Sous-Vide Technology

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Most meat processors are looking for ways to increase their sales and profitability by selling more value-added products. Prepared entrees are one way: for example one kilo of beef, trimmed and cut, selling for 6 dollars, could fetch over 20 dollars sold as a prepared meal.

Sous-vide is a technology suitable to add value to food items. The consumer or institutional customer could see a real benefit in buying a fresh product that combines taste, convenience, wholesomeness, with little or no preservatives. Mr. J.W. Marriott, Jr., President of Mariott Corporation, also confirmed that the U.S.A. is fast running out of labor for foodservice operations and lower skilled employees. For example, wages are $10 per hour in the San Francisco area. At the recent AMI and Restaurant Business Conference, he talked about the key role of "sous-vide" meals for the development of the new Courtyards Hotel.

However, there are real concerns about its safety, but also some misconceptions. And surprisingly, for all the controversy, little research was done on the challenges that this technology presents.

I hope this paper will show how some of the barriers could be removed and lead to successful implementation of sous-vide in North America.

The Fresh Chilled Entrees: The European and Japanese Experience

In Europe and Japan, long sections of supermarkets are devoted to chilled (not frozen) entrees. The prepared fresh food market in U.K. represented in 1989, 2 billion dollars. In Italy, Germany and Holland, pasteurization of MAP (modified-atmosphere packaging) entrees has been used for 15 years; some manufacturers, such as Pro Food and Delta Daily Foods, use microwave pasteurization. In France, the sales of chilled entrees grew over 100% from 1983 to 1987. It is expected that in less than 10 years, sales of chilled fresh entrees will outsell the frozen and shelf-stable sectors combined. Japan also shows innovation in MAP technologies.

The primary reasons for the advance of MAP and sous-vide technology in Europe and Japan is the dedication that large retail chains have to have a total quality system. Chilled prepared foods are heavily promoted, to sell these high-margin, quality products. Strict regulations have been imposed on the manufacturers, and the retailers have instituted strict refrigeration and distribution systems to obtain extended shelf-life. For sous-vide in particular, the majority of producers are in France.

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"Sous-Vide" in France

There are three types of manufacturers: First, the meat processors who benefit from access to raw materials, expertise and distribution channels; second, the end users, such as restaurants, retailers or cafeteria chains; third, the newcomers exploiting market segments not covered by the meat processors or central commissaries.

Two-thirds of the 40,000 tons annually produced is sold to the restaurant-hotel-institution trade. Of this volume, one-third of the meals are red-meat based.

We assist to a concentration of the retail market suppliers: 52% of the meals were produced by three manufacturers, Fleury Michon being the leader. The same tendency is observed in the institutional trade.

Studies also revealed that 88% of fresh chilled prepared foods are sold through hypermarkets (very large supermarkets), or supermarkets. This contradicts the North American assumptions that these meals are bought on a daily basis.

Most French manufacturers were allowed 21 days shelf-life on their products; with sufficient pasteurization, 42 days shelf-life can be obtained.

But the trend, with manufacturers and distributors alike, is to decrease the period between production and pull-out date, because of the consumer perception of what "fresh" should be.

North American Marketplace

Unlike in Europe, in North America the demand for fresh chilled products is consumer driven. The retailers moved away from manufacturing and are not interested in a total approach except for a few notable exceptions: Grand Union, Wawa (a chain of 400 convenience stores) and Cub Foods, in Minneapolis.

In the U.S.A., retail sales of refrigerated microwaveable meals were expected to reach 15 million dollars in 1989, and are expected to grow to 1.7 billion dollars in the next 10 years.

In the food service trade, sales could top 50 million dollars in 1989, according to Carl Randall, president of Culinary Brands, Sausalito, California. Retail chilled entrees sales are expected to reach 500 million dollars in sales in 1990, according to Kraft Foods.

What is Sous-Vide?

