



Laboratory of Food Chemistry and Technology
School of Chemical Engineering
National Technical University of Athens, GREECE

*Polytechnioupoli, Zografou
15780, Athens, GREECE*

Tel: 00302107723165, Fax:00302107723163

E-Mail: tzia@orfeas.chemeng.ntua.gr

SAFETY OF FRIED PRODUCTS

E. Vorria, V. Giannou, C. Tzia

INTRODUCTION

Nowadays the production of **healthy foods**, as well as food with **improved sensory** characteristics is very important. **Chips and French fries**, which are studied in this assay, are widely consumed all over the world especially by young people and children due to their tastefulness; children can find French fries in fast foods, and chips at school and in almost every store.

Fried foods pose many **quality** (appearance, taste, consumer acceptability) and **safety** (microbiological, chemical or physical) **hazards**.

In this assay, an effort is made to describe and outline the incoming safety hazards, starting from raw materials harvest and throughout processing until the final product. The **critical factors and limits** existing are determined and the relative measures for their control are proposed.

DEEP FRYING AND HAZARDS

Deep frying processing can pose **hazards**; it occurs at high temperatures (~180°C) and frequently means **deterioration** of oil or fat if some simple but very important rules are not followed. **Fats** used for deep-frying gradually undergo certain chemical changes. The most important **changes** are: oxidation, polymerization, hydrolysis and color formation. In addition, other physical changes such as odor and flavor development are noted. During frying, some **components** are produced which are considered to be **harmful** to human health, such as *trans* fatty acids, highly oxidized or polymerized constituents of fatty acids and acrylamide.

Thus, **care must be taken** for the frequent renewal of used oil or fat, temperature maintenance below 190°C, and other conditions or factors, which are described in the main text of the assay. Industries should keep these in mind and try to find ways to produce healthy foods with specifications in accordance to the directions of EC.

EUROPEAN LEGISLATION FOR FOOD SAFETY AND HACCP SYSTEM IMPLEMENTATION

Directive 98/43/EC, published on June 14th, 1993 by the EC Council, is very important for **food hygiene**. According to this, the **protection of human health** constitutes an objective of fundamental importance. This agrees with the internationally acceptable approach recommended by **Codex Alimentarius** for food hygiene published in 1997.

Regulation 178/2002, of European Parliament and Council published on January 28th, 2002, underlines the need for the examination of all aspects of **food production chain** (from primary production until food sale or supply to the consumer). It necessarily requires the establishment of a **traceability** system inside the food industry, so that it will be possible to withdraw products in case a **problem** occurs in respect to **food safety**, thus avoiding the probability of pointless dysfunctions creation.

HACCP

HACCP (Hazard Analysis Critical Control Point) is the current technological food safety rationale and has been rapidly evolved and is being addressed by a number of organizations (**Dir. 43/93 EEC**).

HACCP approach on **food safety** is focusing on the **critical control points (CCPs)** of food processing and is considered to be the most effective method of maximizing product safety. It is a cost-effective system and therefore reduces the risk of manufacturing and selling unsafe products.

HACCP is a highly specialized system for food safety which necessitates the performance of an analytical study on microbiological, chemical and physical risks.

