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PACKAGING APPLICATIONS FOR READY-TO-EAT FOODS

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ABSTRACT

Packaging of ready-to-eat (RTE) foods is an important topic because the application of packaging has direct effects on shelf life of these products. Ready-to-eat foods have generally short shelf life which mainly arises from processes for making convenient food. Shelf life can be extended with some chemical additives but this affects natural behavior of food product which is not approved by consumer nowadays. In this context, different packaging techniques and materials become the choices for extending shelf life. In this study, for improving packaging solutions of ready-to-eat foods, microbiological concerns and deteriorative parameters of different RTE food types are examined, possible processing techniques are researched and suitable packaging techniques and materials are investigated based on the type of foods and processes. Modified atmosphere packaging, vacuum packaging and skin packaging are observed as main packaging techniques and plastic materials which are generally used as tray/lidding foil or pouches are main packaging materials for RTE food packages.

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ABBREVIATIONS

Alu	Aluminum foil
BOPP	Bi-oriented polypropylene
CAC	Codex Alimentarius Commission
CPET	Crystallized polyethylene terephthalate
EPS	Extended polystyrene
EVA	Ethylene vinyl acetate
EVOH	Ethylene vinyl alcohol
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FSIS	Food Safety and Inspection Service
GMP	Good Manufacturing Practice
HACCP	Hazard Analysis at Critical Control Points
HDPE	High-Density Polyethylene
HPP	High Pressure Processing
IAEA	International Atomic Energy Agency
LDPE	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
MAP	Modified Atmosphere Packaging
MRE	Meals, Ready to Eat
OPP	Oriented Polypropylene
PA	Polyamide
PE	Polyethylene
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PUFA	Polyunsaturated fatty acid
PVC	Polyvinyl chloride
PVDC	Polyvinylidene chloride
RH	Relative Humidity
RTE	Ready to Eat
S&D	Security and Dependability
USDA	United State Department of Agriculture
UPVC	Unplasticed Polyvinyl chloride
VP	Vacuum Packaging
VSP	Vacuum Skin Packaging

1. INTRODUCTION

New life styles that appears with changes in social and economic structure of society, brings its own rules. Life styles of individuals play an important role in selection and consumption of foods. In Turkish society, with industrialization and urbanization, intense participation of family members, especially woman, to business life affects the time spent for cooking in the kitchen (Sürücüoğlu & Çakıroğlu, 2000). Besides increasing female labor, extended working hours, tendency to eat healthy, reducing cooking abilities, decreasing importance of traditional mealtimes, welfare of consumers and selfhood life of people also affect the rising demand for convenience property of foods (Tudoran et al., 2012). According to Buckley et al. (2007) convenience as part of foods can be explained as minimization of time period and effort for purchasing, storing, preparation and consuming food. In this point, ready-to-eat foods which are the main type of convenient foods become the solution of these problems and demands.

Until recent years, there were few foods which are preferred for short time cooking like pasta, pizza and mantı; however, these types of foods do not fulfill the meal expectation of families. Therefore, perception of convenient food changed and variety of these foods is extended with some processing and packaging techniques. Ready-to-eat foods which include these wide range of foods are defined as foods which are pre-cooked or prepared and packaged with a suitable material and provide quick meal option to consumer (Spencer, 2005). Ready-to-eat foods save natural characteristic with packaging techniques such as vacuum packaging and modified atmosphere packaging and without chemical preservative use (Arvanitoyannis & Andreou, 2012).

In this research, ready-to-eat foods are firstly classified according to preparing requirement before consumption. Then, microbial concerns which are crucial for safety of RTE foods, processing techniques directly effecting taste and texture and deteriorative parameters for different types of RTE foods are reviewed. Packaging techniques, packaging materials and suitable storage conditions for RTE foods are also investigated separately and compared with each other.

2. READY-TO-EAT FOODS

2.1. Definition

Ready-to-eat food expression has some different definitions with regard to extend of it. Based on the study of Paulus (1978) (as cited in Harris & Shiptsova, 2007), it can be said that, there are five phases of ready foods: ready to process, ready to kitchen process, ready-to-cook foods, ready-to-heat and ready-to-eat foods. This classification is predicated on treatment and processing requirement of ready foods. Also, there are some definitions which directly emphasis on one approach. For example, Tucker (2005) states that ready-to-eat foods can be defined as combination of precooked foodstuffs within a package and it is sold by cold retail chain to achieve rapid meal solution to consumer (Tucker, 2005). In this definition it can be said that only requirement to a heating process gives the RTE property to foods. Also, according to the Codex definition (CAC/GL 22-1997), “ready-to-eat food includes any food (including beverages) which is normally consumed in its raw state or any food handled, processed, mixed, cooked, or otherwise prepared into a form in which it is normally consumed without further processing” (FAO, 2001).

When the areas for use of RTE foods is analyzed, it can be said that RTE foods have wide consumer range from house scale to catering companies, hospitals, hotels and restaurants, military services and camping (Dawson, 2008). Moreover, some inventions are made for simplifying consumption of the ready meal under difficult conditions. For example, flameless heater product for RTE meals is the one of the major invention for the military services and people in camping areas where reaching to a flame is difficult or using it is dangerous.

2.2. Classification of RTE Foods

In this research, RTE foods are classified and studied as precooked products, directly consumed products and products to be cooked. Precooked RTE foods which only need low degree of cooking to serve, are pre-cooked meals, meats and poultries; directly consumed products are cured meats, smoked fishes, fresh cut fruits and vegetables, salads, sandwiches, some desserts and delicatessen foods and finally, products to be cooked are shaped meat balls and baked foods such as pizza and fresh pasta. This classification is based on post process need of RTE foods.

2.3. General Microbial Concerns for RTE Foods

Ready-to-eat foods which do not generally need further processing have serious microbial risks. During preparation of RTE foods which include processing, packaging and human handling like slicing or cutting, cross contamination can be possible (Jaroni et al., 2008). Therefore, hygiene practices are non-ignorable requirements for RTE food production. Despite the fact that initial microbial load of raw meat can be decreased with thermal process, some bacterial spores and thermoduric bacteria can continue to live which is a problem for ready-to-eat foods (Mendonca, 2010). There are four major foodborne pathogenic bacteria which are hazardous for RTE foods and these can be listed as *Listeria monocytogenes, Salmonella enterica, Escherichia coli* O157:H7 and *Clostridium perfringens.* Also, as it can be seen at Table 2.1., these bacteria are the major microbiological reasons of recalls in some countries.

Table 2.1. Reasons for meat and poultry recalls in the US (Dawson, 2008)

Year	*Listeria*	*E. coli*	*Salmonella*	Other bacteria
1994	17	3	0	3
1995	11	5	2	2
1996	6	2	1	1
1997	3	6	1	5
1998	7	13	2	2
1999	30	10	6	0
2000	36	20	4	0
2001	25	26	2	0
2002	40	24	4	0

2.3.1. *Listeria monocytogenes*

Firstly, *L. monocytogenes* which have caused many outbreaks within decades is ubiquitous risk for RTE foods such as vegetables, meat, poultry, seafood and dairy products (Brackett, 1988). Also, some salads with meat, seafood and cheese have risk about *L. monocytogenes* (Smittle, 2000). According to researches, some sources facilitate the growth, survival and transfer of pathogens; for example, growth and survival of *L. monocytogenes* is increased with using pesticides for vegetable crop cultivation (Jaroni et al., 2008). Furthermore, production areas, processing equipment and the hygiene of workers can bring about contamination where raw meat using exists. Also, re-exposing of cooked meats to production environment during packaging has risk about existence foodborne pathogens on conveyor belts, condensation trickle, contaminated air filters or the workers (Jaroni et al., 2008).

There are some strategies for controlling *L. monocytogenes* in RTE foods. According to announcement of FSIS, application of HACCP (Hazard Analysis at Critical Control Points) at some processing steps, checking of end-products and instructing consumer about the danger of listeriosis and stopping of microbial growth are the main strategies (FSIS, 1999). Also, environmental sample survey, S&D (security and dependability) processes practice and development sanitary of equipment and plant design are examples of environmental control strategies (Malley et al., 2015). When the controlling methods are studied for every kind of RTE foods, it can be seen that washing treatment with or without sanitizer has effect on RTE fresh fruits and vegetables to remove *L. monocytogenes.* Also, some internal parameter changes of foods like decreasing of water activity, acidification which gives low pH, integrating antimicrobials in meat products and modified atmosphere packaging provide controlling *L. monocytogenes.* Besides chemical treatments and physiological changes, some physical treatments like thermal treatments, high pressure processing, drying, smoking and irradiation are used for passivation of *L. monocytogenes* (Jaroni et al., 2008). Tough *L. monocytogenes* is destroyed with thermal processing, it can grow under refrigeration temperature on the food product which is contaminated during post-processing (Su & Liu, 2010).

2.3.2. *Salmonella enterica*

Another important bacteria for RTE foods which causes food borne illnesses is *Salmonella enterica.* According to researches, RTE foods which are susceptible to this bacteria, are mainly meat and poultry products, seafood, sauces, salad dressing and some deserts (USFDA, 2009). The causes of *Salmonella enterica* extensity in animal based products are enteric characteristic and high endurance to utmost environmental conditions of microorganism (Jaroni et al., 2008). Also *Salmonella enterica* is the major concern for minimally processed fruits and vegetables.

Contamination ways are generally fecal matter or dirty water usage for fruits and vegetables, intestinal contents which are critical during evisceration, post-harvest processing and cleaning of meat (Jaroni et al., 2008).

Eliminating methods for Salmonella contamination are adequate cooking for meat products, good agricultural practices and good hygiene practices for minimally processed fruits and vegetables. Moreover, general growth requirements for *Salmonella* which is quite wide, includes 7°C to 46°C temperature range, minimum 0.94 water activity and 4.4 to 9.4 pH range (FSIS, 2008).

2.3.3. *Escherichia coli O157:H7*

Other microbial concern for RTE foods is *Escherichia coli* O157:H7 which is serious food pathogen. Besides being especially harmful to ground beef (Kaçar, 2005), it is also associated with fresh produces like salads, leafy greens, lettuce coleslaw and grapes (Jaroni et al., 2008). It is also considered that, outbreaks about *E. coli* generally originate from cross contamination during processing; also, fertilizer and watering in the growing area; washing water, equipment, inadequate handling practice in the processing area; during transportation and finally storage apparatus can cause contamination of RTE foods (Jaroni et al., 2008).

There are some controlling ways for contamination of *E. coli* O157:H7. For example, irradiation sterilization which is common in America is used for inactivating of bacteria which can easily spread with mincing process in ground beef (Kaçar, 2005). Also good manufacturing practices and good farm practices are the main action for decreasing contamination with *E. coli.* Some ways of decontamination of FDA and USDA can be lined as using antimicrobial on animal carcass, hot water and steam applying, steam vacuuming for meats (Jaroni et al., 2008). Moreover, pasteurization, labelling, irradiation and disinfection are used as controlling strategies for *E. coli.*

2.3.4. *Clostridium perfringens*

Final major bacterial risk for RTE foods is about *Clostridium perfringens* which is spore forming bacteria. It is generally considered for foods like meat and poultry which has high protein content; moreover, feces contamination from infected animals and soil from skin and piles are the way of contamination with *Clostridium perfringens* of RTE meats (Cutter et al., 2012). In addition to animal based products, it is general concern about vegetables products and undercooked or treated foods (Jaroni et al., 2008). According to Crouch and Golden study (2005), thermal processes can destruct the vegetative cells during production of RTE foods with the exception of semi-cooked RTE foods, although spores of the microorganism which are heat resistant cannot be destroyed during processes. Also, cooking process of RTE foods facilitates the germination of *Clostridium perfringens* spores (Dominguez & Schaffner, 2009).

