RISK MANAGEMENT IN PRODUCTION OF EGG-PASTA

Ayse Handan Baysal[1], Savvas Gennaris[2], Primož Likar[3], Darja Peterka[4], Oana Popescu[5] & Tiina Veskus[6]

[1] Izmir Institute of Technology, Gulbahce, Izmır, Turkey
[2] Veterinary Services, Cyprus
[3] Mlinotest d. d. Adjovščina, Slovenia
[4] Pekarna Pecjak d. o. o. Škofljica, Slovenia
[5] S.C. Vel Pitar S.A., Romania
[6] Tallinn University of Technology, Tallinn, Estonia

Pasta (Italian for "dough") is a generic term for Italian variants of noodles, food made from a dough of flour, water and/or eggs. The word can also denote dishes in which pasta products are the primary ingredient, served with sauce or seasonings. There are approximately 350 different shapes of pasta. Examples include spaghetti (solid, thin cylinders), maccheroni (tubes or hollow cylinders), fusilli (swirls), and lasagne (sheets). Two other noodles, gnocchi and spätzle, are sometimes considered pasta. They are both traditional in parts of Italy. Pasta is categorized in two basic styles: Dried and fresh. Dried pasta can be stored for up to two years under ideal conditions, while fresh pasta can be kept for a couple of days in the refrigerator. In preparation for consumption, pasta is generally boiled. Pasta is made from a simple combination of flour and water. Pre-packed speciality pasta often includes spices, cheese or added colouring from spinach, tomatoes or food dye. Under Italian law, dry pasta (pasta secca) can only be made from durum wheat flour or durum wheat semolina. Durum flour and durum semolina have a yellow tinge in colour. Italian pasta is traditionally cooked al dente (Italian: "to the tooth", meaning not too soft). Outside Italy, dry pasta is frequently made from other types of flour (such as wheat flour), but this yields a softer product, which cannot be cooked al dente. Egg-pasta is a very popular food in world and its appreciation is growing in Europe and in the United States. Starting from very simple ingredients (semolina and eggs), the secret to obtain the best quality is to find the higher quality of the two base-materials (no water is added to the kneading) and the best drying process. A high percent content of eggs and good semolina are the basic starting points to obtain egg-pasta of a good quality. However, the drying process is the final fundamental step to obtain a quality product. In fact, the right drying process assures the production of a safe, tasty, and nutritious product after the cooking process with the proper sensory characteristics.

The food chain has become more and more complex and that is why it now represents an important issue, which requires specific measures, meant to assure an acceptable standard for food security. The general legislative framework, which will enforce preparation and distribution of food fit for consumption must be strengthened by the organizations through specific regulations. These regulations require adequate standards concerning food safety, correct labelling that is easily read and understood, good manufacturing practice, good hygiene practice and also proper management systems concerning food quality. If there is an established system for controlling food risks, the authorities respond quickly if a food safety problem appears. A lot of effort is put into preventing food risks and food safety laws are stringently enforced by the authorities which results in an active consumer protection. Therefore the process of weighing policy alternatives in the light of the results of risk assessment (RA) and, if required, selecting and implementing appropriate control options, including regulatory measures which is defined as “Risk Management” by FAO (1997) meets these goals. The objectives of the present study were (1) to analyze probable microbial hazards in the dried egg-pasta production, (2) to establish the critical control points of the whole process, and (3) to evaluate the risk assessment (RA).

PASTA MANUFACTURING

General

Although pasta products were first introduced in Italy in the 13th century, efficient manufacturing equipment and high-quality ingredients have been available only since the 20th century. Prior to the industrial revolution, most pasta products were made by hand in small shops. Today, most pasta is manufactured by continuous, high capacity extruders, which operate on the auger extrusion principle in which kneading and extrusion are performed in a single operation. The manufacture of pasta includes dry macaroni, noodle, and spaghetti production.

Process Description

Pasta products are produced by mixing milled wheat, water, eggs (for egg noodles or egg spaghetti), and sometimes optional ingredients. These ingredients are typically added to a continuous, high capacity auger extruder, which can be equipped with a variety of dies that determine the shape of the pasta. The pasta is then dried and packed for market.

Raw Materials

Pasta products contain milled wheat, water, and occasionally eggs and/or optional ingredients. Pasta manufacturers typically use milled durum wheat (semolina durum granules and durum flour) in pasta production, although farina and flour from common wheat are occasionally used. Most pasta manufacturers prefer semolina, which consists of fine particles of uniform size and produces the highest quality pasta product. The water used in pasta production should be pure, free from off flavours, and suitable for drinking. Also, since pasta is produced below pasteurization temperatures, water used should be of low bacterial count. Eggs (fresh eggs, frozen eggs, dry eggs, egg yolks, or dried egg solids) are added to pasta to make egg noodles or egg spaghetti and to improve the nutritional quality and richness of the pasta. Small amounts of optional ingredients, such as salt, celery, garlic, and bay leaves, may also be added to pasta to enhance flavour. Disodium phosphate may be used to shorten cooking time. Other ingredients, such as gum gluten, glyceryl monostearate, and egg whites, may also be added. All optional ingredients must be clearly labelled on the package. The kinds of wheat used to make pasta are two: durum wheat (*Triticum durum*) and wheat (*Triticum vulgare*). The first one is milled in order to produce durum wheat flour and is mainly used to make pasta. The second one is milled and the flour is used to make homemade egg-pasta, as well as other recipes. At first sight these two kinds of wheat do not show big differences, durum wheat’s grain is a little longer and more opaque, whereas the grain of wheat is less opaque and rounder (Walsh & Gilles, 1977; Anonymous, 1992).