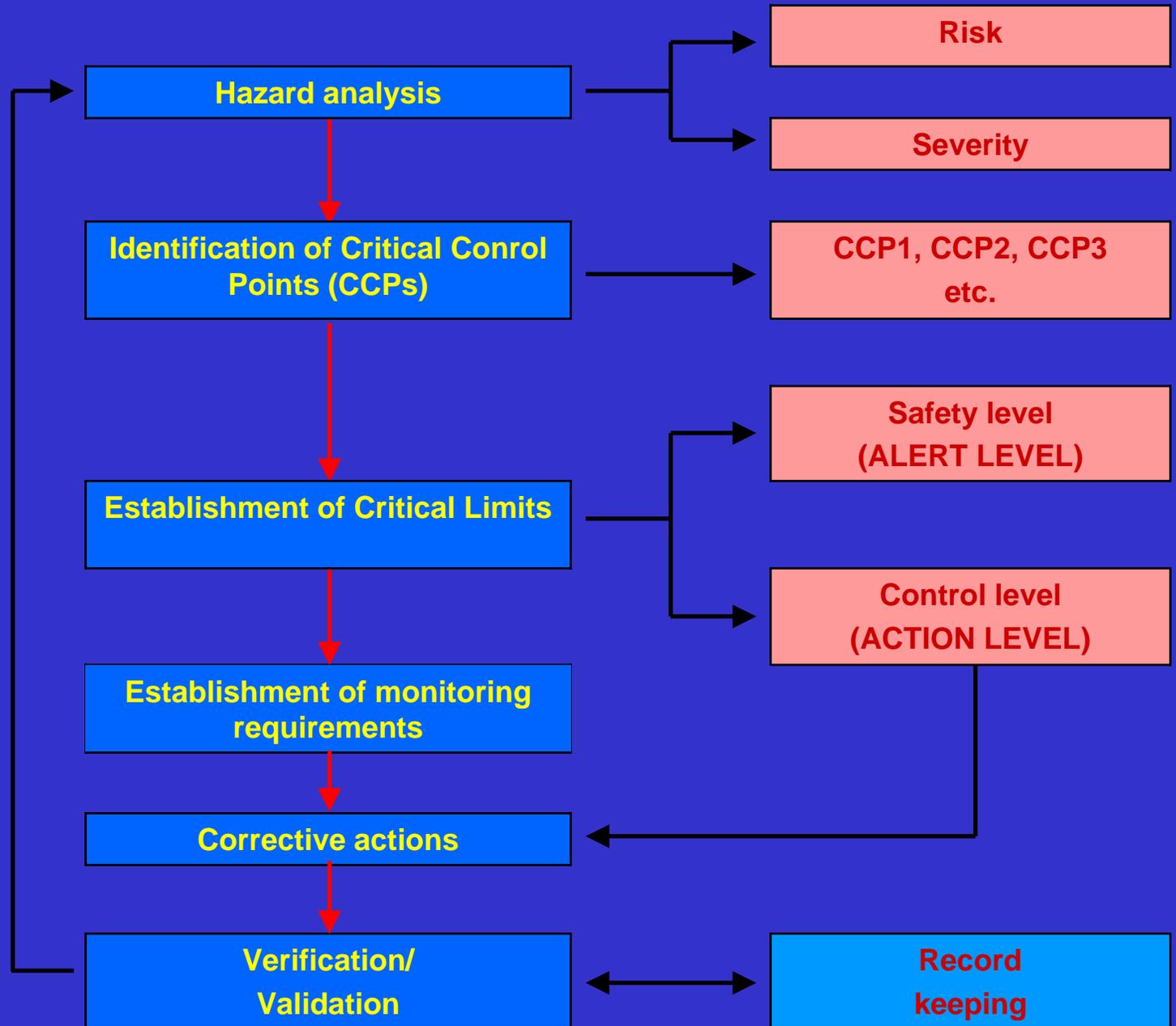
Hazard analysis contains the identification of the potential risks throughout food processing and the critical stages (CCPs) that must be controlled to assure food safety.

HACCP system may be certified according to EL0T standard 1416 in Greece, or international standard **ISO 22000** "Food safety management system".

The HACCP System consists of seven Principles:

1. Conduct a **hazard analysis**. Prepare a list of steps in the process where significant **hazards** occur and describe the **preventative measures**.
2. Identify the **Critical Control Points (CCPs)** in the process (a decision tree is used).
3. Establish **Critical Limits** for preventative measures associated with each identified CCP.
4. Establish **CCP monitoring** requirements. Establish procedures from the results of monitoring to adjust the process and maintain control.
5. Establish **corrective actions** to be taken when monitoring indicates from an established critical limit.
6. Establish effective **record-keeping** procedures that document the HACCP system.
7. Establish procedures for **verification** that the HACCP System is working correctly.