According to researches, there are 2 main parameters for controlling *Clostridium perfringens* based food borne illnesses. Jaroni et al. (2008) state that temperature fluctuations and cooling rates and periods are effective on germination, growing and spreading of *Clostridium perfringens* on RTE foods. All studies are taken into consideration, it can be realized that cooling period of cooked products is quite critical. According to FDA registers, while duration of cooling process of cooked foods from 60°C to 21°C is recommended as 2 hours, this duration is 6 hours for decreasing to 5°C (FDA, 2001). Acceptable cooling period is 25% longer for cured meats (Juneja et al., 2006). Also some chemical prevention methods can be used like addition of sodium citrate and sodium diacetate which restrict the outgrowing and germination of *Clostridium perfringens* during reaching to chill temperatures after cooking (Knipe, 2010).

2.3.5. Other microorganisms

Researches show that besides these four major pathogen bacteria, there are also some microorganisms which have negative effects on RTE foods. According to Hwang (2010), *Staphylococcus aereus* which has danger for salads with egg, tuna, chicken and potato; *Campylobacter jejuni* which has second severe risk for salad vegetables after poultry products and *Aeromonas spp.* which is also critical for raw vegetables have risk for RTE products. *Aeromonas spp.* can survive at lower pH and has psychotropic properties which give growing chance to bacteria under refrigeration temperatures. Also, Liu and Su (2010) assert that the main microbial hazards related with RTE seafoods are caused from *L. monocytogenes*, *Vibrio parahaemolyticus*, *Vibrio vulnificus*, *Clostridium botulinum* and some viruses Furthermore, thermoduric, psychrotrophic facultative anaerobic bacteria and some bacterial spores are risk for RTE meat products. Mendonca (2010) says that these thermoduric bacteria are certain Lactobacillus, Micrococcus and Enterococcus which have endurance to heating process above 71.1°C; psychrotrophic facultative anaerobic ones are *Listeria*, *Lactobacillus*, *Leuconostoc* and certain *Clostridium spp* which can reproduce in controlled atmosphere and vacuum packages (Mendonca, 2010). Also some other microbial spoilage sources and spoilage defects for cooked meat product can be seen at Table 2.2.

Table 2.2 Summary of some microbial spoilage defects in vacuum packaging and modified atmosphere packaging cooked meat products (Mendonca, 2010).

RTE meat product	Spoilage Indicator	Microorganism
Vacuum-packaged uncured turkey breast meat	H_2S odor and gas	Psychrotrophic clostria
Vacuum-packaged roast beef	H_2S odor and gas	Psychrotrophic clostria
Vacuum-packaged bologna	Greening	*Carnobacterium viridans*
Frankfurters packaged in modified atmosphere (CO_2 and N_2)	Greening	*Weissella viridescens*
Vacuum-packaged wieners and bologna	Greening/slime	*Weissella viridescens*
Vacuum-packaged luncheon meat	Souring	Lactic acid bacteria
Vacuum-packaged luncheon meat	Yellowing	*Enterococcus casseliflavus*

3. PROCESSING TECHNIQUES FOR RTE FOODS

Foods are processed for mainly giving edibility to foods, preventing microbial spoilage and risks, increasing shelf life and providing convenience property to food products. Processing techniques of foods are basically classified as thermal processing and non-thermal processing which are generally novel technologies. These both of methods are preferred for production of ready-to-eat foods. When processing techniques for RTE foods are examined, cook-chill processing, pasteurization, sterilization, *sous vide*, high pressure processing, irradiation, ohmic heating, microwave processing, smoking and curing can be considered separately.

3.1. Cook-Chill Processing

Association of cooking and chilling processes is protection method for the ready to eat foods and meals which are growing in demand day by day. This combination provides freshness and convenience to the food products which is generally preferred for minimally processed foods. Fresh-cut vegetables, ready sandwiches and meals are studied within this scope (Venugopal, 2005). Definition of cook-chill process is that after food is cooked, chilling operation is achieved immediately, and finally product must be stored at 0-3°C which is under control (Moir and Szabo, 1998). Based on researches, it can be said that cook-chill process can be applied as conventional cook-chill, MAP (modified atmosphere packaging) cook-chill and *sous vide* which is different method but can combined with cook-chill process.

Proposed shelf life for conventional cook-chill products is 5 days which is statement of Department of Health and is cited in Arvanitoyannis and Andreou. Also this duration can be protracted with modified atmosphere, vacuum packaging (Arvanitoyannis and Andreou, 2012) and cooking under vacuum, hot filling, low dose irradiation, sanitary and aseptically packaging (Venugopal, 2005).

Pasteurization which reduces the initial microbial load is also used as thermal part of process and temperature range can be change between 65°C and 95°C. Moreover, 70°C heating is needed for cook-chill products before consumption (Venugopal, 2005).

3.2. *Sous Vide*

Sous Vide is the French term with meaning of under vacuum and application of it can be described as raw or partially cooked foods under temperature and time control within vacuumed pouches which has endurance to heat (Baldwin, 2011). Foods which are vacuumed in plastic pouches are pasteurized at controlled temperatures, this temperature is between 70-80°C internal temperature for meats, after heating, chilling achieved via ice bath in general and stored at between 0-3°C (Venugopal, 2005). Vacuum packaging with afterwards cooking is the main difference between *sous vide* processing and other cook-chill processing. The main advantages and disadvantages of *sous vide* processing compared to conventional cooking is shown at Table 3.1.

Table 3.1 Advantages and disadvantages of *sous vide* processing compared to conventional cooking (Tansey and Gormley, 2005).

Advantages	**Disadvantages**
Diminished post process cross contamination risk	High psychrotrophic *Clostridium botulinum* spores risk if undercooked product or temperature abuse exist
Prolonged shelf life at 0-3°C	Requirement of staff education costs
Maximum keeping of aroma, texture, flavor and nutrients	High equipment costs
Centralized production	-
Decreased cost of raw materials	-
Enlargeable product range	-

First disadvantage of *sous vide* at Table 3.1 is the main problem about process which caused from mild heat treatment and anaerobic conditions, and decrease the admissibility of the method in the world (Venugopal, 2005). Also some substances and processes are developed and combined for preventing microbial growth and enzyme activity for food products which is named as hurdles and types of hurdles for *sous vide* and cook-chill processes are demonstrated at Table 3.2.

The shelf life of *sous vide* processed products which change with heating time and temperature is between 6-42 days (Schellekens, 1996) but in general 21 days at 0-4°C (Tansey and Gormley, 2005). And some suggested thermal processing time and temperature for *sous vide* are demonstrated at Table 3.3.

Table 3.2 Types of hurdles for *sous vide* and cook-chill processes (Ghazala and Trenholm, 1998).

Physical Hurdles	Physicochemical Hurdles	Microbiological Hurdles
Heat processing	Water activity	Competitive microflora
Storage temperature	pH	Starter cultures
Packaging	Redox potential	Bacteriocins
MAP	Salt	Antibiotics
	CO_2, O_2	
	Organic acids	
	Ascorbic acid	
	Spices and herbs	

Table 3.3 Some suggested thermal processing time and temperature for *sous vide* (Greed, 1998).

Temperature/Time	Purpose	Aimed microorganism
70°C for 40 minutes	6 days (0-4°C) shelf life	*Enterococcus faecalis*
70°C for 100 minutes	21 days (0-4°C) shelf life	
70°C for 1000 minutes	42 days (0-4°C) shelf life	
70°C for 2 minutes	5 days (0-4°C) shelf life	*Listeria monocytogenes*
80°C for 26 minutes	Maximum 8 days (0-4°C) shelf life	*Clostridium botulinum* type E
90°C for 4.5 minutes		
90°C for 10 minutes	Minimum 10 days (0-4°C) shelf life	*Clostridium botulinum*
70°C for 2 minutes	Short shelf life and reliable storage temperature	*Listeria monocytogenes*

3.3. Pasteurization

Pasteurization is the thermal treatment method that aim of it is the preventing activation of vegetative cells, not spores and it is generally used for acidic or refrigerated foods which has inhibiting effect on spores of pathogenic bacteria (Skipnes and Hendrickx, 2008). This process is generally applied to ready to eat foods as in-package pasteurization. Dawson (2008) states that preventing contamination till opening of the package gives impressiveness to the method in ready-to-eat meat products particularly. Also, mortality of method depends on holding period and temperature of it. However, obtaining better lethality effect with minimum process duration is the main difficulty due to excessive thermal process influence organoleptic properties of food product (Mangalassary, 2012). Pasteurization which is generally ended with rapid cooling can be classified under cook-chill processing technique.

3.4. Sterilization

Sterilization is the operation which destroys the all viable microorganisms such as yeasts, molds, spore forming or vegetative bacteria in food product and provides increased shelf life at ambient temperatures (Ramesh, 2007). Quality and nourishment properties of foods can decrease with entire sterilization; therefore, commercial sterilization which does not affect sensory properties as complete sterilization and provide enough microbial prevention is applied to the foods. (Ramesh, 2007). Sterilized ready to eat products are especially desired for places where the cold chain is not trustworthy.

3.5. High Pressure Processing

High pressure processing (HPP) is the common non-thermal operation in food industry which provides decreasing the unwanted effects on quality of thermal processes. These unwanted effects are diminishment of vitamin amount, flavor and bioavailability of fundamental amino acids and changing of aroma and color. Also Rastogi (2010) states that, HPP is the useful especially for foods with high moisture content like fruits, vegetables, RTE meats and sauces.

HPP which is achieved pressure application between 100-1000 MPa can be applied to fluid or solid food products with or without package. Although this pressure can be raised up to 1000 MPa, high pressure processing equipment's are manufactured with maximum 600 MPa pressure applications (Özlü and Atasever, 2007). According to Tucker (2005), while this pressure destroys the microorganisms, effect on spores and enzymes relatively limited. Therefore, some hurdles such as chilling and low pH are needed for inhibiting spoilage. As an example for shelf life HPP RTE foods, it can be given that, shelf life of packaged RTE sliced roasted beef and turkey is longer than 27 days which is provided with 591 MPa pressure and 2°C storage (Knipe, 2010).

Packaging material for HPP is also important issue. According to Juliano et al. (2010) PP, PE, PET and EVOH which are used as alone or lamination are general materials for high pressure processed ready meal packaging. Also, hurdle of HPP and MAP which is achieved with giving some gaseous to package provides to increase sensibility to pressure of *E. coli* and *L. monocytogenes* for RTE poultry products (Venugopal, 2005). Moreover, endurance of product package up to 15% volume changes must be high and during revert to first shape, it must not lost seal entirety and permeability features (Rastogi, 2010).

