du Pont Surlyn ionomer resin. The film keeps the red meat color, eliminates juice drip, dehydration, and ice crystal formation. Directly above the film is a headspace area where modified atmosphere gas is present. Barrier lidding is applied over that headspace.

Cook-Fill-Chill and Sous-Vide Packaging:

Packaging for Grace's cook/chill foods consists of multilayer barrier pouches and casings. The transparent flexible packages are easier to handle, store, and dispose of than alternate forms. The cook/chill and sous-vide technology has been described in detail by Lingle (1991).

According to Cooperhouse (1993), technology, not marketing, holds the key to pushing this type of chilled foods to their potential. By using a better post pasteurization process combined with improved barriers (such as the natural acidity of chicken products), we can extend the shelf life up to 30-45 days. Cryovac's sous-vide package includes meat/chicken/seafood with vegetables. Its package clings tightly to the products, consists of a multilayer, high barrier coextruded polyester over a crystallized polyethylene terephthalate (CPET) tray.

Microwaveable Food Packaging:

Microwave ovens have become a house-hold item and microwaveable or a dual-oven type package is needed. Microwave active packaging, which includes susceptors, reflectors, guidance systems, microwave "doneness" indicators, and "smart adhesive", that can be used on form/fill/seal machines. An Ultem 1000 resin (Pittsfield, MA) for susceptor films can generate higher heat with a thinner metal layer than polyester substrates; a water soluble "smart adhesive" has been applied to a dual-ovenable paperboard tray with a self-venting lid. As the steam vents from the package at the appropriate temperature, the product is "done".

Packaging for Gohan rice (a Japanese rice lunch box) is an effective blend of aseptic, low oxygen, barrier plastic and controlled product water activity to create an ambient temperature shelf-stable rice, ready for microwave heating. In the process, the rice is steam-cooked and aseptically packaged in a pre-sterilized

tray which is composed of co-extruded PP/EVOH copolymer. The tray is then exposed to ultraviolet radiation. Prior to hermetic heat sealing, the tray is flushed with sterile nitrogen gas. The top film, a lamination of polyester/cast PP, is laminated with a partially slotted interior web engineered to contain an oxygen scavenger sachet. The product has a 6-month ambient shelf life.

Other unique Japanese packaging innovations include a glass-coated microwave film, retort pouches with peelable aluminum foil that protects the product integrity during distribution and is removed before microwaving; ethylene-absorbing granules within package films that extend the shelf life of fresh fruits and vegetables; plastic films that incorporate microbiocidal compounds; plastic film containing natural clays that emit infrared radiation alleged to preserve foods.

MAP and Military Feeding System:

While the concept of minimally processed foods may be a potential application for military feeding systems, the author feels that the current MAP products are not suitable, especially for field feeding. The lack of universal, strict microbial standard and a rapid microbial test for both spoilage and pathogenic bacteria has limited MAP products to supermarket refrigerators (Conca and Yang, 1994). Based on the current military logistical distribution exercise, it will be years before MAP foods can be implemented into the military system. At this moment, the closest military rations that are convenient to eat without tedious rehydration or reheating are the eat-out-of-hand rations; namely low and/or intermediate moisture foods that requires minimum packaging material to render them shelf stable.

Package for the Innovative Processing Technologies:

Since there is an increasing demand from the consumers for a better quality entrees, various new thermal and non-thermal stabilization technologies have emerged (Mertens and Knorr, 1992). These techniques were developed to reduce the quality deterioration due to overprocessing. Several examples are: aseptic processing, ohmic heating, split-phase aseptic processing for particulates, high-pressure stabilization, microwave treatment, magnetic electrical field pulses, irradiation, etc. Many of the conventional packaging materials may no longer be adequate to withstand these new methods. Also, when newly developed biodegradable packaging material is used, a thorough investigation is needed to determine the effect of these new processing treatments on the container and its interaction with the food it contains.