Wheat Milling

Durum wheat is milled into semolina, durum granular or durum flour using roll mills. Semolina milling is unique in that the objective is to prepare granular middling with a minimum of flour production. After the wheat is milled, it is mixed with water, eggs, and any other optional ingredients (Walsh & Gilles, 1977; Anonymous, 1992).

Mixing

In the mixing operation, water is added to the milled wheat in a mixing trough to produce dough with a moisture content of approximately 31%. Eggs and any optional ingredients may also be added. Most modern pasta presses are equipped with a vacuum chamber to remove air bubbles from the pasta before extruding. In case of the air is not removed prior to extruding, small bubbles will form in the pasta, which diminish the mechanical strength and give the finished product a white, chalky appearance (Walsh & Gilles, 1977; Anonymous, 1992).

Extruding

After the dough is mixed, it is transferred to the extruder. The extrusion auger not only forces the dough through the die, but it also kneads the dough into a homogeneous mass, controls the rate of production, and influences the overall quality of the finished product. Although construction and dimension of extrusion augers vary by equipment manufacturers, most modern presses have sharp edged augers that have a uniform pitch over their entire length. The auger fits into a grooved extrusion barrel, which helps the dough move forward and reduces friction between the auger and the inside of the barrel. Extrusion barrels are equipped with a water-cooling jacket to dissipate the heat generated during the extrusion process. The cooling jacket also helps to maintain a constant extrusion temperature, which should be approximately 51°C. If the dough is too hot (above 74°C) the pasta will be damaged. Uniform flow rate of the dough through the extruder is also important. Variances in the flow rate of the dough through the die cause the pasta to be extruded at different rates. Products of non-uniform size must be discarded or reprocessed, which adds to the unit cost of the product. The inside surface of the die also influences the product appearance. Until recently, most dies were made of bronze, which was relatively soft and required repair or periodic replacement. Recently, dies have been improved by fitting the extruding surface of the die with Teflon® inserts to extend the life of the dies and improve the quality of the pasta (Walsh & Gilles, 1977; Anonymous, 1992). The low-temperature drying process is clearly a better way to obtain the best egg-pasta quality, even if the final cost for the consumer is higher because of both the longer time needed and the higher quality of the starting semolina and egg (Materazzi et al. 2008).

Drying

Drying is the most difficult and critical step to control in the pasta production process. The objective of drying is to lower the moisture content of the pasta from approximately 31% to 12–13% so that the finished product will be hard, retain its shape, and stored without spoiling. Most pasta drying operations use a preliminary drier immediately after extrusion to prevent the pasta from sticking together. Pre-drying hardens the outside surface of the pasta while keeping the inside soft and plastic. A final drier is then used to remove most of the moisture from the product. Drying temperature and relative humidity increments are important factors in drying.

Since the outside surface of the pasta dries more rapidly than the inside, moisture gradients develop across the surface to the interior of the pasta. If dried too quickly, the pasta will crack, giving the product a poor appearance and very low mechanical strength. Cracking can occur during the drying process or as long as several weeks after the product has left the drier. If the pasta is dried too slowly, it tends to spoil or become mouldy during the drying process. Therefore, it is essential that the drying cycle is tailored to meet the requirements of each type of product. If the drying cycle has been successful, the pasta will be firm but also flexible enough so that it can bend to a considerable degree before breaking (Walsh & Gilles, 1977; Anonymous, 1992). Times and methods for the drying process vary from six to eight hours, from 40° to 80°C. Currently there is the tendency to increase the drying temperature because it was observed that the overall structure of the product is improved and gets a better consistency during cooking. The drying process varies according to the style of pasta to be made, it is very important because it gives pasta higher preservation, moreover stabilizes the raw materials while exalting organoleptic properties, as well as optimizing its characteristics for a good cooking. The process consists of ventilating pasta with a hot air stream, followed by a cooling process in order to have pasta at a room temperature. At this point pasta is ready to be packed (Walsh & Gilles, 1977; Anonymous, 1992).

Packaging

Packaging keeps the product free from contamination, protects the pasta from damage during shipment and storage, and displays the product favourably. The principal packaging material for noodles is the cellophane bag, which provides moisture-proof protection for the product and is easily used on automatic packaging machines but is difficult to stack on grocery shelves. Many manufacturers utilize boxes instead of bags to pack pasta because boxes are easy to stack, provide good protection for fragile pasta products, and offer the opportunity to print advertising that is easier to read than on bags (Walsh & Gilles, 1977; Anonymous, 1992).