3.6. Microwave Processing

Microwave processing is the thermal processing which provides the heating from electromagnetic waves having 950 and 2450 Hz frequency for pasteurization at about 80°C and sterilization at about 121°C respectively. Pasteurization of the food and package are achieved with created heat from microwaves and product with long shelf life is obtained by combination with chilling (Tucker, 2005). Advantages of the process are quick temperature rise, high quality for heat sensitive foods and simple clean-up property (Ahmed & Ramaswamy, 2007; Tucker, 2005). Commercial pasteurization and sterilization of the RTE foods are performed with microwaves for improved microbial elimination and food quality.

Packaging is also paramount for foods which are processed in microwaves. There are three types of microwavable materials and these are categorized according to permeability property as microwave transparent, reflective and absorbent. Transparent materials which are required for effective processing are paper and plastic for frozen ready meals, reflective materials, generally aluminum, are used for multi-ingredient meals that there are some ingredients with necessity of low heating and finally absorbent materials are used for giving crunchiness and brown color to the foods like frozen pizza, waffle etc. (Yam & Lai, 2004). Packaging materials will be detailed in Section 5. Moreover, bursting of package is the considerable problem for microwave applications and some new techniques are developed for this problem such as package with re-closable valve that position of valve is adjusted as pressure and temperature, so bursting can be prevented (Bart Wehman, personal communication, 2015).

3.7. Ohmic Heating

In this process, food material is heated by passing electrical current within foods which act as a resistance (Kaletunç, 2009). According to research, ohmic heating is used for especially RTE fruits and in package sterilization of ready meals (Sastry et al., n.d). According to Ruan et al. (2001), there are some advantages of ohmic heating and these are listed as heat transfer is not limited during creation of heat in contrast to traditional methods, higher temperatures can be obtained for particulate foods and it minimize the mechanicals harms and losing of nutrition and vitamin value.

Ohmic heating has special pouch for achieving heating process. Pouch with foil electrodes generally is composed of polypropylene based laminations which have endurance to sterilization temperatures (Somavat, 2011).

3.8. Irradiation

Ionizing radiation which is performed with superior energy per atomic passage is utilized to provide hygiene and protection of foods from microbial spoilage by irradiation processing (Irawati & Sani, 2012). Advantages of the irradiation are that microbiological grade of food is improved with preserving physical state of food, recontamination of packaged products is inhibited, psychrotrophic microorganisms are destructed easily which is problem for chilling storage and risk of disease-causing microorganisms is decreased (IAEA, 2003).

Dose usage is determined based on target food and specific purposes. For example, sterilization of ready meals is achieved with maximum 50 kGy which provides to destroy microorganisms even spore formers and extending shelf life of chilled ready meals is done with 0.5-3 kGy dose range which can damage to spoilage microorganisms (Wilkinson & Gould, 1996). Also some RTE foods, irradiation dose, packaging methods and shelf life of products are shown in Table 3.4.

Table 3.4 Some irradiation processes for RTE foods and packaging solutions (Patterson & Stewart, 2003; Thayer, 2003)

Product	**Packaging Solution**	**Dose**	**Shelf life**
Smoked sausage	MAP (20%CO_2, 80% N_2)	2 kGy	+2 months (at 3-7°C)
Sliced Ham	LDPE film	6 kGy	7 weeks (at 0-4°C)
Vegetable Salad	PVC film	2 kGy	1 week (at 1-3°C)
Fruit salad in gelatin	PP trays with lids	2 kGy	1 week (at 1-3°C)
Pizza (with antimicrobial coating)	_	1 kGy	21 days
Fish-based and chicken-based dishes	Vacuum packaged in laminated pouches	45 kGy	18 months (without refrigeration) / Sterile
Ready-to-eat smoked and cured fish	_	7-11 kGy	12 weeks (ambient temperature)
Intermediate moisture meat cubes (Ready to use)	Vacuum packaging	10 kGy	9 months (ambient temperature) / Non-sterile
Cooked meats, fish, bean curd, preserved radish, date and pickle	Vacuum packaging	2.5 kGy	2 years (ambient temperature)
Ready meals	_	2 kGy	14 days (< 3°C)

3.9. Smoking

Smoking is food preservation and flavoring method which is performed at closed areas with smoke of some trees in determined periods. There are three types of performing ways and these are specialized for different foods as cold, warm and hot smoking. Details about these methods are shown in Table 3.5.

Curing also is used before cold smoking process for meats because spoilage risk exists which comes from slight thermal treatment, moisture of food and overlong processing. In contrast to cold smoking, there is no need to pre-curing with salts for hot smoking (Park & Park, 1992). Shelf life of some smoked fish types like cod, kipper and salmon are 14, 10, 20 days respectively at 5°C (Gibson, 1994). Also, generally non-opaque, shrink-wrapped films which prevent entering air to package and aroma loss from food are used for smoked products (Tucker, 2011).

Table 3.5. Smoking types (Simko, 2009; Park & Park, 1992).

Type of smoking	**Temperature range**	**Purpose**	**Applied foods**
Cold smoking	15-25°C	Aromatization	Uncooked sausage, raw ham, fermented salami, meat, fish
Warm smoking	25-50°C	Aromatization and mild pasteurization	Frankfurters sausage, meat pieces, gammon
Hot smoking	50-85°C	Aromatization and thermal treatment	Hams, salami, sausages, meat, fish

3.10. Curing

Curing is a process which extends the shelf life of product and develops the aroma and texture as pioneer to drying process like salting, fermentation, marination and smoking. Also curing contributes to microbiological, aromatic and textural properties of meat (Doğu & Sarıçoban, 2015). Martin (2001) states that curing agents are mainly salt, sweeteners (sucrose, dextrose and corn syrup), nitrite and nitrate. All cured products are not ready to eat; some of them need further cooking, brining or dying processes. General cured RTE foods are cured salmon, ham or some traditional meat products. For example, pastırma which is special for Turkey is the cured, dried, pressed and coated with fenugreek product (Doğu & Sarıçoban, 2015).

According to Toldra et al. (2004), the most important parameter which affect stability for sliced fermented and cured meats is oxygen. Therefore, modified atmosphere and vacuum packaging (VP) are common methods for packaging of cured; also, active and intelligent packaging are used for becoming solution for this problem. Moreover, general gas composition for MAP for cured meats is 20–30% carbon dioxide and 80–70% nitrogen (Toldra et al., 2004).

4. MAIN DESTRUCTIVE PARAMETERS FOR RTE FOODS

Hazards which can cause deterioration of foods and conditions which foods are exposed to are significant parameters for determining shelf life of product, suitable packaging methods and materials. In here, intrinsic and extrinsic factors which affect shelf life of product will examined for each types of ready to eat foods.

Firstly, ready meals are the precooked products which are mainly affected from oxygen which should not be higher than %1 percentage in package and microbial growth. Also, reduced temperature which can be maximum 4°C is required for ready meals because MAP application can be efficient at low temperatures that solubility and preventive activity of CO_2 are increased with at low temperatures (Subramaniam, 1993). Ready meals and main deterioration reactions are shown in Table 4.1.

Table 4.1 Some destructive reactions for ready meals (Calligaris & Manzocco, 2012)

Food Product	Deterioration Reaction	Effects on Product
Frozen ready meals containing fruit and vegetable derivatives	Enzymatic reactions	Color, flavor, texture changes, nutrient and bioactive compound loss
	Oxidative reactions	Off-flavor formation, color changes, nutrient and bioactive compound loss toxic compound formation
Chilled ready meals	Bacterial and mould growth	Off-flavor formation, visible colony formation, texture and color changes

Effective factors on shelf life of ready to eat fresh-cut fruits and vegetables are summarized according to Day's study and shown at Table 4.2.

Day (1993) states that respiration rate of fruits and vegetables are affected by cutting operation, temperature of environment and MAP. Rising storage temperature causes increasing of respiration rates which reduces shelf life of product. Also, while acidity of some fruits like lemon, apple, orange are high; most vegetables have higher pH values which requires low temperature storage below than 3°C for anaerobic packages because of *C. botulinum* risk. Moreover, because fruits and vegetables high a_w, modified atmosphere packaging and chilling temperature is used for preventing proliferation of spoilage and pathogen microorganisms. Also, ethylene activity which affects shelf life by the means of rapid ripening is decreased with MAP. Besides mainly temperature, relative humidity of environment is one of the extrinsic factor affecting shelf life. If the RH of environment is below than 80-95%, this causes water loss of fruits and vegetables that 3-6% of water loss is enough for decreasing quality.

Table 4.2 Factors affecting shelf life of RTE fruits and vegetables (Day, 1993)

Intrinsic Factors	Extrinsic Factors
Respiration rate	Harvesting
Acidity	Handling
Water activity	Hygiene
Biological structure	Temperature
Ethylene production and sensitivity	Water loss and relative humidity (RH)
	Packaging materials
	Packaging machinery
	Gas/product ratio

Raw or cooked cured meats are also affected by some factors during storage. Interaction between air and product is the cause of unstable color of these products and induces emerging of grey color. Also, fading can be obtained with light exposure to product. Moreover, if cured meats are stored at high temperatures and low humid areas, drying and alteration of meat pigments can be observed which are concluded with browning discoloration (Blakistone, 1999). According to Robertson (1993), discoloration, rancidity based on oxidation and microbial growth are the main deteriorations for cured meats.

Cooked meat products are mainly spoiled with post process contamination which is originated from inadequate hygiene and processing practices. Besides microbial spoilage, oxidation and temperature abuse bring about decreasing shelf life of products. Oxidation causes color changes of cooked meats and it is concluded with rancidity and off flavor (Mullan, 2002). According to studies, oxidation of polyunsaturated fatty acids has also influences on nutritional quality and textural properties of cooked meat products (O'Sullivan & Kerry, 2012).

Frozen RTE pizza is susceptible to oxidative rancidity and hydrolytic rancidity which is induced by moisture, temperature and endogenous lipases during storage. Lipase and lipoxygenase enzymes naturally exist in ingredients of pizza and they play a role in oxidation of PUFA (polyunsaturated fatty acid) which causes obtaining peroxides and off odor compounds. Oxidative rancidity of pizza end with emerging of aldehydes, ketones and short chain free fatty acids which causes decreasing quality of product (Smith, 1993). Also, temperature fluctuation must be avoided for frozen foods because of microbiological aspects. Moreover, Calligaris and Manzocco (2012) expressed that dehydration, lipid oxidation for salami frozen pizza and pigment discoloration for tomato sauce on pizza are the possible deterioration reactions for frozen salami pizza.

Fresh pasta is another RTE food which requires different approach for shelf life from dry pasta because of higher moisture content than dry pasta. Fresh pasta has approximately 24-30% moisture content and it is considered as perishable food; therefore, storage temperature can be maximum 4°C. Microbiological activity which includes bacteria, mold and yeast activity is the main spoilage reason of fresh pasta and it affects shelf stability and sensory properties of product (Lucera et al., 2014).