The French call it "sous-vide" which simply means "under vacuum." It is a process by which meal components are packaged in a barrier bag or rigid container, from which the air is evacuated, with or without compensation by neutral or bacteriostatic gases. It is then cooked in a high-moisture environment to a temperature sufficient to cook and pasteurize, but not sufficient to sterilize. The package is then rapidly chilled. The meal is then sold in the same package, either fresh at temperatures of 0°-3°C, or frozen.

Concerns About Sous-Vide Process

The main concern with this method, as with any MAP application, is its microbial safety and the growth of pathogenic anaerobic psychrotrophilic bacteria under temperature abuse, most likely to occur between the manufacturing plant and the customer.

The most important factors to determine the shelf-life and the resistance to temperature abuse are:

- the initial microbial load (nature, quantity).
- the severity of the heat treatment to lower that microbial load, or the pasteurizing value.
- the means to prevent their growth through temperature controls, and packaging expertise.

The sous-vide process requires careful screening of raw materials, hygienic processing conditions and temperature controls of the total food chain, right to how the consumer reheats the product in the microwave or boiling water.

Because of the conditions we are dealing with, such as pasteurized food in anaerobic conditions kept at refrigerated temperatures, the organisms of concerns are:

- anaerobics, microaerobics or facultative anaerobics.
- psychrotrophilic and psychrotropic spore-forming organisms.
- heat-resistant spores and toxins.

Aerobics, such as *pseudomonas* involved in spoilage, are inhibited in oxygen-free atmosphere. In fresh fish, *pseudomonas* can use trimethylamine oxide as electron acceptor, but in sous-vide product, *pseudomonas* growth is related with the permeability of the film to oxygen. Mycotoxins production is inhibited at oxygen level of 0.5%. Of the spoilage organisms, *lactobaccilli* are the predominant bacteria.

Some pathogens can proliferate and survive at refrigerated temperatures.

- *Clostridium botulinum* (thermo-resistant spore).
- *Clostridium perfringens* (thermo-resistant enterotoxins).
- *Staphylococcus aureus* (thermo-resistant toxins).
- *Listeria monocytogenes.*

Monocytogenes are the most resistant of the non-sporing pathogenic bacteria, but steam cooking at an internal temperature of 71°C will kill *listeria,* and storage under vacuum at a temperature of 4°C or lower won't promote growth. *Yersinia enterocolitica, Escheria coli,* and *Aeromonas hydrophilia* are easily destroyed by pasteurization, and sous-vide eliminates risks of cross-contamination after cooking.

For *Clostridium Botulinum,* there must be growth in order to produce toxins. No growth is detected at pH lower than 5.5 if temeprature is kept lower than 16°C. At higher pH, there is no growth at 3.5°C and lower. Oxygen-permeable films don't prevent toxigenesis if the food is temperature-abused.

Quality Assurance

In order to assure bacteriological quality of the finished food product, additional hurdles would prevent safety hazards and conditions that stimulate production of thermo-resistant toxins from developing in the product. The synergetic effect of the combinations of the limiting factors would prevent growth.

The most determinant factors to insure safety during the shelf-life of sous-vide products are: the initial concentration of bacteria in the raw materials; and that refrigeration is properly controlled.

But other factors will increase the safety of the food stuff:

- high F value during the heat treatment.
- pH.
- aw and rH.
- packaging expertise.

The cooking process has to be devised to maximize the bacteria destroying rate with no adverse effects on the quality, by combining F and C values. The F value is affected by:

- initial concentration of bacteria before the heat treatment.
- the severity of the heat treatment in relation with time and temperature.
- the thermal diffusivity into the food, depending on the nature of the food itself; the geometry of the package (surface in contact with heat); the presence of entrapped gas in the food. Although CO_2 has a bacteriostatic effect, it insulates the surface of the food and impedes heat transfer.
- the type of heat treatment: steam is more effective than water for heat transfer at the surface of the food.
- the thermo resistance of bacteria.