Emissions and Controls

Air emissions may arise from a variety of sources in pasta manufacturing. Particulate matter (PM) emissions result mainly from solids during handling and mixing. For pasta manufacturing, PM emissions occur during the wheat milling process, as the raw ingredients are mixed and possibly during packaging. Emission sources associated with wheat milling include grain receiving, pre-cleaning/handling, cleaning house, milling, and bulk loading. There are no data for PM emissions from mixing of ingredients or packaging for pasta production. Volatile organic compound (VOC) emissions may potentially occur at almost any stage in the production of pasta, but most usually are associated with thermal processing steps, such as pasta extruding or drying. No information is available on any VOC emissions due to the heat generated during pasta extrusion or drying. Control of PM emissions from pasta manufacturing is similar to that Grain Elevators and Processes. Because of the operational similarities, emission control methods used in grain milling and processing plants are similar to those in grain elevators. Cyclones or fabric filters are often used to control emissions from the grain handling operations (e.g., unloading, legs, cleaners, etc.) and also from other processing operations. Fabric filters are used extensively in flourmills. However, certain operations within milling operations are not amenable to the use of these devices and alternatives are needed. Wet scrubbers, for example, may be applied where the effluent gas stream has high moisture content (Walsh & Gilles, 1977; Anonymous, 1992).

Quality characteristics of pasta

The qualities that pasta must have in order to meet the criteria and expectations of consumers are as follows: (i) a uniform, amber-yellow colour without shades of grey or red; (ii) clean surface appearance without brown, black or white spots or other signs indicating faulty milling; (iii) when cooked, pasta must not be glutinous on the surface i.e. stick together, but should have good ribbing and resistance to mastication; (iv) a pleasant aroma and taste typical to pasta; (v) practically zero contamination from chemical pesticides and preservatives. All these characteristics can be measured using instruments, organoleptic and taste tests and constitute the basic requirements for high quality pasta. To produce pasta with these characteristics requires: raw materials with the characteristics needed to guarantee the final quality required, suitable and modern technologies for processing raw materials, production and human resource management systems focused on quality and systems which therefore involve personnel at all levels in the attainment of quality objectives. This system is known as Integrated Production Process Management, which developed at the end of the eighties. In Table 1 the product specification and the quality parameters of egg-pasta are given.

Table 1. Product specification and the quality parameters of egg-pasta.

<table>
<tr><th>Name of the product</th><th colspan="4">Egg spaghetti</th></tr>
<tr><td>Description of the product</td><td colspan="4">Dried egg pasta, which must be cooked before consumption</td></tr>
<tr><td>Ingredients</td><td colspan="4">Durum semolina and eggs 16,5% (3 egg per 1 kg semolina)</td></tr>
<tr><td>Packaging</td><td colspan="4">PE-PP, per 1 kg</td></tr>
<tr><td>Parameters of quality</td><td colspan="4">Length 30 cm</td></tr>
<tr><td>Parameters of safety:</td><td colspan="4">Moisture below 12,5%, water activity a_w 0.5</td></tr>
<tr><td rowspan="7">Microbial parameters</td><td>Parameter</td><td>n</td><td>c</td><td>Criteria</td></tr>
<tr><td>Salmonella spp</td><td>5</td><td>0</td><td>n. n. in 25 g</td></tr>
<tr><td>Coagulase (+) Staphylococcus and Staphylococcus aureus</td><td>5</td><td>2</td><td>m = 10^2 cfu/g
M = 10^3 cfu/g</td></tr>
<tr><td>Bacillus cereus</td><td>5</td><td>2</td><td>m = 10^3 cfu/g
M = 10^4 cfu/g</td></tr>
<tr><td>Enterobacteriaceae*</td><td>5</td><td>2</td><td>m = 10 cfu/g
M = 10^2 cfu/g</td></tr>
<tr><td>Clostridium perfringens*</td><td>5</td><td>2</td><td>m = 10 cfu/g
M = 10^2 cfu/g</td></tr>
<tr><td>Moulds</td><td>5</td><td>2</td><td>m = 10^3 cfu/g
M = 10^4 cfu/g</td></tr>
<tr><td>Storage and transport conditions</td><td colspan="4">Storage in ambient conditions, dry and dark place</td></tr>
<tr><td>Shelf life:</td><td colspan="4">2 years</td></tr>
<tr><td>Instructions for food preparation</td><td colspan="4">Product must be cooked before consumption (10 min) “al dente”</td></tr>
<tr><td>Target population</td><td colspan="4">Healthy population without limits in food consumption – exception are individuals with gluten intolerance, egg allergy</td></tr>
<tr><td>Properties of cooked product</td><td colspan="4">Cooked product has to be non sticky, without any other untypical smell and taste, typical yellow colour without discolorations. During cooking the product should not fall apart.</td></tr>
</table>

SUPPLIERS AND DEMANDS FOR RAW MATERIALS

Raw materials for the production of egg-pasta include eggs (fresh eggs, frozen eggs, dry eggs, egg yolks, or dried egg solids), durum semolina and potable water. All raw materials should be of high quality. This can only be assured by the careful selection of suppliers who fulfil the necessary requirements set by the producing company. The suitability of water should also be monitored both from the supplier and company with the relevant microbial and physico-chemical analysis. Special quality and safety criteria should also apply for the packaging material supplier. Here below follows some of the main requirements for raw material.