Packaging Innovation for Convenience:

Many packaging examples (Lingle, 1990; Watanabe, 1993; Bush, 1990) illustrating consumer convenience are described as follows:

- a. Trilaminated foil pouches are sometimes hard to open. A laser-scored package was developed for easy opening without

compromising the package integrity. A "FC-cut" easy-tear method uses many very fine (barely visible) dots scattered along the edge of the outmost container, and uses arrows to indicate the tearable edge.

b. An easy peel sealant for containers uses special polymer alloy of PP/Polystyrene in a 70/30 blend. The 30% polystyrene spherulites are dispersed in the PP matrix (Fig. 1) and polystyrene spherulites in the PP sealant migrate to the surface when the sealant is hot pressed and sealed on the rim of a container. The seal strength is controlled by the number of polystyrene spherulites on the PP sealant surface.

c. Microwave heating enhancers are implemented by using metallized aluminum patches for uniform browning.

d. Carnaud Metalbox (CMB) introduced a polyester-laminated (coated) microwave steel can, which prevents arcing should the can touch the sidewalls of a microwave oven. It also protects the metal against the corrosive effects of a food product.

e. Flexible beverage pouches with built-in straws that eliminates the sometimes awkward step of inserting a straw.

f. A plastic-coated glass bottle is currently being used in Japan, Canada, and Netherlands. The bottle won't shatter when broken, it provides higher impact strength, reduces noise levels on bottling lines, and weighs less than a noncoated glass bottle. The opposite approach is to apply a thin glass layer on plastic structures. For example, Eastman Chemical Co.'s silica-coated PET bottles (trade name "QLF") offer three times the barrier property of conventional PET bottles and can be recycled as PET bottles. This type of "plasma" deposition process can also be applied to flexible films. The barrier properties of the film remain constant regardless of temperature or humidity. It can withstand retort sterilization and is microwaveable.

g. A PVDC-OPP/CPP (oriented PP/cast PP) container is used for a weekly produced coffee to let consumers enjoy freshly roasted and ground coffee. Designed to sustain coffee's rather short shelf life (i.e., 3 weeks at room temperature) from the day of roasting and grinding, a valve is attached to let the carbon dioxide gas generated from the fresh coffee escape from the package.

h. Sunkist's Freshly Peeled citrus products combine pectinase solution, vacuum infusion technology, and a mechanized line to produce pre-peeled orange and grapefruit with 16-day shelf life at 1-2°C.

Vented Foods:

Today's vented foods are rapidly moving beyond the confines of chips, pastries, and chewing gums to an "engineered food" which is an integral blend of formulation, processing, and packaging technologies. These engineered foods ranged from refrigerated hamburgers, french fries, pizza, and hot dogs to frozen vending food products. The latter were developed by using a microwave to heat frozen foods to 71°C in 10 to 45 seconds. The microwave system (Whiz microwave; STH System, Chicago, IL) is especially designed to have