Some ready to eat foods like sandwiches are composed of multi ingredients, so considering destructive parameters for both rolls and other components is necessary for this type of foods. According to Galic et al. (2009), substantial factors which affect shelf life for fresh bakery products are mainly oxygen, temperature and moisture which are resulted with microbiological spoilage, hardening with losing moisture, staling and oxidative rancidity of product. Besides main component, all effective factors for every component of sandwiches must be defined. Also, moisture transfer between components can cause quality decreasing which arises from relative humidity of environment and moisture gradient of components (Roudaut & Debeaufort, 2011).

Another ready to eat products with multicomponent is delicatessen salad which is composed of cooked or uncooked fruits and vegetables, meat particles and dressing foods like mayonnaise and vinaigrette. Some type of delicatessen salads are potato salad, macaroni salad, ham salad, seafood salads and other salads to special for some areas (Hwang, 2010). Chilling at 0-5°C is required for storage of delicatessen salads because of perishable properties of all ingredients. Interaction between dressing and other components can be observed and affects stability during shelf life. Generally, dressing has high acidic content so it provides stability against microbial growth and also gives desired taste to salads (Brocklehurst, 1994). Most important spoilage reaction of these salads originates from cross contamination which can be prevented with GMP (good manufacturing practice), hygiene and handling during production, distribution and storage (Hwang, 2010). Also, deteriorative reactions for all ingredients must be taken into consideration during packaging and shelf life.

Finally, RTE desserts which are also called as dairy desserts are mainly custards, jellies, trifles, mousses and cheesecake like products. Shelf life effective factors for RTE chilled desserts are raw materials, product formulation, operation parameters, applying GMP, storage, distribution and consumer handling. During storage, some properties of RTE dessert must be preserved for quality like crunchy structure, stable aeration of dessert, emulsion stability and color. As an example of providing stability of products, milk based dessert which is suitable flora for microorganism must be stored at chilling temperatures. Also, rancidity can occur with lipase enzyme degradation which is common for dessert cream with high fat content. Adjustment of temperature is important for desserts with starch like custard because of gelling property of starch. Main extrinsic factors for RTE dessert are oxygen and light which are the reason of oxidation of milk fat and discoloration of flavors (Lewis & Dale, 1994).

5. PACKAGING AND STORAGE OF RTE FOODS

Packaging of the all types of products is required for providing protection, containment, convenience and communication functions to products. Protection of properties of final product and presenting to consumer with desired quality are the main targets of packaging. Packaging methods and materials are determined according to deteriorating parameters of foods and generally special for them (Üçüncü, 2011). Also, incidence of extrinsic factors about destruction of foods is reduced with true packaging selection. Improvements about packaging methods and materials provide longer shelf life to foods which have normally relatively short shelf life (Tung et al., 2001). Therefore, many ready to eat foods gain shelf stable property with packaging techniques and materials.

5.1. Packaging Techniques

According to studies, modified atmosphere packaging and vacuum packaging are the main packaging techniques for RTE foods. Also, skin packaging which is a new technology can be packaging solution for RTE foods. These packaging techniques are selected for removing effects of oxygen in air which causes chemical degradations in food and spoilage by aerobic microorganisms. These unwanted effects of oxygen are inhibited with chilling storage, but it is not adequate by oneself (Parry, 1993). Thereby, packaging is used as the way of reducing oxygen amount which is interaction between food products.

5.1.1. Vacuum packaging

Vacuum packaging is the elementary type of MAP which is performed as evacuating air from package, using packaging film with high oxygen barrier and sealing of package hermetically (Rachtanapun & Rachtanapun, 2011). Decreasing oxygen amount under the 0.1% is the indication of good vacuuming (Parry, 1993). Vacuum packaging technology is used for generally cured and cooked meats, smoked fish, hard cheese, such acidic fruits and *sous vide* products that vacuuming is the basis of the production technology of it (Gibson, 1994; Parry, 1993; Rachtanapun & Rachtanapun, 2011). In Figure 5.1, example of *sous vide* processing with vacuum package can be seen. VP is not useful for easy deformable and soft food products like bakery products because removing all air can damage shape and structure of foods (Parry, 1993).

Vacuum packaging mainly contributes prohibiting of recontamination and exudation of ingredients from package. Also, it provides saving volatile components and water in food during thermal treatment for *sous vide* processing. Furthermore, oxidation mechanisms, color degradation and aerobic microbial spoilage are prevented by removing oxygen from package. Thereby, only risk about vacuum packaging is anaerobic spoilage by microorganism such as *Listeria, Salmonella, Escherichia coli*, *Yersinia*, *Staphylococcus* and *C. botulinum*. This problem can be solved with combination of vacuum packaging with chilling/freezing storage (Rachtanapun & Rachtanapun, 2011).

Figure 5.1 Vacuum packaged, *sous vide* cooked lamp

5.1.2. Skin packaging

Skin packaging is a new technology which has similar operation technique to vacuum packaging. In this technology, vacuum is used for both removing oxygen and shaping. Skin packaging provides motionless to foods and preventing dispersing oil or water of food in package (Üçüncü, 2011). According to Hood and Mead (1993), skin packaging supplants vacuum packaging with regard to improvement appearance of products which tends to leakage. Sliced meat products, ham, pastrami, cheese, sea foods and smoked fish fillets can be packaged with this way which provides long shelf life to product, strength to package and simplicity of stowage (Üçüncü, 2011).

Figure 5.2 Skin packaged products

Skin packaging technology is suitable for foods which have lower height than 50 mm and examples of this type of packaged products can be seen in Figure 5.2. (Üçüncü, 2011).

5.1.3. Modified atmosphere packaging

Modified atmosphere packaging which is most common packaging technique for ready to eat foods is performed with changing the composition of atmosphere in package. Shelf life of product is increased and quality is developed by means of MAP (Lee et al., 2008). Mechanism of this packaging technique is achieved by 2 ways that first way is giving determined gas composition to unclosed package and providing sweeping of present atmosphere, second way is based on vacuuming of air in package before injection of MAP gas composition. Also, sealing of package without possibility of gas leakage is vital for this packaging technique (Üçüncü, 2011).

Atmosphere modification in package is done by two ways as active and passive modified atmosphere packaging. Passive modification emerges by products like fruits and vegetables which continue to respiration in package, produce CO_2 and use up O_2. In this context, determining package material and suitable barrier properties are important for beneficial usage of this type of MAP and preventing improper conditions like excessive CO_2 accumulation or occurring anaerobic condition in package with running out of O_2 (Day, 1993). Active MAP is targeted modification of gas composition and does not change with time; also, packaging materials are generally O_2 impermeable.

Gases which are preferred for modified atmosphere packaging are generally carbon dioxide, nitrogen and oxygen; also, some other gases uses rarely such as argon, nitrous oxide and helium which are allowed by European food laws (Lee et al., 2008). Moreover, Parry (1993) express that gases are used in modified atmosphere packaging as single or mixture; also, these used gases are characterized according to mixtures as inert jacketing for only N_2 containing packages, half-reactive jacketing for CO_2/N_2 or $O_2/CO_2/N_2$ mixtures and fully-reactive jacketing for CO_2 or CO_2/O_2. Functions of all gases in package atmosphere are different and can be seen in Table 5.1.

Table 5.1 Main gases for MAP and effects on foods (Lee et al., 2008).

Gas	Advantages	Disadvantages
Oxygen	• Bright red meat color • High concentrations override microbial growth • Small amounts require for respiration of fresh produces • Stop growing of strict anaerobe microorganisms	• Aerobic spoilage • Oxidation of fat and other components • Acceleration of respiration • Enzymatic browning
Carbon dioxide	• Override aerobic spoilage microorganism • Decrease aerobic respiration rate of fresh produces • Retard microbial deteriorations • Decrease staling rate of bread • Decrease the physiological activities of fresh produces	• High concentrations can cause discoloration and acid taste
Nitrogen	• Inert gas • Dislocate oxygen so prevent its effects • Inhibit collapsing of package	
Argon	• Inert gas • Dislocate oxygen so prevent its effects • Higher density than nitrogen so dislocation property against oxygen is more	• Expensive

Market of the MAP is very wide and contain large amount of products types. Minimally processed foods, fresh and precooked poultry products, fresh and fresh-cut fruits and vegetables, soft bakery products, fresh pasta, processed meats, cooked fish, sandwiches, delicatessen salads and almost all food types can be packaged with modified atmosphere packaging technique (Broady, 1999). Ready to eat foods are also take place between modified atmosphere packaged products and shelf life of RTE foods are extended substantially by means of MAP. In this context, some recommended MAP gas compositions are shown in Table 5.2 for ready to eat food types.

Table 5.2 Recommended gas compositions ofMAP for RTE foods (Arvanitoyannis &Andreu, 2012; Blakistone, 1999; Church, 1998; Lee et al., 2008; Scetar et al.,2010 Üçüncü, 2011)

RTE Food type	%O_2	% CO_2	%N_2	Recommended storage temperature (°C)
Cured Meat	-	30	70	1-3
Cooked Meat	-	20-30	70-80	-
Cooked Meat, sliced		80	20	-
Processed meat	-	0-40	60-100	0-3
Pastrami	-	50	50	-
Ground beef	70	30	-	4
Cooked Cured Meats	<0.1	35-45	55-65	-
Fresh Pasta	-	80	20	4
	-	-	100	-
Lasagna	-	70	30	2-4
Pizza	0-10	40-60	40-60	5
Sandwiches	8-10	50-60	30-40	-
Fresh Fruits	1-10	1-15	80-90	0-10
Fresh Vegetables	1-5	3-10	85-90	0-10
Sliced Apple	-	50	50	-
Sliced Lettuce	5	5	90	-
Sliced Potato	5	10	85	-
Smoked Sausage	-	30	70	-
Smoked Turkey	-	30	70	-
Cooked Turkey	<0.2	30	70	-
Cooked Poultry	-	40	60	-
Precooked Fish	-	50	50	-
Cook-Chill fried chicken drumsticks	-	100	-	1
Cook-chill chicken in béchamel sauce	-	50	50	5

As it is seen at Table 5.2, gas compositions for RTE food types are different which brings about complicity of this packaging technique. There are some specific limiting factors about gas usage for some foods. According to Üçüncü (2011), due to the solubility of CO_2 in water and oil is high, collapsing of package of meats with high water and lipid content is limiting for excessive CO_2 usage in package atmosphere. Main reason of the collapsing is decreasing of internal pressure in package which comes from diffusion of CO_2 from head space of package to inside of foods. Also, O_2 execution from package environment is generally preferred for inhibiting microbial growth and chemical destructions. Nevertheless, anaerobic microbial growth become a concern when all oxygen removed and these problem can be solved by using %2 O_2 in gas mixture and storing product at under 3.3°C which prevent possible growth of aerobic pathogens (Subramaniam, 1999). Another remarkable point about gas concentration is that minimum tolerated O_2 and maximum tolerated CO_2 levels are specific for types of fruits and vegetables. Minimum tolerated oxygen level depends on mainly respiration rate of plants and these rates are different for commodities and indicator for perishability of food (Day, 1993). Some optimum gas composition for modified atmosphere packaging of fruits and vegetables with different respiration rates are shown at Table 5.3.