In France, the reference is *Streptococcus Faecalis,* because of its high heat resistance.

Z = 10°C
D at 70°C = 2.95 min.
p10° = 100 for 21 days shelf-life
70° = 1000 for 42 days shelf-life

Acidification of the foodstuff, although limited so the food remains palatable, increases the resistance to bacterial growth.

Salt and sugar levels are also too low to affect the water activity in sous-vide product (around 1%), but the Japanese manufacturers use control of the aw in MAP products. Distribution is made at temperatures around freezing point (-1°C to -5°C depending on the product), effectively lowering the aw in those "super-chilled" products.

After the product is packaged, cooked and chilled, it is important to maintain the internal conditions required to preserve its microbiological quality.

The growth of aerobic bacteria is effectively controlled by the removal of oxygen, but it is not proven that anaerobics cannot grow in packages where oxygen is present.

And as said earlier, air presence in the package will decrease heat transfer rates and retard heating. Complete deaeration of the product is essential for the safe processing of sous-vide products.

The packaging is done either in preformed trays or in flexible pouches thermoformed by roll stock machines; the materials used should maintain barriers to oxygen, or organic gases in presence of steam. There should be no migration of polymers into the food, or absorption of flavor compounds. The quality of the heat seal is equally important to determine the integrity of the package. Stretching and creasing increase the permeability of the film.

Quality Control and Monitoring

A total production audit should be instituted. Temperatures of ingredients are to be checked at every step of processing. The total processing times, from the moment the goods are received to the moment they are being cooked, are to be recorded and kept as short as possible.

Rapid microbial tests have improved the speed at which

products can be processed and then can be coupled with conventional tests.

Plant layout has to be designed to prevent any cross-contamination of cleaned and ready-to-cook food from raw products, dirt and soilage. The components of the meals are moved around following strict "go forward" protocols. Excellent hygienic conditions should prevail, and ample refrigerated spaces must be allowed.

After the packaged food has left the plant, means are to be taken so its microbial quality is maintained during its shelf-life, mainly through temperature controls. Transit temperature recorder should be used during transportation. These indicators could also be used as the basis for a legal claim if a shipment had spoiled or temperatures were abused.

Time-temperature indicators could be indicative of microbial quality deterioration in fresh chilled foods. They correlate with specific quality attributes of refrigerated food, and the effect of temperature on response rate is related with Arrhenius equation, or with exponential curve.

On the other hand, it is difficult to predict bacterial growth with temperature increases, at refrigerated temperatures. Time-temperature indicators are not modulated for every type of food, since the evolution of microbiological population is closely related to raw materials quality and processing techniques, and a new indicator should be used for every new product. They are nonetheless useful in identifying links in distribution chains.

There is a concern that food packaged under anaerobic conditions (oxygen levels below 4%) allows growth of potentially harmful bacteria, while inhibiting spoilage bacteria which produce offensive odors and taste which serve as a warning to consumers. But rejection is very subjective and as a safety warning system, this is not very effective at best. The sensitivity to off-taste and odors varies with each individual, not to mention every culinary culture. At higher temperature abuse, either in aerobic or anaerobic conditions, toxin production occurs before sensory rejection in food inoculated with *C. botulinum* type E. Gas flushing with CO_2 could delay sensory rejection at +8°C or +12°C, but not at 4°C, and in straight vacuum packaging, the time of rejection is the same as with oxygen-permeable packages (Post, Lee, Solberg, Furgang Specchio, Graham 1985) Organic spoilage is not always related to toxigenecity.

The Feasibility of Sous-Vide

The only way to ensure safety in sous-vide is to control the bacteriological quality of the food at every step of the process and the distribution (critical control points) and build in safeguards.