HACCP Principles



METHODS

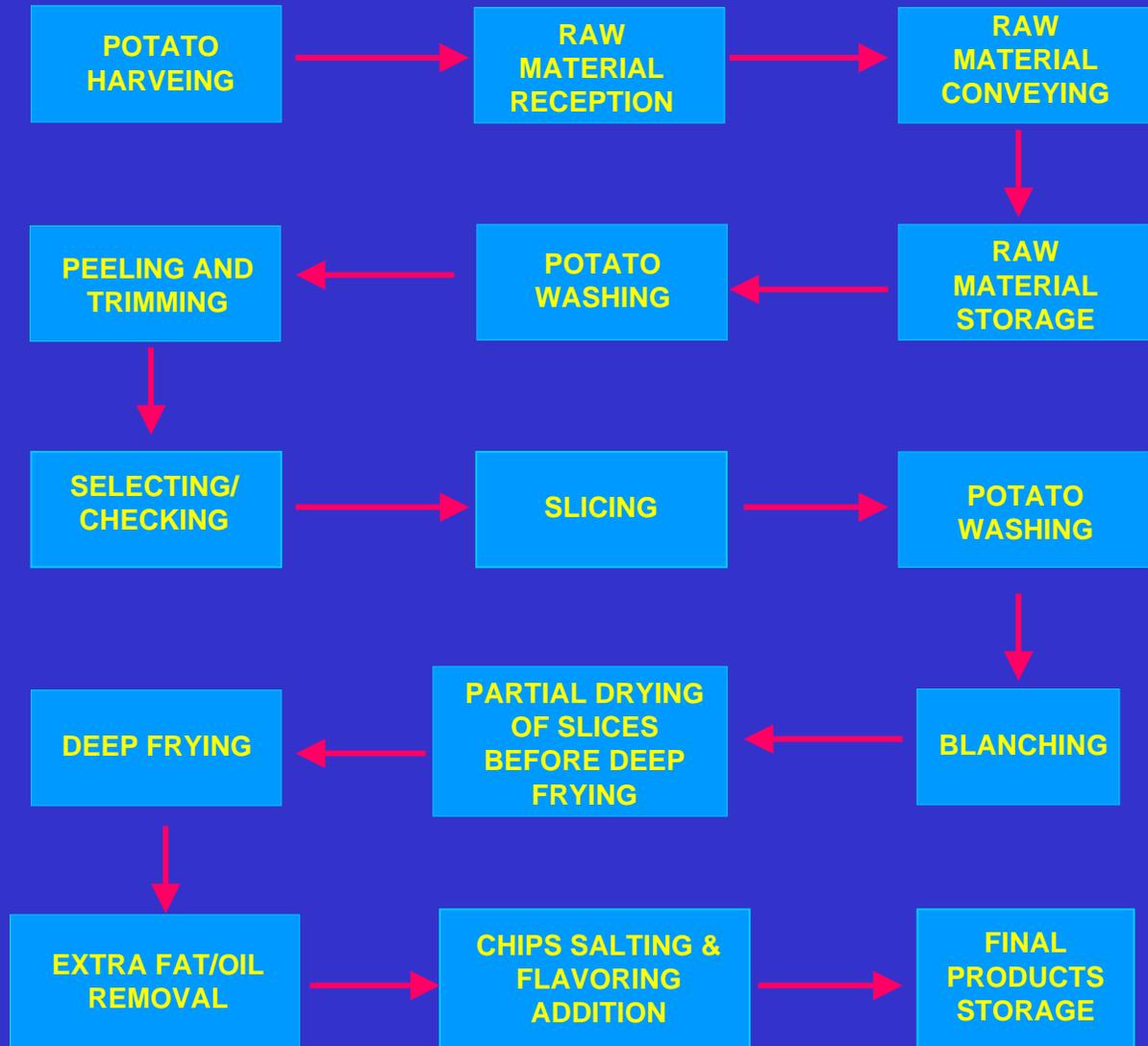
A detailed analysis of **safety hazards** throughout the chips and French fries production, including all main and supporting stages from harvesting the potatoes till final products packaging, was carried out according to HACCP approach.

The **analysis** of **chips** and **French fries** production was concentrated basically on the first three principles and includes three steps:

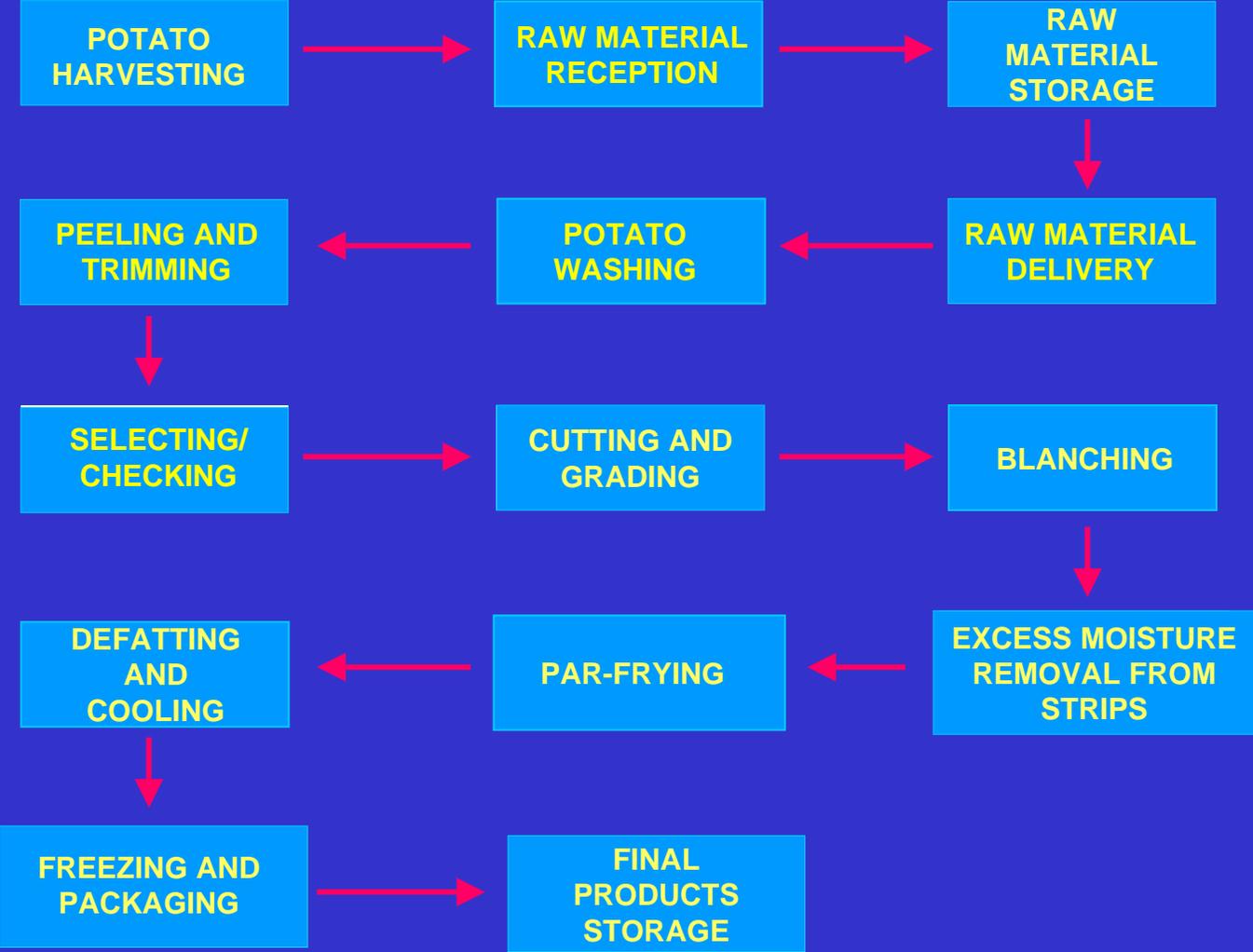
- 1) identification of all **possible hazards** (physical, chemical, microbiological),
- 2) the **preventative measures** for the introduced hazards and
- 3) the **determination of CCPs** with the required control and the relative critical limits.

The results are presented in a Table (HACCP flowsheet).

CHIPS PRODUCTION FLOW CHART



FRENCH FRIES PRODUCTION FLOW CHART



FAT CHANGES AND REACTIONS DURING FRYING

Oxidation

Oxygen from the air reacts with the fat in the fryer. Some of the reaction products are removed from the fryer by the steam formed during food frying, while other products remain in the fat and can accelerate further fat oxidation.

At **frying temperatures**, oxidation can proceed rapidly. Therefore, it is important that the temperature of the frying fat remains at the levels required for cooking. Most foods can be fried at **177°C** in food service operations, but in food processing plants the frying temperature can reach 204.4°C, because many of these foods are conveyed through the frying oil in as little as 1-2 min.

In order to keep the **oxidation level** of the frying fat to a **minimum**, it is important to use a **good-quality frying fat**, keep the temperature of the fat as low as possible, follow frying rules which indicate the **maximum rate of fat turnover**, and avoid **copper contamination**. Regular removal of food particles from the frying fat is also important.