Table 5.3 Optimum conditions for MAP of fruits and vegetables at approximately 95% relative humidity (Lee et al., 2008).

Product	Temperature (°C)	%O_2 composition	%CO_2 composition
Apple	0-9	1-3	1-3
Banana	13-15	2-5	2-5
Orange	3-9	5-10	0-5
Peach	0-5	1-2	3-5
Cabbage	0-5	3-5	3-6
Cucumber	8-12	3-5	0
Lettuce	0-5	1-5	0
Mushroom	0-5	1-3	10-15
Tomato	8-12	3-5	0-3

Also some researches show that optimum range of oxygen and carbon dioxide for fresh produces is between 2-10% and 10-20% respectively. This limited value of CO_2 for fruits and vegetables is originated from anaerobic respiration which concludes with quick spoilage, and deterioration based on established microflora activities at high CO_2 levels (Garret, 1999).

5.2. Packaging Materials

Packaging techniques and materials are substantial for foods with regard to provide microbiological safety, facilitate usage of product, give information about product and preserve sensory properties of foods. Ensuring some of these duties is directly related with oxygen, moisture, flavor and light barrier properties of packaging material; so packaging has important role on shelf life of products (Stöllman et al., 1994). Also, packaging materials have effects on increasing efficiency of packaging technique which is determined and designed according to product characteristic. For example, in modified atmosphere packaging of fresh produce, gas composition in package changes during storage because of respiration. If oxygen permeability of package material is low, oxygen can be completely consumed and anaerobic respiration starts that cause deterioration of product (Üçüncü, 2011). Barrier properties of some packaging materials within the context of function for different packaging techniques can be seen in Table 5.4.

There are many packaging material solution for ready to eat foods which are determined based on suitability of material to processing technique, easiness to consumer usage and other technical properties of package materials for safety of product. Plastic, aluminum foil and paper is the possible materials and layers for packaging of RTE foods. Ready meals can be packaged with shaped aluminum trays, pouches with aluminum foil layer or paper box with aluminum foil layer, for example (Üçüncü, 2011). Also, in plastic packaging, sometimes usage of one plastic material cannot be solution; therefore, some combination of materials is done by the ways of lamination, coextrusion and extrusion coating (Greengrass, 1993). Moreover, rigid retort food bowls can be used for packaging of convenience foods like soups, ready meals, baby foods and snacks. These bowls have microwavable properties and examples of them are shown in Figure 5.3. For production of these bowls, microwave transparent materials are used such as low density polyethylene (LDPE), polypropylene (PP) and crystallized polyethylene terephthalate (CPET) trays which have endurance up to 75°C, 110°C and 220°C temperatures respectively (Lee et al., 2008).

Table 5.4 Packaging materials and barrier properties (Galic et al., 2009).

Material	Barrier Properties
Polyamide (PA)	Water vapor permeability (low) Resistant to grease
Polyethylene terephthalate (PET)	Volatile impermeable
Polyvinyl chloride (PVC)	Gas permeability (low) Resistant to grease
Polyvinylidene chloride (PVDC)	Volatile impermeable Resistant to grease Negligible water vapor permeability
Ethylene vinyl alcohol (EVOH)	Gas and volatile barrier
Polypropylene (PP)	Resistant to grease
Oriented Polypropylene (OPP)	Gas permeable Negligible water vapor permeability
High-Density Polyethylene (HDPE)	Negligible water vapor permeability Resistant to grease
Low-Density Polyethylene (LDPE)	Gas permeable Negligible water vapor permeability
Aluminum foil (Alu)	Negligible water vapor permeability Resistant to grease
SiOx-coating	Negligible water vapor permeability Gas barrier Resistant to grease
Ethylene vinyl acetate (EVA)	Gas permeable Resistant to grease
Polystyrene (PS)	Gas permeable
Ionomer	Resistant to grease

Figure 5.3 Microwavable retort bowls for convenience foods

There is also another different approach about packaging of RTE foods which is used for 'Meals, Ready to Eat' (MREs) and designed for mainly military services. Packaging material of this products which can be seen in Figure 5.4, has supreme oxygen and moisture impermeability property. Also, this material which is mainly composed of polyolefin, aluminum foil, polyamide and pigmented polyester layers, has endurance to physical damages and environmental conditions like falling from long distances and cold weather which are possible situations for military services. Moreover, heater which achieves heating of meals by exothermic reaction between water and iron/magnesium elements is designed for these meals and provides approximately 40°C heating in 12 minutes (Lerman & Whelan, 2014).

Figure 5.4 MRE package and heater

5.2.1. Vacuum packaging materials

In vacuum packaging technology, most important requirement about packaging material is having high oxygen and moisture barrier, high mechanical durability and heat sealable property (Hood & Mead, 1993). In order to supply these requirements, multilayered films which consist of layers with high barrier and heat sealable properties are preferred. Some plastic materials providing these functions are seen at Table 5.5.

Table 5.5 Layers and functions for vacuum packaging (Rachtanapun & Rachtanapun, 2011).

High barrier layers	Heat sealable layers
Polyamide (PA) or nylon	Polyethylene (PE)
Polyethylene terephthalate (PET)	Polypropylene (PP)
Polyvinylidene chloride (PVDC)	Copolymer of PE
Ethylene vinyl alcohol (EVOH)	Linear Low-Density Polyethylene (LLDPE)

According to Rachtanapun & Rachtanapun (2011), necessity to combination of these layers originates from some negative properties of materials. For example, materials with high barrier property are generally expensive, susceptible to wetness and not sealable with heat. Also, Toldra et al. (2004) states that puncture resistance and elasticity of vacuum pouch must be high because of taking form of package with vacuuming.

In ready to eat aspect, vacuum packaging is mainly used for *sous vide* production technique. Tansey and Gormley (2005) express that *sous vide* pouches are mainly composed of PP laminations which have endurance to cooking temperatures, relatively low permeability and durability against puncturing. Moreover, pasteurized ready to eat foods can be packaged with vacuum packaging that packaging material must be light impermeable and low oxygen permeability which must be smaller than 100 N cm^3/m^2.day.bar. Pouches which are composed of PA/PE, PA/PP and PET/PE laminations can be used for this type of food products (Üçüncü, 2011). Also, according to Toldra et al. (2004), polyamide is the most convenient material for vacuum packaging because of having gas barrier and mechanical endurance and it is generally laminated with PE because of heat sealability and water barrier properties. Determining thermal resistance of package, it must be known that maximum tolerable temperatures for plastic materials which are shown in Table 5.6.

Table 5.6 Plastic materials and maximum temperature for usage (Lee et al., 2008)

Plastic material	**Maximum temperature (°C)**
Low density polyethylene (LDPE)	75
Polyester (amorphous PET)	75
High density polyethylene (HDPE)	85
Polyvinyl chloride (PVC)	85
Polypropylene (PP)	110
Polyamide (Nylon 6)	160
Polyethylene terephthalate (CPET)	220

Some recommended vacuum package material combinations of different layers for some ready to eat foods are shown in Table 5.7. Conservation requirement of these combinations also related with expected shelf life and storage conditions (Toldra et al., 2004).

Table 5.7. Combinations for vacuum package material (Jang & Lee, 2005; Rachtanapun & Rachtanapun, 2011; Toldra et al., 2004).

Product	**Laminations**	**Storage conditions**
Fermented and Dry-Cured Meat	PA/EVOH/PA/PE	Room Temperature
	PA/PVdC//PE	Room Temperature
	PA/SiOx//PE	Room Temperature
	PET/AlOx//PE	Room Temperature
	PET/SiOx//PE	Room Temperature
	HDPE	Refrigeration Temperature
Boneless ham	nylon/LDPE	Refrigeration Temperature
	LLDPE/PVDC/EVA	Refrigeration Temperature
Fresh-cut meat	nylon/PVDC/LLDPE	-
	PET/PVDC/LLDPE	-
Cheddar cheese	nylon/LLDPE	-
Ground beef	EVA/nylon/EVOH/nylon/PE	-
Cooked beef slices	nylon/PE/nylon/PE/nylon/LLDPE	-

5.2.2. Skin packaging materials

In skin packaging technology, packaging material is formed by 2 components. Bottom part can be base plate, rigid PVC or tray which is produced from PP or PET; while upper film is chosen as laminations of LDPE or LLDPE and/or coextrusion of ionomers (Üçüncü, 2011). Packaging material requirements of vacuum packaging and skin packaging are not different, but package of skin packaged products has shiny appearance and no ripples unlike vacuum packaging (Davis, 1999). Lee et al. (2008) state that sliced meat, cured meat, pastry and fish products are the vacuum skin packaging (VSP) applicable products. Permeability features of upper film can change with product type; for example, cured meats and fishes need to prevent oxygen transfer into package; while for fresh meats, upper film can have permeability property. Also, for fresh cut meats, some skin packaging laminations are like that LLDPE/PVDC/LLDPE, LLDPE/EVOH/LLDPE (Rachtanapun & Rachtanapun, 2011).

5.2.3. Modified atmosphere packaging materials

There are many different applications of MAP with regard to packaging materials and food products. According to Üçüncü (2011), packaging systems which are used in MAP are classified under 7 groups as rigid or semi-rigid tray which is covered with plastic films, stretchy plastic pouch, tray which is wrapped with plastic films, bag in a bag, bag in a cartoon, bag in a box and box in a bag.

In their study, Arvanitoyannis and Andreou (2012) listed ready to eat foods which can be packaged with modified atmosphere, as precooked, cooked and smoked poultries; sliced, cooked, cured meats; Turkish pastırma; cooked, smoked seafoods; salads, delicatessen products, prebaked or ready to baked pizza, fresh pasta and fresh cuts. Also, based on other researches, MAP is preferred for sandwiches, dairy desserts and meat balls from ground beef which are included to this study.

Commonly held MAP materials are composed of 2 parts as trays and upper films. Trays which are used for basement of MAP are generally produced from PS foam, molded plastic materials, injection molded plastics, pre-molded pulps which are covered with plastic materials or lamination of cartoon and plastic films. (Üçüncü, 2011). Upper film requirements generally change according to food type which has different sensitivities.

Fruits and vegetables

Some factors which must be taken account for choosing of packaging material for fruits and vegetables are gas and water vapor permeability, mechanical features, opacity, heat sealabilty and microwaveability (Day, 1993). Selection of packaging material is relatively complex for fruits and vegetables due to respiration mechanism; also, optimal material must provide to hold minimum oxygen level which can change according to types of fresh produce and prevent excessive carbon dioxide accumulation for active MAP. PVC or LDPE containing materials ensure this gas stabilization in package (Stöllman et al., 1994). Also according to Ahvenainen (1996), EVA/OPP and EVA/LDPE combinations are more useful than single usage of OPP and PE for salad packaging. Besides considerations about actively formed modified atmosphere packaging, also passive MAP materials must be selected based on supplying respiration conditions to fresh produce by using materials with proper permeability. Bi-oriented polypropylene (BOPP) and oriented polypropylene (OPP) are the most suitable materials for passive MAP applications which provide continuity of slow respiration of products. This problem also can be solved with opening micro holes with desired width on package (Jacxsens et al., 2004). Moreover, transparency of packaging material can be problem for foods with high moisture because of condensation at lower temperature storage; hence, applications for gaining antifogging property to package are achieved by the way of coating and additives (Day, 1993).