At the producer level:

- By the nature of the product, evaluate the types of bacteria expected.
- Strict specifications on raw materials, equipment and packaging.
- Temperature controls at every step of processing.
- Tight production scheduling.
- Check on the gaseous environment of the package.
- Integrity of the package: headspace, seal integrity, minimal stretches and creases.
- Microbiological tests on finished products.
- Good maintenance and sanitation procedures.
- Continuous staff training, good labor relations.
- Perfect inventory control.
- Safeguards for distribution and retail: Insulated packaging ("Thinsulate," Adenko); time-temperature indicators; accurate and clear instructions on how to handle and reheat the product; temperature recording device for expedition; super-chill distribution.
- "Just-in-Time" delivery.
- Closed relationships with distributors, retailers and customers.

At the last conference of the International Association of Refrigerated Warehouses, Gene D. Hoffman, President of Retail Corporate Strategies, talked about the importance of a specialized refrigerated distribution system for freshly prepared, limited shelf-life, chilled products.

At the distributor and retailer:

- Tight inventory control, zero stock.
- Sold through special cabinets devoted to chilled prepared foods (lower temperature).
- Trained staff for handling and checking the product for quick turnovers.

Conclusion

The process called sous-vide, prepared in the right conditions, is the ultimate combination of hurdles that guarantee a safe product under reasonable conditions. Proper applications of known technologies, such as canning and vacuum packaging of fresh foods, helped develop successful "sous-vide" products. Further breakthroughs in more recent technologies, such as microwave pasteurization, new films, controlled release of gases and acidulants, super-chill distribution systems, smart packages acting as mini-thermos, etc., have enabled us to improve the shelf-life, quality and safety of the products, to a level where it is feasible to distribute sous-vide meals over large distances.

But the main keys to success with sous-vide are still freshness, the safety of the consumers using those products, and superior taste compared to frozen or shelf-stable products.

APPENDIX
French Regulations

The "Services Veterinaires" in France, the equivalent to Agriculture Canada or USDA, have regulated every aspect of sous-vide processing.

Plant layout has to be designed according to very strict rules to prevent any cross-contamination of cleaned and ready-to-cook food from dirt and soilage. The components of the meal are moved around following strict "go forward" protocols. Some plants follow "clean-room" standards, but good hygienic conditions will do.

Every product has to be approved by the "Services Veterinaires" for its composition and ingredients, procedures of processing and microbiological quality. The tests are performed either by the "Services" laboratories or private labs approved by the "Services," such as the SSHA directed by

Dr. Bruno Goussault. He became the leader in microbiological studies for sous-vide and worked with most medium to large companies in France.

For shelf-life allocation, a request is put through CNERPAC. For each product they would make:

- A process examination.
- A study on temperature control of distribution from raw material to the stores.
- MAP control by chromatography.
- Microbiological testing at +3°C on delays excessing those asked.
- Temperature abuse tests at +9°C and +20°C.
- Organoleptic assessment.

Prepared entrees are considered separately if they contain meat, poultry, rabbit and game; offals or fish; if they are made with flexible pouches or trays; and if they contain liquids: soups or sauces.

If a company requests an extension of the shelf-life, they go through the whole exercise again. On a statistical basis, 80% of the requests are granted for 21 days shelf-life. Oddly enough, some companies can apply for a much longer shelf-life, but because of public perception of what "fresh" should be, they will still date their products for 21 days.

Of the 20% of requests which are rejected, it is mostly for excessive total mesophilics count, coliforms or moulds in sauces and pastas.

Products cooked at an internal temperature of minimum 65°C, and F_{70}^{10} value for *streptococcus faecalis* of over 100, could have a shelf-life of 21 days. They have to be free of pathogens: *staphylococcus, salmonella, choliforms, streptococcus, sulfito-reductors* (anaerobics). For an extension to 42 days, F_{70}^{10} values are over 1000, cooked to an internal temperature of at least 70°C.

A standard production sheet has to be completed for production audit by the government. The temperature of ingredients is checked at every step and the total processing time, from the moment the goods are received to the moment they are being cooked, has to be as short as possible.

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