Polymerization

Excessive oxidation of oil and fats is often accompanied by polymerization. As oil and fats undergo heating in the deep-frying process, various **decomposition products** are formed.

Some of these products are **volatile** at frying temperature and have relatively little responsibility in developing polymers. Such volatile products are:

Peroxides
aldehydes

monoglycerides
ketones

diglycerides
carboxylic acids

The **non-volatile** decomposition products include polar compounds which may result in gumming and foaming. Such non-volatile products are:

monomers *dimers* *trimers*
other high-molecular-weight compounds

Both of the above are undesirable in the frying process.

Hydrolysis

This is the reaction of food water with frying fat which leads to the formation of **free fatty acids**. The rate of hydrolysis or free fatty acid development depends on the following factors:

- **Amount of water** released into the frying fat (water is generally introduced from the food that is being fried).
- **Frying temperature** (the higher the temperature, the more rapid the rate of free fatty acid production).
- **Fat turnover rate** (the more rapid the replacement of used oil/fat with fresh, the slower the rate of free fatty acid development).

Color formation

Foods contain several components/substances (e.g. sugars, starches, proteins, phosphates, sulphur compounds and trace metals) which are extracted in the fat during the frying process. These materials may become brown by themselves and/or react with the fat and make it darken.

Harmful products

The most harmful products for the human's health, which are formed during frying are the *trans* fatty acids and acrylamide. The most **serious consequences** for human health caused by the components produced during frying are: coronary illness and other cardiologic diseases. It has also been proved that the *trans* fatty acids increase cholesterol.

Trans fatty acids are produced during hydrogenation. The *trans* content of hydrogenated fats increases during their use. It is difficult to determine the maximum **daily allowance** for the *trans* fatty acids reception, while foods content in *trans* fatty acids may vary. Initial estimations reported that a person should not consume more than **2.7-12.8 g** of **trans fatty acid per day**. A more recent study based on 100 types of foods in 14 European countries, showed that the sum of *trans* fatty acids perceived from foods by a person varies between 1.4 g (or 0.5% of total energy intake) in the Mediterranean countries and 5.4 g (or 2.1% of total energy) in Iceland.

Acrylamide

Acrylamide ($\text{CH}_2=\text{CHCONH}_2$) is a b-unsaturated active molecule which is found in foods especially in the fried potato chips and in all products which contain starch and are fried, heated or cooked in temperatures higher than 171°C .

The **first report** on acrylamide was published in April 2002 by the Swedish National Food Administration (NFA) and the University of Stockholm, where researchers observed high concentrations of it in fried potato products.

Acrylamide is considered to provoke carcinogenesis. The only recognized effect of acrylamide in the human organism is that it can induce **toxic effects** in the nervous system. Experiments in pigs showed that acrylamide destroys the genitals of male pigs and has negative effects on the fertility. It can cause mutations in the genetic attributes in level of genes and chromosomes but in quantities much higher than those daily received by a person via foods (1-10 or 0.001 mg/Kg vs 100.000 mg/Kg). Many experiments have shown that the maximum quantity that can be consumed without problems is **0.5 mg/Kg**.

HACCP FLOWSHEET FOR CHIPS AND FRENCH FRIES

Stage	Hazards/reasons	Preventative measures	Critical factors/limits/controls
1.RAW MATERIALS RECEIPT POTATOES	<u>MICROBIOLOGICAL</u> Fungi, Molds, Bacteria <u>CHEMICAL</u> Fungicides and Pesticides <u>PHYSICAL</u> Foreign materials from soil, harvesting	Suppliers of potatoes (SQA) Inspection of suppliers for hygiene	Control of safety specifications Limits of fungicide and pesticide residues (MRLs – EC directives) Control for foreign materials
OIL/FATS	<u>CHEMICAL</u> Residues of Fungicides and Pesticides Additives Heavy metals	Suppliers of potatoes (SQA) Inspection of suppliers for hygiene	Control of specifications Limit of antifoams: 0.04 mg/Kg Limit of heavy metals: 2%
FLAVORING MATERIALS, SALT, ADDITIVES AND PRESERVATIVES	<u>CHEMICAL</u> Residues of chemicals <u>PHYSICAL</u> Foreign materials	Suppliers of materials (SQA)	Control of safety specifications Limits for chemical residues (according to EC legislation)
WATER	<u>MICROBIOLOGICAL</u> Pathogens: <i>Salmonella</i> , <i>Shigella</i> , <i>Leptospira</i> , <i>E. Coli</i> , <i>Pasturella</i> , <i>Vibrio</i> , <i>Cholerae</i> , <i>Yersinia enterocolica</i> , <i>Mycobacterium tuberculosis</i> Molds and Bacteria <u>CHEMICAL</u> Organic compounds Radioisotopes Heavy metal <u>PHYSICAL</u> Foreign materials from soil	Cleaning and disinfection of water	Control of specifications (according to Dir. 98/83/EC) Limits for pathogens and chemical contaminants (according to Dir. 98/83/EC)