Liquid eggs:

1. Statement about sanitary and suitability that raw material satisfies the requirements EU acts and directives, which define the domain of foodstuff safety.
2. Statement from supplier that, in accordance with safety requirements for foodstuffs, they carry out an internal supervision on HACCP principles during all phases of foodstuff production, and that they have a system for internal supervision, an elaborate plan and a procedure in place for the recall of unsuitable foodstuffs from the market.
3. Product specification of raw materials
4. Statement GMO free – Raw materials do not contain genetically modified organisms as stated in Regulation EC 1829/2003.
5. Statement about suitability of primary package in accordance with Regulation EC 1935/2004.
6. Microbial analysis from an accredited laboratory regarding microbial parameters of safety issued in accordance with the specifications for raw material or in accordance with the Guidelines for microbial safety of foodstuffs or Regulation EC 2073/2005.
7. Statement about registration of establishments engaged in food related activity as per Regulation EC 852/2004.
8. For all establishments which are under veterinary supervision-Provision of veterinary inspection.

Durum semolina:

1. Statement about sanitary and suitability that raw material satisfies the requirements EU acts and directives, which define the domain of foodstuff safety.
2. Statement from supplier that, in accordance with safety requirements for foodstuffs, they carry out an internal supervision on HACCP principles during all phases of foodstuff production, and that they have a system for internal supervision, an elaborate plan and a procedure in place for the recall of unsuitable foodstuffs from the market.
3. Product specification of raw materials
4. Statement GMO free – Raw materials do not contain genetically modified organisms as stated in Regulation EC 1829/2003.

5. Statement about suitability of primary package in accordance with Regulation EC 1935/2004.
6. Microbial analysis from an accredited laboratory regarding microbial parameters of safety issued in accordance with the specifications for raw material or in accordance with the guidelines for microbial safety of foods.
7. Statement about the registration establishments engaged in food related activity as per Regulation EC 852/2004.
8. Analysis is required as per the Regulation EC 1881/2006 about definition of limited values of some pollutants in foodstuffs and regarding the presence of pesticides in accordance with Regulation EC 396/2005 about the limits of pesticide remains in or on food and fodder of vegetal and animal origin (Directive of Council 91/414/EEC amended by Regulation EU 839/2008 and Regulation EC 149/2008).

- Packaging material:

  - Declaration of a good production practice for materials and products that might come in contact with foodstuffs as per provision of Regulation EC 2023/2006.
  - Declaration by the holder of activity engaged in the process that they do / do not use recycled materials and products in their production process.
  - Declaration that the holder of activity engaged in the process for the production of material or product coming in contact with foodstuffs, which is not in accordance with Article 3 of Regulation 1935/2004, have an elaborate plan for the recall of these products and have nominated an authorized person for carrying out this procedure.
  - Statement about the registration of establisments engaged in food related activity as per Regulation EC No. 852/2004.
  - Labelling the material with the following information (name, description of material, structure, dimensions, parameters of quality, parameters of safety, testing methods, labelling of material-traceability, storage conditions and expiry date of these materials).

A systematic approach to safety is an important step towards food quality, safety and sustainable practices. Food safety begins at the farm and must be ensured throughout the manufacturing. In recent years, “Supply Chain Risk Management” has gone through rapid developments. Food manufacturers are no longer judged only by their own actions, but also by those of their suppliers or partners. A sound, corporate and responsible approach helps manufacturers in improving the management of environmental, social and economic impacts on their business. Corporate responsibility helps the manufacturer maintain long-term profitability. By improving supply chain management and food chain traceability facilitates both in tracing problems of food safety and quality. Upstream it helps differentiate and provide credibility to foods with undetectable quality attributes and downstream it can make a product recall more efficient during an incident. Food supply chain is overdue in investment, in cost-effective quality processes and supporting technology that will address these problems and assure consumers that their food supply remains safe. Continued incidents of tainted lettuce, spinach, peanut butter, seafood, and now peppers and tomatoes should be a call for action to address supply chain risk factors among food producers and all other participants of the food supply chain (Jöhr & Ware, 2007).