Ready meals

Ready meals which are mainly susceptible to oxygen are packaged with 2 ways as gas flushing and gas packaging. First one is generally achieved with using elastic pouches and oxygen level can be reduced to 1-2% while trays and proper upper film are used for gas packaging where the leftover oxygen amount can be decreased to 0.5%. Therefore, second one is commonly preferred because of provided oxygen level (Subramaniam, 1993). Also, there are some difficulties about MAP of ready meals. These are originated from effects of gas on appealing of meal and oxygen residues because of multi-dimensional shape of meal ingredients. For ready meals which have different components, trays are divided into parts in order to supply attractive appealing; however, these divisions of tray affect gas flow and efficiency of MAP application. Also, effect of retained air because of the food shape can be prevented by application of high pressure MAP with nitrogen (Spencer, 2005). In order to provide post usage convenience to ready meals, microwaveable and dual-ovenable packages become trends as packaging materials. According to Subramaniam (1993), while dual-ovenable packages which are composed of crystalline polyethylene terephthalate (cPET) trays and non-transparent polyester film are popular in UK, microwaveable packages are common in USA. Also, co-extruded cPET tray with upper film is used for packaging of ready meals which do not need to low temperature storage. Moreover, preventing to light induced oxidation, paper based covers can be used as secondary packaging for ready meals which can be seen at Figure 5.5 (Goddard, 1994). Also this secondary package ensures communication function of package.

Figure 5.5 Secondary package of ready meal

Meats, poultry and fish products

Firstly, meat ball which is made from ground beef are the type of RTE food which can be packaged with modified atmosphere. According to Brodly (1993), packaging material of this product is composed of PVC wrapping over foamed PS trays. Also, PE can be used for ground beefs as material for trays (Scetar et al., 2010). Meat products other than shaped meat balls are cured, cooked and processed meats. These can be sold as retail and bulk which have different packaging considerations. For retail packaging, trays, upper film and secondary packages can be used; while, bag in box and master packs are used for bulk packaging. PET/PVDC/LDPE, PA/PVDC/LDPE, PC/EVOH/EVA are the possible combinations for lidding film; also, UPVC/LDPE, HDPE, EPS/EVOH/LDPE is chosen for materials of trays. UPVC is the unplasticed PVC which has widespread usage for tray production and EPS is extended polystyrene which provide double shelf life with excellent barrier properties. Moreover, PA/LDPE and PA/EVOH/LDPE are used for bulk packaging of RTE meat products (Blakistone, 1999). Some other packaging solutions for meat and poultry products are shown in Table 5.8.

Table 5.8 Packaging materials for RTE meat and poulty products (Arvanitoyannis & Andreou, 2012; Scetar et al., 2010).

Product	Packaging material
Precooked chicken	Nylon/PE barrier bag LDPE/PA/LDPE barrier pouch
Smoked turkey	PET/LDPE/EVOH/LDPE barrier pouch
Turkish pastırma	PE/PA bags OPA/EVOH/PE barrier bag
Cooked ham and frankfurters	PA/PE bag

According to Scetar et al. (2010), antifogging agents which are mainly glycerol esters, polyglycerol esters, sorbitan esters and their ethoxylates, alcohol ethoxylates, and nonyl phenol ethoxylates, are also preferred for packaging of meat products like application on fruits and vegetables.

Packaging materials of modified atmosphere packaged fish and fish products are generally composed of PVC/LDPE trays and PVdC coated polyester/LDPE combination (Üçüncü, 2011). Also, PS trays with multilayered co-extruded lidding are preferred for precooked fish. Generally vacuum packaging is suggested for smoked fish products rather than modified atmosphere packaging (Arvanitoyannis & Andreou, 2012).

Sandwiches, fresh pasta and pizza

Sandwiches are the multicomponent products which are generally packaged with thermoforming or horizontal packaging machines. The most important feature of the packaging material is being carbon dioxide impermeable which is provided with PVdC-coated polyester packaging material (Subramaniam, 1993). Example of packaging solution which is produced with thermoforming machine for RTE sandwiches is shown at Figure 5.6.

Figure 5.6 Packaging material for RTE sandwich

Packaging material of fresh pasta products which are generally packaged with gas composition exclusion of oxygen is PVDC/PE lamination with 80 µm thickness. Also, addition of oxygen absorbers to package extends the shelf life of products at 10°C (Galic et al., 2009). Moreover, there are some studies about packaging of fresh pasta with plastic plate and 90 µm multilayer upper film (PET/EVOH/PE) for providing adequate barrier to oxygen (Lucera et al., 2014). Some researches which are aimed to extend shelf life of MAP pizza shows that packaging with 110 µm LDPE/Nylon-6/LDPE film and 100% carbon dioxide gas composition can provide 300% increasing of shelf life (Singh et al., 2012).

Desserts and delicatessen foods

The most important factor about shelf life for desserts is oxygen and inhibition of effects of oxygen can be provided with decreasing oxygen permeability and light transparency of packaging material (Lewis & Dale, 1994). Desserts such as pudding and flans are packaged with deep drawing plastic plates which are produced with PS or copolymerized PS materials and lidding foils (Üçüncü, 2011). Also, PP trays are generally used for packaging of deli foods which is shown in Figure 5.7.

Figure 5.7 PP delicatessen salad package

5.3. Storage Conditions and Shelf Life of RTE foods

Shelf life of the foods depends on some factors like storage temperature, water activity and pH of food and relative humidity of environment which are mainly related with microbiological growth and deterioration reactions. Low temperature storage which inhibit oxygen induced reactions, microbiological spoilage and increasing of packaging material permeability, is required for almost all types of MAP foods except dried and bakery products (Blakistone, 1999). There are some safety concerns about modified atmosphere packaged products which cannot be exposed to enough processing or contaminated before packaging. The effects of these problems can be removed with low temperature storage than 3.3°C which is critical for pathogen growth especially C. botulinum (Subramaniam, 1999).

For MAP fresh cut, high respiration rate is the most common way of spoilage which is initiated with high temperatures and improper permeability of packaging material. Required storage temperature range for these products is 0.5-5°C and provided shelf life is between 5-21 days (Garret, 1999). However, these storage temperatures must be adjusted to food type which is susceptible to chilling injury and need storage at 5-10°C. Also, relative humidity of environment can cause moisture loss of fresh produce which is ended with shrinkage when packaging material with proper water transfer rate is not used (Day, 1993).

Microbial growth and susceptibility to oxygen are the main factors affecting shelf life of precooked products. Efficiency of carbon dioxide in MAP ready meals is correlated with low temperatures because solubility of carbon dioxide inversely proportional with temperature and it is not effective above 5°C. Therefore, recommended storage temperature for MAP products is maximum 4°C. Provided shelf life with MAP to ready meals is 15 days at 0-3°C; also, shelf life of some ready meals can be extended with processing technique up to 1 year at ambient temperatures (Subramaniam, 1999).

In the matter of processed meat, brown fading of cured meat products is important and also caused from low relative humidity of environment and high temperature storage; hence, packaging material with low water and oxygen transfer and low temperature storage can be solution of this issue for cured meats (Subramaniam, 1999). Also, decreasing oxygen permeability of film from 100cm3/m2/atm/day to impermeable one provides increasing shelf life of sausages from several weeks to 9 months (Church, 1993). Generally, shelf life of cooked and cured meats is between 3-7 days, for salami and pepperoni is 4-8 months at 0-3°C with approximately 30% CO2 and 70% N2 gas composition. (Subramaniam, 1999). Some storage conditions and shelf life of meat products are shown at Table 5.9.

For cooked poultry products, both vacuum and MAP provides 15 days shelf life at 0-1°C (Blakistone, 1999). Ready to eat fish products are generally processed with smoking, irradiation, and *sous vide*. According to Gibson (1994), shelf life of smoked cod and kipper at 5°C is between 10-14 days and shelf lifes of *sous vide*, irradiated and salted cods at 0°C are 28, 20, 500 days respectively.

Shelf of sandwiches is excluded by MAP application with CO_2 gas to 28 days from 10 days which is normally provided with air packaging. Providing refrigeration temperatures for MAP sandwiches is important for both safety and increasing shelf life (Subramaniam, 1999). Another product is fresh pasta and shelf life of it can be extended up to 40 days at 4°C with antimicrobial filter and MAP application (Lucera et al., 2014). Also, shelf life of ready to bake pizza products is relatively increased with 100% carbon dioxide MAP up to 15 days (Singh et al., 2012).

Table 5.9 Some meat products and their shelf life (Scetar et al., 2010).

Meat Product	Packaging method	Storage Temperature (°C)	Shelf life
HPP treated sliced marinated beef loin	Vacuum packaging	4	120 days
Heat-treated sausages	Vacuum packaging	7	6-11 weeks
In-package pasteurized turkey bologna	Vacuum packaging + biocide film	4	8 weeks
Precooked chicken	MAP ($30\%CO_2$ / $70\%N_2$)	4	12 days
Ground beef	MAP ($70\%O_2$ / $30\ \%CO_2$)	4	8 days
Cooked ham and frankfurters	PA/PE film	4	4 weeks
Chicken wings	*Sous vide*- vacuum packaged	2	7 weeks

Lewis and Dale (1994), states that there is a regulation about storage temperature of dairy desserts which is determined as below than 8°C for food with higher than 4.5 pH. Also, optimum storage and distribution temperature is 5°C for these types of foods. Shelf life of dairy desserts at 4°C is determined as 2 days. According to studies about shelf life and storage temperature, shelf life of MAP dressed salad is increased from 12 days to 54 days with decreasing temperature 15°C to 4°C (Subramaniam, 1999). Also, Brocklehurst (1994) states that dressing material with low pH provides extending shelf life of delicatessen salads.

In Table 5.10, some storage conditions and related shelf life of RTE foods are shown based on processing technique.