HACCP FLOWSHEET FOR CHIPS AND FRENCH FRIES (continued)

Stage	Hazards/reasons	Preventative measures	Critical factors/limits/controls
<p>2. STORAGE OF RAW MATERIALS</p> <p>POTATOES</p>	<p><u>MICROBIOLOGICAL</u> <i>Fungi: Phytophthora infestans, Alternaria solani, Fusarium sambucinum, Fusarium coeruleum, Verticillium alboatrum, Verticillium dahliae, Helminthosporium solani, Spongospora subterranean f. Sp. ubterranean</i> <i>Viruses: : Annulus dubius Holmes, Marmor solani Holmes, Solanum virus 14, 16, X, M, Y, S</i> <i>Bacteria: Pseudomonas solanacearum, Streptomyces scabies, Erwinia carotovora ssp. Carotovora, Erwinia carotovora ssp. Atroseptica, Pseudonomas marginalis, Clostridium sp., Corynebacterium sepedonicum</i></p> <p><u>CHEMICAL</u> Chemicals used to control vegetation</p>	<p>GMP - GHP Hygienic conditions during storage Cleaning and disinfection of storage area Use of pallets to allow ventilation Ventilation system Pest control programs Personnel hygiene</p>	<p>Control of storage conditions RH: 90-100%, T=3-10° C Concentration of : O₂ < 18%, CO₂ < 5% Inspection of hygiene during storage Inspection of programs: pest control, cleaning and disinfection of storage area Solanine: max 0.555% dry matter of potato - increase during storage: 20 mg/100g Control for residues of chemicals used to control vegetation</p>
<p>OIL/FATS</p>	<p><u>CHEMICAL</u> Oxidation components in oil/fat (in order to be more stable in oxidation during frying) <u>PHYSICAL</u> Foreign materials</p>	<p>GMP - GHP Cleaning and disinfection of oil silo Pest control programs Prevention of oil from air and light</p>	<p>Control of storage conditions T ≤ 0 ° C Control of oils/fats deterioration Peroxide and p-Anisidine Value < 3-5 meq/Kg</p>
<p>FLAVORING MATERIALS, SALT, ADDITIVES & PRESERVATIVES</p>	<p><u>PHYSICAL</u> Foreign materials</p>	<p>GMP - GHP Conditions during storage Pest control programs Cleaning of storage area</p>	<p>Control of storage conditions Inspection of programs: pest control, cleaning of storage area</p>

HACCP FLOWSHEET FOR CHIPS AND FRENCH FRIES (continued)