RISK ASSESSMENT COMPONENTS

These risk assessments (RAs) reflect, to the extent practicable, a full range of current practices, behaviours, and conditions in the farm-to-table continuum. Major components of the assessments are Hazard Identification, Exposure Assessment, Hazard Characterization and Risk Characterization. Hazard Identification discusses the characteristics of the hazard of concern, the vehicle of human exposure, and host characteristics such as human susceptibility to illness. Exposure Assessment describes consumer exposure to pathogens from food ingredients. It estimates the prevalence and level of pathogens in food ingredients produced on the farm and translates that to the level of pathogens in foods consumed directly or as an ingredient in a meal. This translation involves taking into consideration the change in the level of pathogens in food during distribution, storage, and preparation. The effects of food handling and pasteurization are also evaluated. Similarly, the prevalence and level of the pathogen in food products before pasteurization are estimated and used to estimate the number of pathogens in food products consumed directly or as an ingredient in a meal. The output of the Exposure Assessment is the prevalence and level of pathogens in food products that consumers are exposed to as a function of pasteurization and refrigeration of food ingredients during distribution from farm to processor. Hazard Characterization estimates the likelihood of illness based on the levels of pathogens in a serving of food eaten. These estimates are based on the dose-response relationship developed by FAO/WHO. Risk Characterization estimates illnesses, hospitalizations, and deaths on per serving and per annum basis. Answers are provided to the specific risk management questions and also a sensitivity analysis is included to identify areas to consider.

Risk Assessment Outputs

Hazard Analysis The purpose of the Hazard Analysis and Critical Control Points (HACCPs) in food production is to analyze the potential hazards associated with each processing step to evaluate their risk and, thereby, to identify those operations in which corrective actions will be required. Experience has demonstrated that this approach improves food safety. Hazards vary from one product to another, depending on: (1) the raw material used (2) the particular process employed (3) the commercialization system and (4) the ultimate use of the product. The manufacturing process for dried egg-pasta includes steps ensuring the elimination of microorganisms. However, the primary sources of contamination are raw ingredients and contamination during processing. Heat-resistant toxins produced by *Bacillus cereus* and *Staphylococcus aureus* are not eliminated by pasta cooking, this being the main cause of the reported outbreaks attributed to pasta consumption. These foods have also been associated with outbreaks of salmonellosis (Grady et al. 1986; Woolaway et al. 1986). These data show the pressing need for the application of HACCPs in the manufacturing process of these products. The hazard analysis consists of the following steps: (1) inspection of both preparation and storage practices to identify sources and modes of contamination (2) measuring temperatures of internal region of food during preparation, storage, cooking and holding (3) collecting samples in the preparation stages and testing them for microorganisms of concern and (4) collecting samples after cooking and after overnight holding to evaluate survival, destruction and growth of microorganisms and the decrease of risks associated with the operations.

Application of HACCP Concept in Pasta Manufacturing

The flow chart of the process is shown in Fig. 1. The diagram also indicates the hazards and critical points of the process. In dough preparation, the use of fresh eggs could be dangerous, since they may contain *Salmonella* spp., particularly *S. enteritidis*. The water used in the process should comply with local regulations for drinking water. In the finished product microbial criteria that should be taken in consideration are total microbial counts, moulds, *Enterobacteriaceae*, coagulase positive *S. aureus*, *Salmonella* spp., *Clostridium perfringens* and *B. cereus* counts. The data obtained provides evidence whether the food hygienic procedures are correctly applied or not. The water activity (0.5 with a moisture content of 12.5%) makes these foods not a good substrate for microbial growth, including pathogens. Consumer practices like cooking and holding foods after preparation should also be evaluated since the industrial manufacturing process does not ensure the elimination of all microorganisms. While vegetative forms of pathogenic bacteria would have been killed during cooking, heat-resistant endospores might have survived. Therefore, *B. cereus* and sulfite reducing *Clostridium*, (endospore-forming pathogens), are of primary concern.

Therefore there is a considerable responsibility on the manufacturer to ensure that *Salmonella* does not gain access to the product, in particular by using only pasteurized egg in pasta dough. *Cl. perfringens* has also been reported in dried pasta. However, pasta is unlikely to be a significant source of this organism under normal circumstances. *S. aureus* can grow well on cooked pasta. For example in cooked egg-pasta inoculated with approximately 100 *S. aureus* g^{-1}, production of staphylococal enterotoxin occurred in 3 d at 15°C and only 1 d at 25°C. Hence, cooked pasta needs to be treated with some care to minimize the opportunities for contamination with S. aureus and should be maintained in chilled conditions to retard its growth. Holding hot (> 63°C) prior to serving would be an alternative in a catering situation (Lee et al. 1975; Legan 2000). Dry pasta is extruded and dried below pasteurization temperatures, therefore pathogens may survive in the final product. Salmonellae from egg ingredient have been especially troublesome. Although levels of salmonellae are reduced during processing, significant numbers survive if the original contamination is high (Hsieh et al. 1976b). Once the pasta is fully dry, salmonellae may remain viable for several months (Walsh et al. 1974; Lee et al. 1975). *Salmonella* Infantis and *S*. Typhiurium have been detected in pasta after 360 days storage at room temperature (Rayman et al. 1979). Boiling will destroy the bacteria, but the presence of salmonellae in dried pasta is considered a basis for legal action under the laws of many countries.