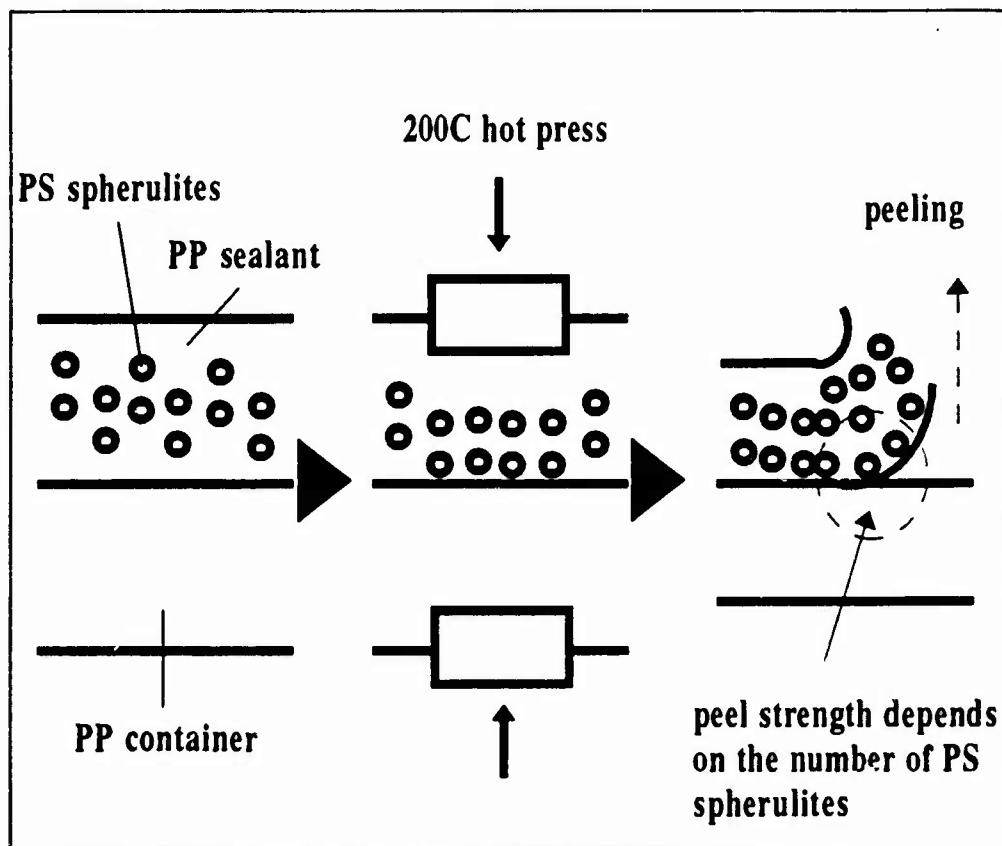


Figure 1. SEAL AND PEEL OF EASY-PEEL SEALANT

two electromagnetic wave-form generators and two wave guides in opposite directions and four halogen lamps to keep the outside surface of products crisp while maintaining the foods moisture and tenderness inside.

A typical convenience food was demonstrated by Pizza Chef's (Nouveau International, Inc., Norristown, PA) pizza vending machine, which can cook and dispense hot pizza in 90 seconds. Specially formulated frozen pizza is packaged in a round box which serves as a cooking device in the microwave. The small pores of the box open up at timed events during the cooking cycle and a metered amount of steam escapes allowing full reconstitution of the pizza.

In Japan, vented food packaging and venting machine technology is well advanced. Items range from a highly sophisticated automatic noodle serving machine (Hayashi and Shimada, 1993), which requires no manpower to process and cook a noodle dish, nor to remove dirty dishes, bowls, to an ever-popular lunch box (i.e., Gohan) at subway stations. Many of these lunch box vending machines are serving lunches with no refrigeration. The secret is the application of antimicrobial packaging material.

Antibacterial Packaging Materials:

Antibacterial compounds have been incorporated into packaging materials to inhibit bacterial growth without compromising food quality. Several examples are:

1. Fretek: A wafer (Techno International) was introduced at Food Expo '89 for MAP package of bakery products (Fig. 2). With customized sizes, it emits a GRAS antimicrobial gas mixture of ethanol and acetic acid, which inhibits growth of yeast and molds to extend shelf life and retard staleness.

2. Zeomic: Zeo is the name designated by Mitsubishi Corp. to describe its "super clean" food containers that utilize Zeomic for aseptic applications. Zeomic is a neutral inorganic material and a new ceramic. It is an alkaline earth metal; its crystalline structure causes it to act as a molecular sieve. Zeomic is heat-resistant up to 550°C, far in excess of any nonmetallic packaging material. A less than 1% mixing ratio of Zeomic into the packaging material will render the food containers bacteria-free. Zeomic food containers are very stable since the compound neither vaporizes nor decomposes, and it has no bacteriostatic effect on the content.