Table 5.10. Storage conditions and shelf life of foods based on processing technique (Farkas, 2003; IAEA, 2003; Rastogi, 2010; Tansey & Gormley, 2005)

Product	**Processing Technique**	**Temperature (°C)**	**Shelf life**
Ready meal	HPP (600 MPa, 20°C, 3 min)	4	98 days
Sliced vacuum packaged raw ham	HPP (600 MPa, 5 min)	3	30 days
	HPP (400 MPa, 15 min)	-	85 days
Poultry	HPP (400–900 MPa, 10 min)	4	27-98 days
Salted, vacuum-packaged freshwater trout	Irradiation (2 kGy)	4	28 days
Smoked sausage MAP (20%CO_2, 80% N_2)	Irradiation (2 kGy)	3-7	2 months
Pizza	Irradiation (2 kGy)	-	14 days
Roast beef slices vacuum packaged	Irradiation (45 kGy)	24	>24 months
Chicken sheek kababs vacuum packaged	Irradiation (10 kGy)	Ambient	9 months
Sous vide product	-	0-4	21 days

6. CONCLUSION

Ready-to-eat foods which do not need serious pretreatment before consuming have become famous trend in daily routine by means of its convenience property (Jaroni et al., 2010). This new market mainly includes ready meals & entrees, pizza, sandwiches, fresh pasta dishes, vegetable side dishes, meat poultry and fish products, sauces and gravies (Harris & Shiptsova, 2007). It is realized that RTE foods have some microbial concerns about *Listeria monocytogenes, Salmonella enterica, Escherichia coli* O157:H7 and *Clostridium perfringens* because they are generally consumed without pre-heating. Therefore, cross contamination and initial microbial load of raw materials are the causes of these microbial problems which can be prevented with good hygiene practices and adequate thermal treatment (Mendonca, 2010). Moreover, it is seen that there are some difficulties about processing and packaging of ready meals based upon multi-ingredient content, necessity to different packaging systems which emerges for providing sufficient containment and appealing of food product (Spencer, 2005). According to Arvanitoyannis and Andreou (2012), proper packaging techniques provide saving of natural properties of RTE foods without need to preservative use during production. Packaging of RTE foods is mostly performed with modified atmosphere packaging, vacuum packaging and skin packaging according to type of food and destructive parameters of it. According to researches, modified atmosphere packaging is accepted as most developed packaging technique for RTE foods; however, in some cases, vacuum packaging can be more effective than MAP. Chosen gas composition, storage temperature and permeability of packaging materials sometimes cause this dominance of vacuum packaging (Blakistone, 1999). Also storage conditions are vital for providing stability of RTE foods. Recommended storage temperature for MAP RTE food products is generally chilled temperatures (Subramaniam, 1999). This requirement can be changed based on processing technique of food product and ambient shelf stable foods can be produced by more effective treatments. There are some issues about packaging of RTE foods which must be developed with new researches. These issues can be listed as designing new multi-divided packages and gas applications for multi-component ready meals, improving appearance of packaged ready meals with sauces, generating new gas compositions for different foods and studying of gases other than oxygen, carbon dioxide and nitrogen.

REFERENCES

Ahmed, J. and Ramaswamy, H.S. 2007. Microwave Pasteurization and Sterilization of Foods. In: Rahman, M.S. (Ed), *Handbook of Food Preservation*, 2nd ed. CRC Press, pp. 691–711.

Ahvenainen, R. 1996. New approaches in improving the shelf life of minimally processed fruit and vegetables. *Trends in Food Science & Technology*, 7: 179-187.

Arvanitoyannis, I.S. and Andreou, M. 2012. Chapter 12: Ready-to-Eat Foods. In: Arvanitoyannis I.S (Ed.), *Modified Atmosphere and Active Packaging Technologies*. Boca Raton: CRC Press, pp.557-591.

Baldwin, D. E. 2011. *Sous Vide* Cooking: A Review. University of Colorado, Boulder, CO 80309-0526 pp.1-33.

Blakistone, B.A. 1999. Meats and poultry. In: *Principles and Applications of Modified Atmosphere Packaging of Foods*, 2nd ed., Gaithersburg, Maryland: An Aspen Publication, pp.240-283.

Buckley, M., Cowan, C. and McCarthy, M. 2007. The convenience food market in Great Britain: Convenience food lifestyle (CFL) segments. *Appetite* 49(3): 600.

Broady, A.L. 1999. Markets for MAP foods. In: Blakistone, B.A. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Foods*, 2nd ed., Gaithersburg, Maryland: An Aspen Publication, pp.1-13.

Brocklehurst, T.F. 1994. Delicatessen salads and chilled prepared fruit and vegetable products. In: Man, C.M.D & Jones, A.A. (Eds) *Shelf Life Evaluation of Foods*, Chapman & Hall, pp.87-123.

Calligaris, S. and Manzocco, L. 2012. Chapter 4: Critical Indicators in Shelf Life assessment. In: Nicoli, M.C. (Ed), *Shelf Life Assessment of Food*, CRC Press, pp.61-75.

Church, I. 1998. The sensory quality, microbiological safety and shelf life of packaged foods. In: Ghazala, S. (Ed), *Sous vide and cook-chill processing for the food industry*, Gaithersburg, Maryland: An Aspen Publication, pp.190-202.

Church, P.N. 1993. Meat Products. In: Parry, R.T. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Food*, Chapman & Hall, pp.229-262.

Crouch, E., and Golden, N.J. 2005. A Risk Management for Clostridium perfringens in Ready-to-Eat and Partially Cooked Meat and Poultry Products. September 2005. Cambridge Environmental Inc., 58 Charles Street, Cambridge, MA 02141 and the Risk Assessment Division, Office of Public Health Science, Food Safety Inspection Service, USDA.

Cutter, C. N., Senevirathne, R. N., Chang, V. P., Cutaia, R. B., Fabrizio, K. A., Geiger, A. M., Valadez, A. M. and Yoder, S. F. 2012. Major microbiological hazards associated with packaged fresh and processed meat and poultry. In: Kerry J. P. (Ed) *Advances in Meat, Poultry and Seafood Packaging*, Cambridge: Woodhead Publishing, p.33.

Davis, H.K. 1999. Fish and shellfish. In: Blakistone, B.A. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Foods,* 2nd ed., Gaithersburg, Maryland: An Aspen Publication, pp.194-228.

Dawson, P.L. 2008. Chapter 18: Novel methods to improve the safety and quality of in-pack processed ready-to-eat meat and poultry products. In: Richardson P. (Ed), *In-pack processed foods.* Boca Raton, FL: CRC press, pp.358-376.

Day, B.P.F. 1993. Fruits and vegetables. In: Parry, R.T. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Food*, Chapman & Hall, pp.114-132.

Day, B.P.F. 1998. *Campden and Chorleywood Food Research Association Chilled Food Packaging*. Retrieved from: ftp://166.111.30.161/incoming/new_book/Food%20Science/Chilled%20Foods%20(2nd%20Edition)/34990wp_06.pdf

Doğu, S.Ö. and Sarıçoban, C. 2015. Et kurutma teknolojisi ve dünyada tüketilen bazi kurutulmuş et ürünleri. *Journal of Food and Health Science*, 1(3): 103-117.

Dominguez, S. and Schaffner, D.W. 2010. Microbiological Quantitative Risk Assessment. In: Toldra F. (Ed), *Safety of Meat and Processed Meat*, New York: Springer, pp.591-615.

FAO, 2001. Risk Assessment of *Listeria monocytogenes* in Ready-to-Eat Foods. In: *Joint FAO/WHO Expert Consultation on Risk Assessment of Microbiological Hazards in Foods.*, FAO headquarters, Rome, p.18.

Farkas, J. 2003. Food Irradiation. In: Mozumder, A. & Hatano, Y. (Eds), *Charged Particle and Photon Interactions with Matter: Chemical, Physicochemical, and Biological Consequences with Applications*, CRC Press.

Food Safety and Inspection Service (FSIS), 2008. Disposition/ food safety: overview of food microbiology. http://www.fsis.usda.gov/PDF/PHVt-Food_Microbiology.pdf. Accessed May 2009.

Galic, K., Curic, D. and Gabric, D. 2009. Shelf Life of Packaged Bakery Goods — A Review. *Critical Reviews in Food Science and Nutrition*, 49(5): 405–426, DOI:10.1080/10408390802067878

Garret, E.H. 1999. Fresh-cut produce. In: Blakistone, B.A. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Foods*, 2nd ed., Gaithersburg, Maryland: An Aspen Publication, pp.125-133.

Ghazala, S. and Trenholm, R. 1998. Hurdle and HACCP concepts in sous vide and cook-chill products. In: Ghazala S. (Ed) *Sous Vide and Cook-Chill Processing for the Food Industry*. Gaithersburg, Maryland: An Aspen Publication, pp.294-310.

Gibson, D.M., 1994. Preservation technology and shelf life of fish and fish products. In: Man, C.M.D & Jones, A.A. (Eds) *Shelf Life Evaluation of Foods*, Chapman & Hall, p.81.

Goddard, M.R. 1994. The storage of thermally processed foods in containers other than cans. In: Man, C.M.D & Jones, A.A. (Eds) *Shelf Life Evaluation of Foods*, Chapman & Hall, pp.269.

Greed, P.G. 1998. Sensory and nutritional aspects of sous vide processed foods. In: Ghazala S. (Ed) *Sous Vide and Cook-Chill Processing for the Food Industry*. Gaithersburg, Maryland: An Aspen Publication, p.59.

Greengrass, J. 1993. Films for MAP of foods. In: Parry, R.T. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Foods*, Chapman & HalI, pp.63-95.

Harris, J.M. and Shiptsova, R. 2007. Consumer Demand for Convenience Foods: Demographics and Expenditures. *Journal of Food Distribution Research*, 38(3): 25.

Hood, D.E. and Mead, G.C. 1993. Modified atmosphere storage of fresh meat and poultry. In: Parry, R.T. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Foods*, Chapman & HalI, pp.269-295.

Hwang, C.A. 2010. Chapter 2: Delicatessen salads. In: Hwang, A. and Huang, L (Eds), *Ready-to-Eat Foods Microbial Concerns and Control Measures*. Boca Raton: CRC Press, pp.63-66.

International Atomic Energy Agency (IAEA), 2003. Radiation processing for safe, shelf-stable and ready-to-eat food. Proceedings of a final Research Co-ordination Meeting held in Montreal, Canada. pp.1-260.

Irawati, Z. and Sani, Y. 2012. Feeding studies of radiation sterilization ready to eat foods on sprague dawley rats: In vivo. *Natural Science*, 4(2): 116-122.

Jang, J.D. & Lee, D.S. 2005. Development of a sous-vide packaging process for Korean seasoned beef. *Food Control*, 16 (2005): 285-291.

Jaroni, D., Ravishankar, S., Juneya, V. 2010. Chapter 1: Microbiology of ready-to-eat foods. In: Hwang A. and Huang L (Eds), Ready-to-Eat Foods *Microbial Concerns and Control Measures*. Boca Raton: CRC Press, pp.1-60.

Jacxsens, L., Devlieghere, F. and Debevere, J. 2004. Quality of Equilibrium Modified Atmosphere Packaged (EMAP) Fresh-cut Vegetables. In: Dris, R. and Jain, S.M. (Eds.), *Production Practices and Quality Assessment of Food Crops*, Vol. 3, “Quality Handling and Evaluation”, Kluwer Academic Publishers, pp. 473–523.

Juliano, P., Koutchma, T., Sui, Q., Barbosa-Canovas, G. V., Sadler, G. 2010. Polymeric-Based Food Packaging for High-Pressure Processing. *Food Engineering Reviews*, 2(4): 274-297.

Juneja, V.K., Huang, L. and Thippareddi, H. 2006. Predictive model for growth of *Clostridium perfringens* in cooked cured pork. *International Journal of Food Microbiology*. US:Elsevier, 110(2006): 85–92.

Kaçar, O. 2005. Çeşitli hazir gidalarda bulunan patojenik mikroorganizmalarin belirlenmesi. Yüksek lisans tezi, Marmara Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul, pp.1-64.