Mixing equipment in pasta factories is often not cleaned more frequently than once a week, and in the early stages of drying, *S. aureus* can grow because conditions are nearly ideal (35–40°C, a_w 0.90–0.95, pH~ 6). Inadequate or inefficient mixing will add to this hazard. As with *Salmonella*, drying increases the stability of the bacteria, and death during storage may be incomplete (Walsh & Funke, 1975). In a survey of dried pasta products in retail stores in the US, *S. aureus* was found in 42 of 1533 packages of macaroni, and in related factory investigations, was found in 179 of 350 samples (Walsh & Funke, 1975). Dried spaghetti has been reported to be a source of *Cl. perfringens* endospores (Keoseyan, 1971), and this should be taken into consideration in the handling of prepared foods that contain pasta, and which could act as a favourable growth medium.

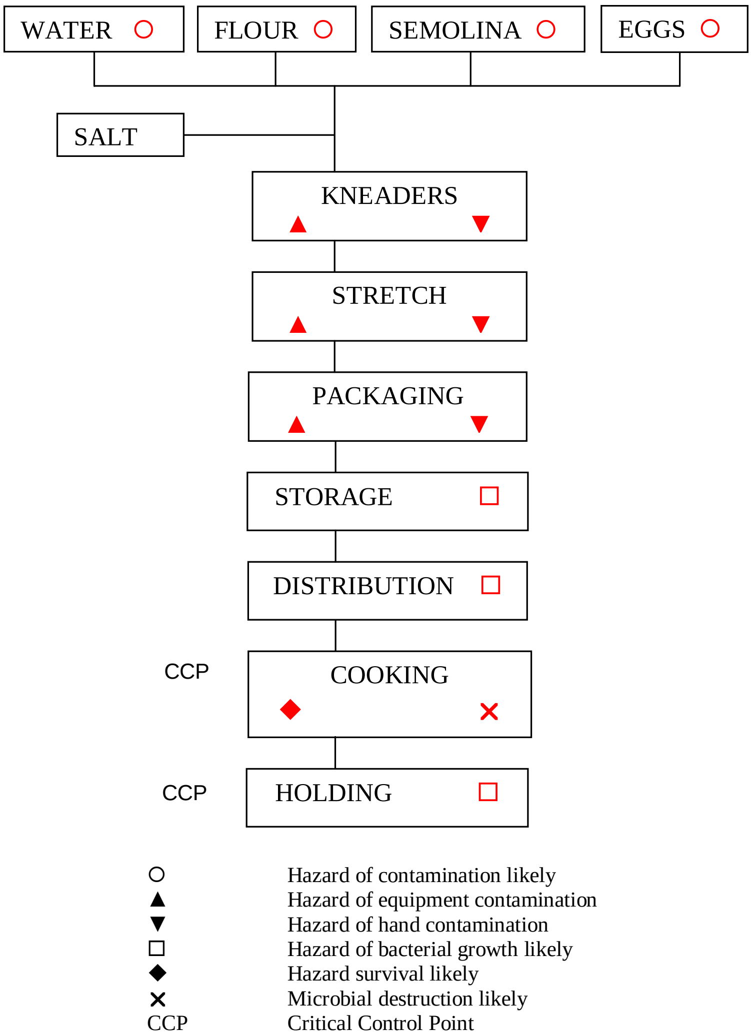

Figure 1. Flow chart for the pasta production.

Improvements of Pasta Manufacturing Process

From the HACCP application some drawbacks concerning sanitary conditions are corrected. At the end of the working day, both the mixer and the kneader should be thoroughly washed with a solution of sodium hypochlorite (0.02% active chlorine) for 30 min and then rinsed several times with drinking water. Another action should be taken is the incorporation of basins with liquid soap allowing periodic handwashing of operators. Both the machine used to rub and stretch the dough and that used to form the pasta should be dry-cleaned by high power vacuum cleaners to remove dry residues. Periodically, additional swabbing of the equipment should be done. In addition, the use of separate cold stores for raw materials and final product to avoid cross-contamination can be suggested. It is recommended that products made first should be removed first from the store, i.e. "first in first out". After all corrections suggested are implemented, the process is inspected again. Considerable improvements are obtained in microbial quality of the finished product, owing to the use of raw materials of better quality and to the adopted corrections regarding process hygiene. People in countries are routinely buying pasta with more than 1×10^8 CFU/g with no substantial health problems. But, it should be remembered that these products are always eaten cooked; people boil pasta in water for more than 7 min. However, the pasta industry is qualified to produce better quality products, provided good manufacturing practices, critical control point's analysis and raw materials of adequate quality are considered.