Stage	Hazards/reasons	Preventative measures	Critical factors/limits/controls
3. CONVEYING OF RAW MATERIALS	<p><u>MICROBIOLOGICAL</u> Microorganisms from surfaces</p> <p><u>PHYSICAL</u> Foreign materials</p>	<p>GMP - GHP</p> <p>Cleaning and disinfection of equipment</p> <p>Cleaning agents approved for foods</p>	<p>Control of cleaning and disinfection programs for surfaces and equipment</p>
4. POTATO WASHING	<p><u>MICROBIOLOGICAL</u> Microorganism from equipment, water</p> <p><u>CHEMICAL</u> Residues of cleaning agents in the equipment</p> <p><u>PHYSICAL</u> Foreign materials</p>	<p>GMP - GHP</p> <p>Assurance of hygienic conditions</p> <p>Cleaning and disinfection of equipment</p> <p>Renewal of water</p>	<p>Microbiological control of water</p> <p>Control of washing efficiency</p> <p>Control of cleaning and disinfection programs</p> <p>Control of reuse of water</p>
5. PEELING AND TRIMMING	<p><u>MICROBIOLOGICAL</u> Microorganism from equipment, surfaces</p> <p><u>CHEMICAL</u> Residues of cleaning agents in the equipment and lubricants</p> <p><u>PHYSICAL</u> Foreign materials (from metallic surfaces)</p>	<p>GMP - GHP</p> <p>Assurance of hygienic conditions</p> <p>Cleaning and disinfection of equipment</p> <p>Maintenance of equipment</p> <p>Lubricant approved for foods</p>	<p>Control of cleaning and disinfection programs</p> <p>Control for foreign materials and draw away</p>
6. SELECTING AND SLICING	<p><u>MICROBIOLOGICAL</u> Microorganism from equipment, personnel</p> <p><u>CHEMICAL</u> Residues of cleaning agents in the equipment</p> <p><u>PHYSICAL</u> Foreign materials (from metallic surfaces)</p>	<p>GMP - GHP</p> <p>Assurance of hygienic conditions</p> <p>Cleaning and disinfection of equipment</p> <p>Lubricant approved for foods</p> <p>Maintenance of equipment</p> <p>Personnel training</p>	<p>Microbiological control</p> <p>Control of cleaning and disinfection programs</p> <p>Control for foreign material and draw away</p> <p>Removal of potatoes with defects</p>

HACCP FLOWSHEET FOR CHIPS AND FRENCH FRIES (continued)

Stage	Hazards/reasons	Preventative measures	Critical factors/limits/controls
7. POTATO WASHING & 8. BLANCHING	<p><u>MICROBIOLOGICAL</u> Microorganism from water, equipment</p> <p><u>CHEMICAL</u> Residues of cleaning agents</p> <p><u>PHYSICAL</u> Foreign materials</p>	<p>GMP - GHP</p> <p>Assurance of hygienic conditions</p> <p>Cleaning and disinfection of equipment</p> <p>Renewal of water</p>	<p>Microbiological control of water</p> <p>Control of cleaning and disinfection programs</p> <p>Blanching max time: 5 min opt. temperature: T=73°C</p>
9. PARTIAL DRYING OF SLICES BEFORE DEEP FRYING	<p><u>MICROBIOLOGICAL</u> Microorganism from equipment, environment (potato slices remain for a short time before frying)</p> <p><u>PHYSICAL</u> Foreign materials</p>	<p>GMP - GHP</p> <p>Assurance of hygienic conditions</p> <p>Protection the product from the environment</p> <p>Cleaning and disinfection of equipment</p> <p>Personnel training</p>	<p>Control of cleaning and disinfection programs</p> <p>Control of environment hygiene</p> <p>Max removal of moisture: 4%</p> <p>Draw away of foreign material</p>
10. DEEP FRYING	<p><u>MICROBIOLOGICAL</u> The majority of microorganisms are destroyed</p> <p><u>CHEMICAL</u> Residues of cleaning agents and lubricant Oxidation and polymerization products of oil</p> <p><u>PHYSICAL</u> Foreign materials Contamination of fresh oil/fat with used oil/fat</p>	<p>GMP - GHP</p> <p>Assurance of hygienic conditions</p> <p>Cleaning and disinfection of equipment</p> <p>Antifoam and antioxidants and their percent in oil/fat approved for foods</p> <p>Use lubricant and cleaning agents approved for foods</p> <p>Personnel training</p> <p>Maintenance of equipment</p>	<p>Temperature: 165-185°C (opt. T: 177°C)</p> <p>Turn over time of oil/fat 5-10 h</p> <p>Control of correct use of antifoams and antioxidants</p> <p>Replace oil/fat according to specifications (country's legislation)</p> <p>Max consumption of trans fatty acid: 2,7-12,8 g/day</p> <p>Max consume of acrylamide: 0,5 mg/Kg</p> <p>Control for foreign materials</p>

HACCP FLOWSHEET FOR CHIPS AND FRENCH FRIES (continued)