3. Chitin/chitosan: U.S. Army Natick RD&E Center (Natick) and Marine Polymer Technology (MPT) cooperate in research effort to explore the feasibility of developing novel edible food coatings prepared from a highly purified form of chitin and chitosan, produced by MPT. Chitin, the second most abundant natural biopolymer (cellulose being the most abundant) occurs in nature as a structural component in the exoskeletons of crustacea and a number of other organisms. Chitin is a polymerized acetyl glucosamine and chitosan is its deacetylation product. As food barriers, chitin and chitosan have many advantages. They are: resistant to heat, freeze-thaw and

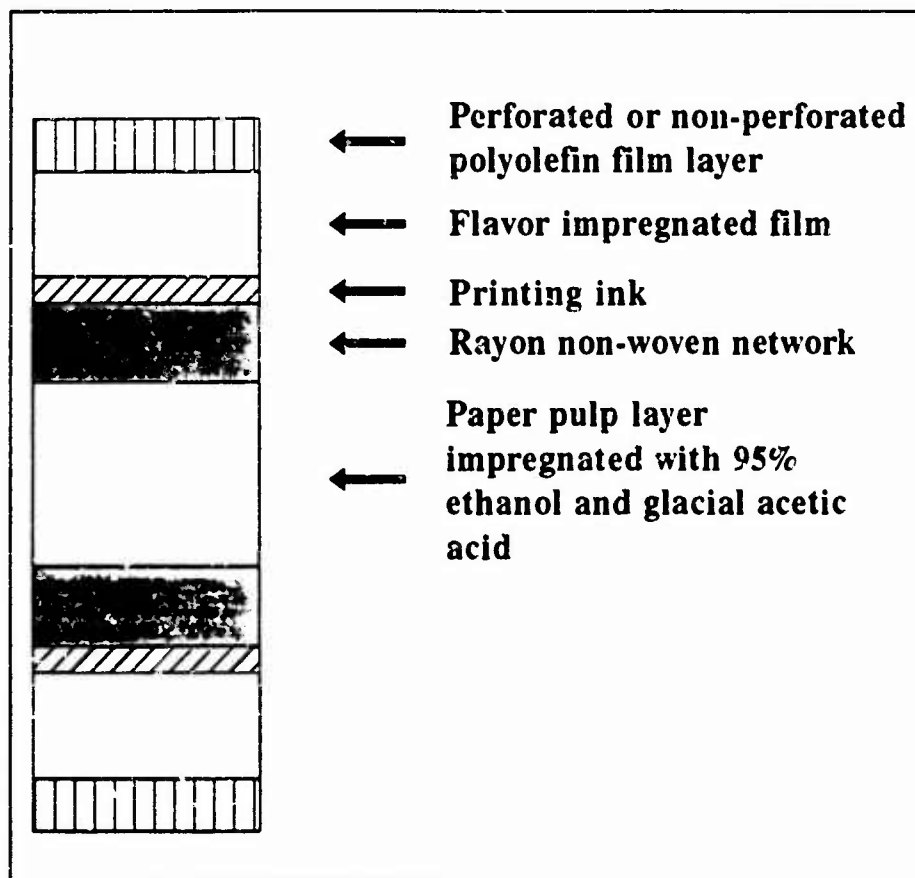


Figure 2. ANTIMICROBIAL WAFER

freeze drying, are bacteriostatic and fungistatic, and have antioxidant and cholesterol-lowering capabilities. Most importantly, chitin and chitosan are biodegradable. Chitosan laurate films are effective edible barriers (Pennisi, 1992). The use of chitin and its derivatives will help solve an existing waste-disposal problem that plagues shellfish and other food processing plants. Natick is currently evaluating several grades of chitin/chitosan films, ranging from low grade to very pure material, for coating suitability, permeability to water, oxygen and microorganisms, to determine the films' acceptability and their effectiveness as edible coatings. The coating will be tested on dry and intermediate moisture food items for quality control, antioxidant, bacteriostatic and fungistatic effects. Particular attention will be given to study the role these coatings might play in preventing the development of lipid oxidation and rancidity in the packaged food.