Hazard Identification for Pasta Manufacturing

Salmonellae are susceptible to heat and killed at temperatures ≥55°C. Ordinary cooking is sufficient to destroy salmonellae provided sufficient time. Because of *Salmonella's* thermal susceptibility, food borne infection is frequently associated with consuming foods containing raw eggs such as egg-pasta. However, warm temperatures provide an environment in which Salmonella can grow during the processes of production, transport, and storage. The age of patients with Salmonella infections follows a bimodal distribution, with most infections occurring in those at the extremes of age. The highest number of cases is seen among children. The association between salmonellosis and age, however, may be due to reporting bias because children and the elderly with diarrhoea may be more frequently cultured than other age groups (Aureli et al. 1986).

Exposure Assessment for Pasta Manufacturing

The first part of the exposure assessment estimates the frequency with which people are exposed to different doses of pathogen (e.g. *Salmonella* Enteritidis) in servings prepared from egg-pasta. The second part estimates exposures to all *Salmonella* spp. in servings of egg-pasta products. This exposure assessment should follow eggs from the farm to the pasteurizer, from the egg-pasta production (cooking step) and from the production to consumption (holding). Pasteurization of raw egg and the cooking step in pasta production has the special prominence in this assessment because it is the principal risk management measure being evaluated by this RA.

HACCP for Egg-Pasta Production

The food industry is currently working with two management systems, namely, HACCP and ISO 9001:2000. In September 2005 a new ISO standard has been published ISO 22000:2005, which for the first time provides a framework for the harmonized approach of quality and safety issues applicable in the entire food chain (Rotaru & Borda, 2007). HACCP on the other hand remains an extremely flexible approach to safety management issues concerning products intended to be consumed as food. HACCP systems rely on a series of preliminary measures programs called prerequisites (Wallace & Williams, 2001). The prerequisites programs may contain Hygiene programs, Good Manufacturing Practices (GMPs), Supplier Quality Assurance (SQA) and statistic process control (SPCs) programs. Thus, the managerial strategy can be oriented in three directions, depending on the specific and the resources of the organizations in food industry: (1) the implementation of the ISO 22000:2005 standard; (2) the implementation of HACCP where ISO 9001:2000 already exists; (3) organisation of an ISO 9001:2000 where HACCP has been implemented. It is extremely important to understand that HACCP does not replace the hygiene programs or other prerequisites programs, but if correctly implemented these programs represent its support network (Rotaru & Borda, 2007).

It is necessary that each producer develops specific procedures for good hygiene practices. It is necessary to classify the products and the ingredients regarding the magnitude and the frequency of the risk like: high risk products, medium risk products low risk products. The hygiene practices are a solid base line for the accomplishment of the HACCP system (Jouve, 1999). Good communication is the heart of any successful system. Communication in this case is not just about dialogue between the “HACCP expert” and the “person from the food business”, it also involves many other people – the legislator, the enforcer, the food worker, the various people in the food chain from producer to retailer, the consumer and the media. The HACCP team should be in contact with competent authorities, chamber of commerce, and research institutions. The team should have meetings regularly at least once per month. The topics discussed in the meetings frequently should be the following: non-conformities at the reception of raw material, consumer complaints, monitoring CCPs, hygiene in production room and microbial tests’ results both of raw materials and final products, monitoring and changes in food legislation. At the end of the year HACCP team leader should prepare an annual report, which is going to be the base of planing for next year.

HACCP Study

Hazard analysis: Hazard analysis is made by evaluating each process step and possible hazards. Results of assessment are made by stating probability of the hazard (points between 1 and 5) and by severity of the hazard (points between 1 and 5). Point 1 means very low probability – very rarely implicated. Points 2–3 mean that is probable to have a certain hazard. Points 4–5 mean very high probability and indicate that the hazard has occurred again in the past. Point 1 means very low severity – no effect on consumers' health, points 2–3 indicate medium severity on health – or chronic effect on health and points 4–5 indicate high severity problems like digestion problems or vomiting due to the hazard or even cases where the health of the consumers might be in danger. The result of each assessment is between 1 and 25. Process step which has 15 points or more is considered as CCP and preventative measures have to be implemented (Fig 2.). The Master plan is given in Fig. 3.