Kaletunç, G. 2009. Gıda Endüstrisinde Alışılmamış Yöntemler. *Bilim ve Teknik*, p.61

Knipe, C.L. 2010. Processing Interventions to Inhibit *Listeria monocytogenes* Growth in Ready-to-Eat Meat Products. In: Knipe C.L. and Rust R.E. (Ed), *Thermal Processing of Ready-to-Eat Meat Products.* USA: Willey-Blackwell, pp.87-127.

Lee, D.S., Yam, K.L. and Piergiovanni, L. 2008. Chapter 13: Vacuum/Modified Atmosphere Packaging. In: *Food Packaging Science and Technology*, Boca Raton: CRC Press, pp.397-422.

Lerman, J. and Whelan, A. 2014. Chapter 16: Food Preservation and Packaging. In: Edelstein, S. (Ed), *Food Science: An Ecological Approach,* Jones & Bartlett Learning Publishing, p.518.

Lewis, M. and Dale, R.H. 1994. Chilled yogurt and other dairy desserts. In: Man, C.M.D & Jones, A.A. (Eds) *Shelf Life Evaluation of Foods*, Chapman & Hall, pp.124-154.

Lucera, A., Costa, C., Padalino, L., Conte, A., Lacivita, V., Saccotelli, M.A., Esposto, D. & Nobile, M.A.D. 2014. Combination of Process Technology and Packaging Conditions to Improve the Shelf Life of Fresh Pasta. *Journal of Food Processing & Technology,* 5(12): 1-5. doi:10.4172/2157-7110.1000403

Malley, T.J.V., Butts, J. and Wiedmann, M. 2015. Seek and Destroy Process: *Listeria monocytogenes* Process Controls in the Ready-to-Eat Meat and Poultry Industry. *Journal of Food Protection,* 78(2): 436-445. doi: 10.4315/0362-028X.JFP-13-507

Mangalassary, S. 2012. In-package Pasteurization of Ready to Eat (RTE) Meat Products-an Effective Way to Control Post-processing Contamination. *Journal of Food Processing & Technology,* 3(9). http://dx.doi.org/10.4172/2157-7110.1000e110

Martin, M. 2001. Chapter 20: Meat Curing Technology. In: Young, O.A., Rogers, R.W., Hui, Y.H. & Nip, W.K. (Eds) *Meat Science and Applications,* CRC Press, DOI:10.1201/9780203908082.ch20

Mendonca, A.F. 2010. Chapter 2: Microbiology of Cooked Meats. In: Knipe C.L. and Rust R.E. (Eds), *Thermal Processing of Ready-to-Eat Meat Products.* USA: Willey-Blackwell, pp.17-39.

Moir, C. J. and Szabo, E. A. 1998. Microbiological safety aspects of cook-chill foods. In: Ghazala S. (Ed) *Sous Vide and Cook-Chill Processing for the Food Industry.* Gaithersburg, Maryland: An Aspen Publication, pp.311-330.

Mullan, W.M.A. 2002. Effect of modified atmosphere packaging on major foods. Available from: http://www.dairyscience.info/index.php/packaging/118-map-major-foods.html

O'Sullivan, M.G. & Kerry, J.P. 2012. Sensory and quality properties of packaged fresh and processed meats. In: Kerry, J.P. (Ed), *Advances in Meat, Poultry and Seafood Packaging,* UK, Cambridge: Woodhead Publishing Limited, pp.86-104.

Özlü, H. and Atasever, M. 2007. Gıdalara Yüksek Basınç Uygulaması. *Atatürk Üniversitesi Veteriner Bilimleri Dergisi*, 2(1): 7-27.

Park, L. and Park, E. 1992. *The Smoked-foods Cookbook: How to Flavor, Cure, and Prepare Savory Meats, Game, Fish, Nuts and Cheese.* Mechanicsburg: Stackpole Books, pp.28-50.

Parry, R.T. 1993. Chapter 1: Introduction. In: Parry, R.T. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Foods*, Chapman & HalI, pp.1-17.

Patterson, M.F. and Stewart E.M., 2003. Effect of gamma irradiation on the shelf-life and nutritional quality of ready made meals. pp.47-62.

Rachtanapun, P. and Rachtanapun, C. 2011. Vacuum Packaging. In: Sun, D.W. (Ed), *Handbook of Frozen Food Processing and Packaging*, 2nd ed., CRC Press. pp. 861–874.

Ramesh, M. N. 2007. Canning and Sterilization of Foods. In: Rahman, S. (Ed). *Handbook of Food Preservation,* 2nd ed, CRC press, pp.586-587.

Rastogi, N. K. 2010. Effect of High-Pressure Food Processing on Physicochemical Changes of Foods: A Review. In: Devahastin, S. (Ed), *Physicochemical Aspects of Food Engineering and Processing*, CRC Press, pp. 105–176. DOI: 10.1201/9781420082425-7

Robertson, G.L. 1993. Chapter 15: Packaging of Flesh Foods. In: Hughes, H.A. (Ed), *Food Packaging: Principles and Practice*, New York: Marcel Dekker, pp.431-470.

Roudaut, G and Debeaufort, F. 2011. Moisture loss, gain and migration in foods. In: Kilcast, D. and Subramaniam, P. (Eds), *Food and Beverage Stability and Shelf Life*, UK, Cambridge: Woodhead Publishing, pp.63-100.

Ruan, R., Ye, X., Chen, P., Doona, C.J. and Taub, I. 2001. Ohmic heating. In: Richardson, P. (Ed), *Thermal technologies in food processing*, Boca Raton FL: CRC Press.

Sastry, S.K., Shynkaryk, M. and Somavat, R. n.d. Ohmic and moderate electric field processing: developments and new applications.

Schellekens, M. 1996. New research sous-vide issues in cooking. *Trends in Food Science & Technology*, Vol. 71, Cambridge, UK: Elsevier, pp.256-262.

Simko, P. 2009. Chapter 13: Polycyclic Aromatic Hydrocarbons in Smoked Meats. In: Toldra, F. (Ed) *Safety of Meat and Processed Meat*, New York: Springer, p.344.

Singh, P., Wani, A.A. and Goyal, G.K. 2012. Shelf-Life Extension of Fresh Ready-to-Bake Pizza by the Application of Modified Atmosphere Packaging. *Food and Bioprocess Technology*, 5:1028-1037.

Skipnes, D. and Hendrickx, M. 2008. Novel methods to optimise the nutritional and sensory quality of in-pack processed fish products. In: Richardson P. (Ed), *In-pack processed foods.* Boca Raton, FL: CRC press, pp.382-398.

Smith, J.P. 1993. Bakery products. In: Parry, R.T. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Food*, Chapman & Hall, pp.134-166.

Smittle, R.B. 2000. Microbiological Safety of Mayonnaise, Salad Dressings, and Sauces Produced in the United States: A Review. *Journal of Food Protection*, 63(8): 1144-1153.

Somavat, R. 2011. Applications and effects of ohmic heating: sterilization, influence on bacterial spores, enzymes, bioactive components and quality factors in food. Dissertation, The Ohio State University, pp.4-5.

Spencer, K.C. 2005. Chapter 12: Modified atmosphere packaging of ready-to-eat foods. In: Han J.H. (ed) Innovations in food packaging. Elsevier, USA, pp. 185-203.

Stöllman, U., Johansson, F. and Leufven, A. 1994. Packaging and food quality. In: Man, C.M.D & Jones, A.A. (Eds) *Shelf Life Evaluation of Foods*, Chapman & Hall, pp.52-69.

Su, Y.C. and Liu, C. 2010. Chapter 4: Seafood and restructured seafood. In: Hwang, A. and Huang, L. (Ed), Ready-to-Eat Foods Microbial Concerns and Control Measures. Boca Raton: CRC Press, pp.132-140.

Subramaniam, P.J. 1993. Miscellaneous applications. In: Parry, R.T. (Ed), *Principles and Applications of Modified Atmosphere Packaging of Food*, Chapman & Hall, pp.170-187.

Sürücüoğlu, M.S. and Çakıroğlu, F.P. 2000. Ankara Üniversitesi Öğrencilerinin Hızlı Hazır Yiyecek Tercihleri Üzerine Bir Araştırma, *Tarım Bilimleri Dergisi*, 6(3): 116-121.

Tansey, F.S. and Gormley, T.R. 2005. Sous vide/freezing technology for ready meals. In: Barbosa G.V., Tapia M.S. and Cano M.P. (Eds), *Novel Food Processing Technologies.* Boca Raton, FL: Marcel Decker/CRC Press, pp.477-490.

Thayer, D.W. 2003. Development of predictive models for the effects of gamma radiation, irradiation temperature, PH, and modified atmosphere packaging on *Bacillus cereus*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Salmonella typhimurium* and *Staphylococcus aureus*. pp.21-27.

Toldra, F., Gavara, R. and Lagaron, J.M. 2004. Fermented and Dry-Cured Meat: Packaging and Quality Control. In: Hui, Y. H., Meunier-Goddik, L., Hansen, A. S., Josephsen, J. (Eds), *Handbook of food and beverage fermentation technology*, New York: Marcel Dekker, pp. 445-458.

Tucker, G. 2005. Thermal processing of ready meals. In: *Thermal Food Processing: New Technologies and Quality Issues*, Da-Wen Sun (ed.), Boca Raton, FL: CRC Press, pp. 363–385.

Tucker, G. 2011. Food Biodeterioration and Methods of Preservation. In: Coles, R. & Kirwan, M. (Eds) *Food and Beverage Packaging Technology*, 2^{nd} ed. Blackwell Publishing, p.53.

Tudoran, A. A., Fischer, A. R. H.,van Trijp, H. C. M., Grunert, K., Krystallis, A. and Esbjerg, L. 2012. Overview of Consumer Trends in Food Industry, Retailer and Consumer Acceptance of Promising Novel Technologies and Collaborative Innovation Management, p.8.

Tung, M.A., Britt, I.J. and Yada, S. 2001. Packaging Considerations. In: Eskin, N.A.M. & Robinson, D.S. (Eds), *Food Shelf Life Stability: Chemical, Biochemical and Microbiological Changes.* Boca Raton, Florida: CRC Press, pp.129-143.

Üçüncü, M. 2011. *Gıda Ambalajlama Teknolojisi,* İstanbul: Ambalaj Sanayicileri Derneği pp.1-877.

Wilkinson, V.M. and Gould, G.W. 1996. *Food Irradiation: A Reference Guide,* Butterworth-Heinemann, Oxford, p.10.

Venugopal, V. (Ed), 2005. Chapter 5: Cook-Chill Processing. In: *Seafood Processing: Value Addition Techniques.* CRC Press, pp.141-166.

Venugopal, V. (Ed), 2005. Chapter 11: High Pressure Processing. In: *Seafood Processing: Value Addition Techniques.* CRC Press, pp. 319–340.

Yam, K.L. & Lai, C.C. 2004. Microwavable Frozen Food or Meals. In: Murrell, K. D., Hui, Y.H., Nip, W.K., Lim, M.H., Legarreta, I.G. and Cornillon, P. (Eds), *Handbook of Frozen Foods,* CRC Press, p.113. DOI: 10.1201/9780203022009.ch32

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