4. WasaOuro: Natick and Lintec (Tokyo, Japan) are working on an application of an antibacterial, antifungal, and preservative agent called WasaOuro. It has been known for a long time that wasabi (*Wasabia japonica* MATSUMURA) has an antibacterial effect. The main ingredient, a glycoside called sinigrin, is hydrolyzed by the catalysis of a coexisting enzyme, myrosin, generating volatile oil, known as allyl isothiocyanate (AIT). It has recently been proved that this main ingredient controls ethylene that is emitted from plants, thereby preserving freshness. AIT, as a form in gas, not only controls bacterial and fungal problems in food without damaging its flavor, it also has very high permeability attributes, penetrating even such film as PE and PP. This means that foods packaged in such films can be stabilized and preserved by applying WasaOuro as a label on the film (Fig. 3). When a high barrier package, such as an a Meal-Ready-to-Eat (MRE) entree or retort pouch (which is a foil-based trilaminant), is used, a WasaOuro sheet is used inside the pouch, as illustrated in Figure 4. Many of the WasaOuro applications were introduced at the first Food Ingredients Japan exhibition in April 1994.

Oxygen Absorbers:

Much food spoilage is tied to the availability of oxygen in the package. Microbial growth, such as molds and putrefying bacteria, are visually and nasally obvious. By reducing the oxygen to under 0.4%, mold will not grow until the tenth day, instead of at the fourth day in atmospheric condition (Idol and Wagner, 1993). Natick has developed a water activity controlled pouched bread which can be stored for 3 years at 27°C (Powers and Berkowitz, 1990). The bread, prepared according to Military Specification (1989) MIL-B-44360(GL) (entitled: Bread, shelf-stable for meal, ready-to-eat), contains 0.05% potassium sorbate and is hot packed (52-60°C) and sealed in oxygen-impermeable trilaminated pouches. The pH of the bread is 5.7 and water activity is 0.825. With an oxygen scavenger system in the pouch, this bread survived growth of a mixed mold inoculum on the surface for 12 months. In the absence of the