Stage	Hazards/reasons	Preventative measures	Critical factors/limits/controls
<p>10a. PREFRYING, FREEZING AND PACKAGING</p>	<p><u>MICROBIOLOGICAL</u> Microorganism from air, equipment, personnel (the product should be cooked by consumers)</p> <p><u>CHEMICAL</u> Residues of cleaning agents</p> <p><u>PHYSICAL</u> Foreign materials</p>	<p>Packaging material approved for foods</p> <p>Suppliers of packaging material (SQA)</p> <p>Maintenance of freezer</p> <p>Protect the product from the environment</p>	<p>T: -20 °C for 7-12 min (unpacked)</p> <p>T: -20 °C for 3-7h (packed in paper boxes)</p> <p>Control of freezing rate</p> <p>Control of cleaning and disinfection programs</p> <p>Control for foreign materials</p> <p>Check for correct closing of the package</p>
<p>11. REMOVAL OF EXTRA (NOT WANTED) QUANTITY OF OIL/FAT</p>	<p><u>MICROBIOLOGICAL</u> Contamination (air, equipment, surfaces, personnel)</p> <p><u>CHEMICAL</u> Residues of cleaning agents</p> <p><u>PHYSICAL</u> Foreign materials</p>	<p>GMP - GHP</p> <p>Assurance of hygienic conditions</p> <p>Cleaning and disinfection of equipment and surfaces</p> <p>Personnel training</p>	<p>Control of cleaning and disinfection programs</p> <p>Microbiological control of equipment and surfaces</p> <p>Control for foreign materials</p>
<p>12. SALTING CHIPS & ADDING FLAVORING MATERIAL</p>	<p><u>MICROBIOLOGICAL</u> Contamination (air, equipment, personnel)</p> <p><u>CHEMICAL</u> Residues of chemicals in the materials</p> <p><u>PHYSICAL</u> Foreign materials</p>	<p>GMP - GHP</p> <p>Assurance of hygienic conditions</p> <p>Cleaning and disinfection of equipment</p> <p>Hygiene handling of materials</p> <p>Maintenance of equipment</p> <p>Personnel training</p>	<p>Control of cleaning and disinfection programs</p> <p>Control for foreign materials</p> <p>Inspection of material handling by the personnel</p>

HACCP FLOWSHEET FOR CHIPS AND FRENCH FRIES (continued)

Stage	Hazards/reasons	Preventative measures	Critical factors/limits/controls
<p>13. INSPECTION & COOLING</p>	<p><u>MICROBIOLOGICAL</u> Contamination (air, equipment, personnel) (the final product remains for a short time for cooling before its packaging)</p> <p><u>PHYSICAL</u> Foreign materials</p>	<p>GMP - GHP Protection the product from the environment Assurance of hygienic conditions Cleaning and disinfection of equipment Ventilation for good cooling Personnel training</p>	<p>Control of cleaning and disinfection programs Control for foreign materials and draw away Control for chips with defects or undesirable characteristics and direct reject Control of hygiene in the environment during cooling</p>
<p>14. PACKAGING</p>	<p><u>MICROBIOLOGICAL</u> Contamination (air, equipment, personnel, packaging material)</p> <p><u>CHEMICAL</u> Contaminants from the packaging materials</p> <p><u>PHYSICAL</u> Foreign materials</p>	<p>Suppliers of packaging material (SQA) Packaging material approved for foods Protection of the packaging area away from the production area Metal detector after packaging Coding of product</p>	<p>Check the specifications of packaging materials Control for foreign materials Check for the correct closing of the package Check for the correct coding Removal of products with defects Control of cleaning and disinfection programs Control of metal detector</p>
<p>15. STORAGE OF FINISHED PRODUCT</p>	<p><u>MICROBIOLOGICAL</u> Contamination (moisture, pests) in case of not correctly closed packaged products</p> <p><u>CHEMICAL</u> Residues of chemicals and pesticides in case of not correctly closed packaged products</p>	<p>GMP - GHP Assurance of hygienic conditions in storage area Control of cleaning and disinfection programs Pests control programs Hygiene storage of final products</p>	<p>Control of programs: cleaning and disinfection, pest control Control of hygiene in storage area Control for foreign materials Check for the correct closing of the package</p>

CONCLUSIONS

For the production of safe **potato Chips** and **French Fries** the most important factors are the following:

- **Frying, which is a CCP and must be monitored**
- **Oil/fat used and its initial oxidative state**
- **Temperature of frying**
- **Oil/fat renewal during frying**

The potential hazards are: **trans fatty acids** and **acrylamide**

The critical limits for the frying temperature and for the potential hazards must be satisfied