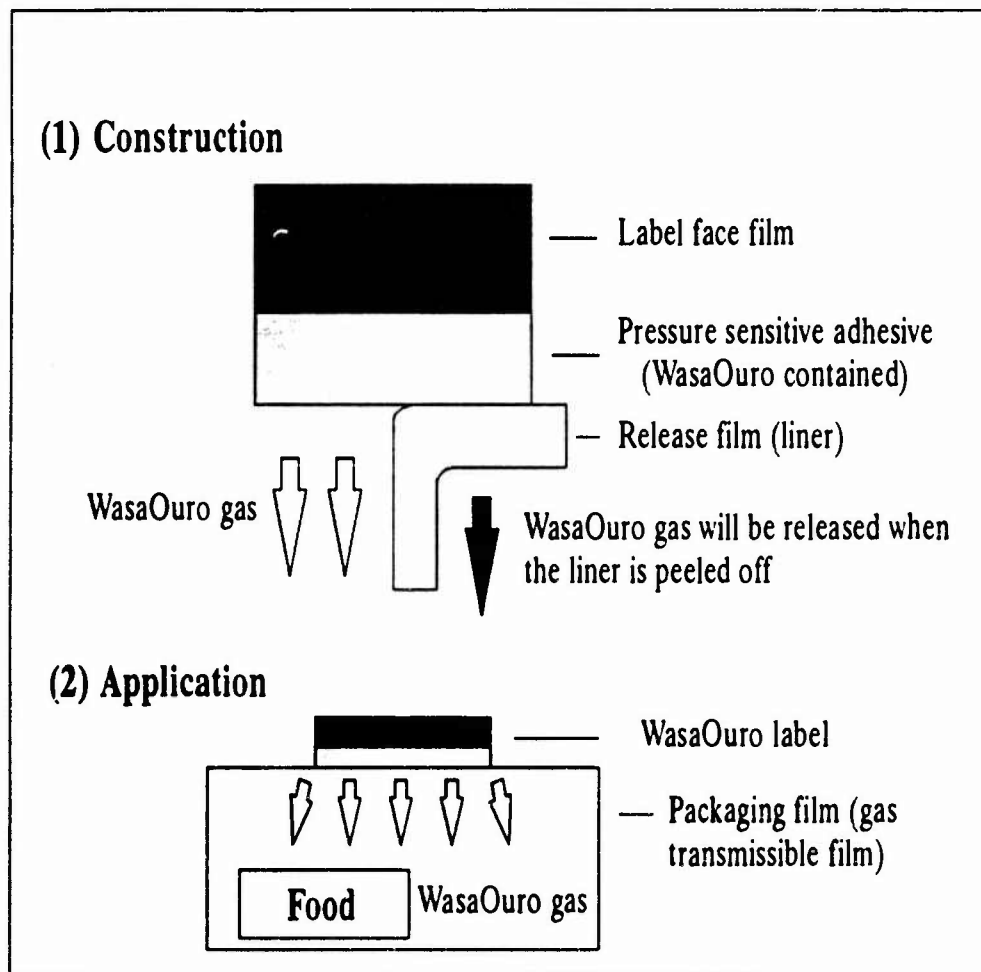
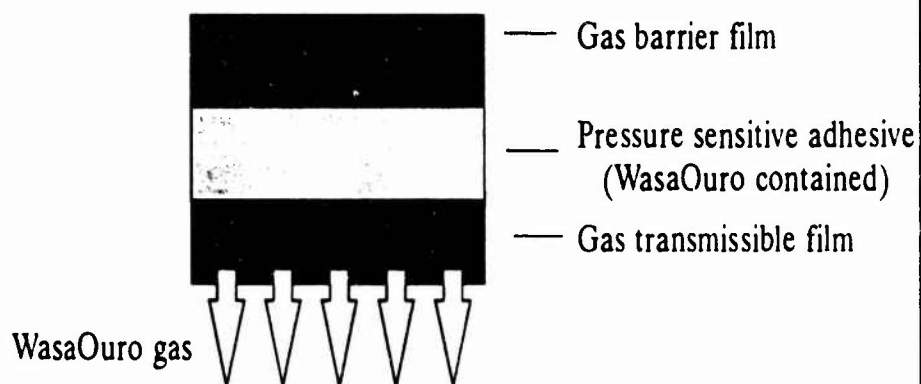


Figure 3. WASAOURO LABEL

(1) Construction



(2) Application

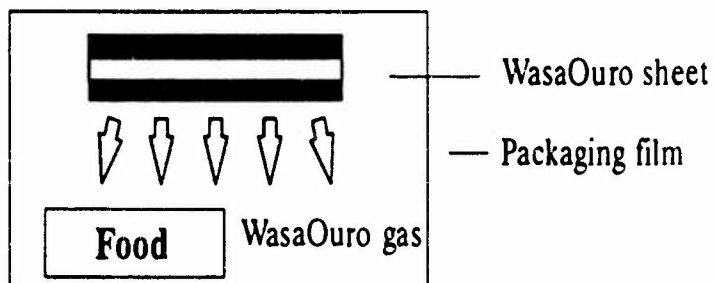


Figure 4. WASAOURO SHEET

oxygen scavenger, growth of Aspergillus and Penicillium is visible on the bread within 14 days.

Mitsubishi Gas Chemical's "Ageless" (distributed by Cryovac in the U.S.) continues to absorb oxygen as it permeates the packaging materials. It removes oxygen completely so that such antioxidants as BHA, BHT, and sulfites can be deleted from the product formulation (Edwards, 1989). The oxygen scavenger, in a packet form, has the potential of being broken during shipping or being accidentally eaten by the consumer. Many new oxygen absorber technologies are being developed. For example, FreshMax (Multiform Desiccants, Inc., Buffalo, NY) is an absorbing label which can absorb up to 50 cc oxygen; Aquanautics Corp. located in California utilized organic oxygen-absorbing materials in which the molecular structure can be engineered to control the strength of oxygen extraction and the rate of reaction to irreversibly absorb oxygen or to recycle it. Besides being used as a small pouch, it can be coated onto the interior wall of the package (or closure), be enclosed in a cap (Smart Cap), or by coextrusion. The compounds can also serve as tamper-evident indicators, which change color when exposed to oxygen. Another oxygen absorbing material consisting of cotton-like fibrous polymers has been co-processed with the packaging material to be part of the inner lining (Novateck, Inc., Newton, MA). The absorption occurs immediately after exposure to oxygen and the material can absorb large amounts of oxygen (up to 12% with 3.5% immediate absorption; i.e., within an hour).

Another source of food spoilage is through chemical degradation (oxidation). Such quality deteriorates are: rancidity, flavor change, discoloration, and loss of vitamins and nutrients when oxygen is present. By eliminating oxygen, many of these deteriorations can be prevented. Oxygen elimination will also stop the insect infestation in grain products, or retard the enzymatic degradation.

Controlling residual oxygen in the package is critical since botulinum and other anaerobic bacteria might become a potential problem for food quality and safety. Using oxygen scavengers in conjunction with antibacterial packaging material may overcome the concern.

Moisture Absorbers:

Desiccant crystals have been incorporated right into the closure, thereby removing any chance of their accidental ingestion. The closures come in PP disposable or polymethylpentene rechargeable types; both will change color, as absorption takes place, from bright blue to light blue to pink.

OZO (Sekkoto Osaka, Japan), a desiccative agent extracted from sea water, has not only extremely high capacity of moisture absorption and desiccation, but also multiple functions in contrast to existing desiccative agents (silicagel, quick lime, etc.) (Kojima, 1985). OZO can absorb 2 to 5 times more moisture than existing agents. It is safe (if accidentally ingested) and noncombustible, can react to both rapid and slow desiccation, and can be added with

any scent of choice. This scent can compensate the loss of flavor during storage or counteract the strange odor emitted by the existing agents. OZO Wrap, an inner wrapping paper of laminate packing film, has been used with a scent for cakes, food bags, candies, and chewing gums in Japan. A special type of OZO has been developed to absorb moisture and desiccate under the condition at -20°C (beyond the conventional performance standards of silicagel and quick lime), such that frosting and beading (caused by the differences in temperatures between inside air and infiltrating outside air containing moisture) in cold storage can be prevented.

Packaging Design and Environmental Concern/Awareness:

Besides special packaging features, which ensure the quality of special foods, artistic package design of the minimally processed foods is important to lure more customers. Popular animated characters are being used on the printing of the package, shaped into the ingredients, or being used as an enclosed toy. Many quality-preserving sachets such as oxygen, moisture absorbers or antibacterial agents, instead of being disposed of, can be designed as a decorating display or a collectable item for the consumers.

Packaging engineers and designers are looking for environmentally friendly packaging and this was the major theme at the Interpack 90, Dusseldorf, Germany. The European trend is to reduce or eliminate packaging material by first removing shrink wrap (film) for multipack, and utilizing biodegradable/edible packaging films. Japan uses 300 tons/year of organic solvents for processing conventional adhesive laminate film OPP/CPP (i.e., oriented PP/cast PP) widely used for flexible pouches. The adhesive laminating process is not only complicated, but also causes environmental concern due to the emission of some solvent into the atmosphere. A thermal laminating process was developed which uses no organic solvents; the laminate has superior clarity and gloss to conventional laminate films [18].

Edible Barrier Coating:

Convenience foods with different components bearing different water activity, oil content, or other migrating components (e.g., a sandwich) present separation challenges. While water-controlling ingredients such as starches and gums are the mainstay of all types of foods, interest is growing in the barrier properties of edible film such as protein/lipid complexes that prevent dehydration of cut vegetables or a sandwich filling from soaking the bread. Edible films or containers have been studied extensively for years (Andres, 1984; Kester and Fennema, 1986; Gilbert, 1986; Aydt et al., 1991; Gontard et al., 1993). An edible coating is defined as a thin, edible film that can be deposited onto the surface of a food and that can provide protection to extend the shelf life of the coated food by acting as a barrier to moisture, oil and vapor transmission. Examples of some food coatings are wax for fresh fruits and vegetables, chocolate, sugar, and shellac coatings on candies and nuts, natural casings on meat products, and gelatin

capsules for pharmaceuticals. Edible coatings offer unique benefits over conventional packaging in that they can be consumed along with food, provide additional nutrients, and enhance sensory characteristics. Quality enhancing preservatives can also be directly added. Food substances that are derived from carbohydrates, proteins, fats, and/or combinations of the above materials are being used.

For military applications, studies have been conducted to evaluate barrier food coating materials that: (i) are tasteless and edible; (ii) provide appealing appearance up to the moment of consumption; (iii) provide long-term protection against bacteria, oxygen, moisture, fat, and inter-food aromatic compound migration. Those substances that may meet these requirements are analyzed for oxygen, moisture/vapor, fat permeability, continuity, adhesion, film integrity and resistance to softening, sticking or cracking. While we match the best candidates with suitable ration items, the coating, film forming and drying procedures are determined. Storage studies for performance and reliability are conducted on substances that may have potential adaptability for the military with respect to withstanding the abusive storage and handling conditions frequently encountered during military operations, such as high temperature and prolonged refrigerated storage.

For military rations, such as the eat-out-of-hand Family of Operational Rations, edible barrier coatings would provide operational convenience, promote consumption, improve the quality and provide additional cohesive strength to food bars, reduce the packaging weight, volume and disposal problems of rations while allowing for multiple combinations of rations. Interest in development of biodegradable and edible packaging is increasing due to changing needs within the military and also concerns for the environment.

Biodegradable Packaging Material:

The Marine Pollution Plastic Research and Control Act (MARPOL) of 1987 (Public Law 100-220) prohibits the overboard discharge of plastics after January 1, 1994 and requires Navy ships to comply with MARPOL, Annex V. To comply with the MARPOL Treaty, the Navy is currently investigating source reduction options to limit the amount of plastic being used on ships, as well as methods for compacting and storing plastics until the vessel reaches shore. Another potential solution is the replacement of conventional plastics with materials that are degradable and nontoxic, yet retain many of the mechanical properties of plastic.

Several priority Navy applications of biodegradable materials are utensils, trash bags, drink cups/lids, foam clam shell/trays, milk bladders, and meat wrappers. To incorporate biodegradable materials into end-items for the military, Luocciarini (1994) recommended several essentials: (i) a more economical biodegradable resin; (ii) an efficient injection mold tooling for biodegradable utensils; (iii) packing methods designed to protect these utensils from insect

infestation and the loss of mechanical properties under extreme storage conditions; and (iv) a universal definition, standard testing methods, and standard of biodegradability.

2. SUMMARY

There are numerous so-called minimally processed foods in the market; they constitute the fastest-growing convenience-foods segment, and they are potentially the most dangerous. With daily addition of new products such as items for dual-oven type and vented foods, factors such as innovative processing technologies, proper package selection and design, consistency of distribution temperature, and most importantly, the universal quality and safety standards are essential for these items' continuous success. To design these products, it will be beneficial to have extensive knowledge in polymer science, package simulation modeling, innovative oxygen/moisture absorbers, antimicrobial package materials, enhancing consumer convenience, environmental awareness, and edible and biodegradable packaging barriers. Also, marketing strategy is essential to avert consumers' negative perception towards packaged foods and to relate the well designed, attractive package to high quality of the products.

This paper has reviewed many aspects of minimally processed foods and their particular packaging systems for commercial markets, it has also briefly discussed military application of some convenient foods and packages as eat-on-the-move rations. For particular package materials, extensive information can be found in material and polymer science textbooks.

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