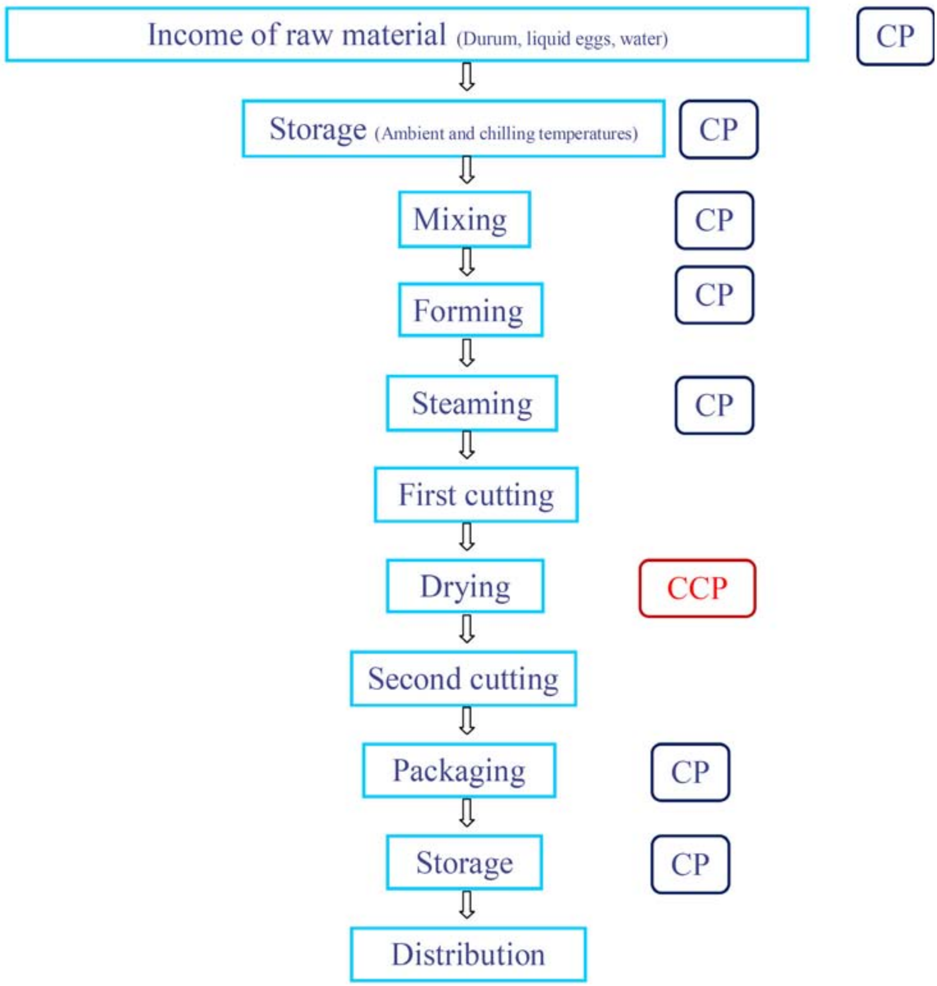

Figure 2. The production process of the egg pasta product is shown in the process flow diagram. CCP's location has been marked on the relevant diagram.

Table 2. Hazard Analysis Chart.

Process Step	Description of Hazard	Preventative Measures	Probabi-lity	Severity	Result	CCP/CP
R&S – Durum Semolina	(M)Moulds-Mycotoxins, (C)Pesticides and heavy metals (P)Foreign body	Quality specifications & control; Emptying elevators totally, Frequency of delivery is 1/14 d; Durum semolina is sowed through control sieve before dosing into mixing vessel	2 2 2	4 4 2	8 8 4	CP
R&S – Liquid eggs	(M) *Salmonella* spp.	Control of temperature at reception, microbial analysis according to the plan, control of storage temperature	3	4	12	CP
R&S-Pack. materials	(C) Chemical residues (P) Foreign body	Approved suppliers Clearly set specifications	1 1	3 2	3 2	CP
Mixing	(M)Cross contam. (*S. aureus*) (C) Residues of cleaning agents	Sanitation programme in place Good rinsing after cleaning	2	2	4	CP
Forming	(M) Cross contam. (*S. aureus* Moulds) (C) Residues of cleaning agents	Sanitation programme in place Daily cleaning Good rinsing after cleaning	2 2	3 3	6 6	CP
Steaming	(M)Cross contam.	Control of steam quality	2	3	6	
1st cutting	No hazard identified					
No hazard identified	(M)Cross contam. (*Salmonella* spp, *S. aureus*) - survival & growth	Control of time, humidity, temperature of drying cell, a_w, survival of *Salmonella* spp. and other microbes	3	5	15	CCP
2nd cutting	No hazard identified					
Packaging	(M)Cross contam. (C) Residues of cleaning agents	Visual control for foreign body contamination, quality control of packaging	2	4	8	CP
Storage	(C) Residues from packaging materials	First in first out, control of batch number	1	4	4	CP
Distribution	No hazard identified					

R&S = Reception & storage (M) Microbial hazard; (C) Chemical hazard & (P) Physical hazard

Verification Activities

Verification activities such as random sampling and analysis, auditing and verification procedures are used to ensure that a system is working correctly. Verification activities are shown in Table 3. Monitoring programs for the cleaning and sanitation, pest control, health certificates, records of inspection of premises and equipment in the plant are also important and should be in place. A plan of annual training activities with data and the main topics of training activities should be prepared. Topics of interest are: personal hygiene (hand washing, health certificates, and reporting health problems), good manufacturing practice, good hygiene practice, general information about hazards and HACCP systems, principles of cleaning and sanitation, basics of microbiology and consumer complaints. Implementation of training activities should take place at least once per year (annual training) for whole company and then monthly training activities should be performed according to the problems which occur in production plant – for smaller groups of people. Basic themes for all training activities are: personal hygiene, good manufacturing practice, and good hygiene practice.

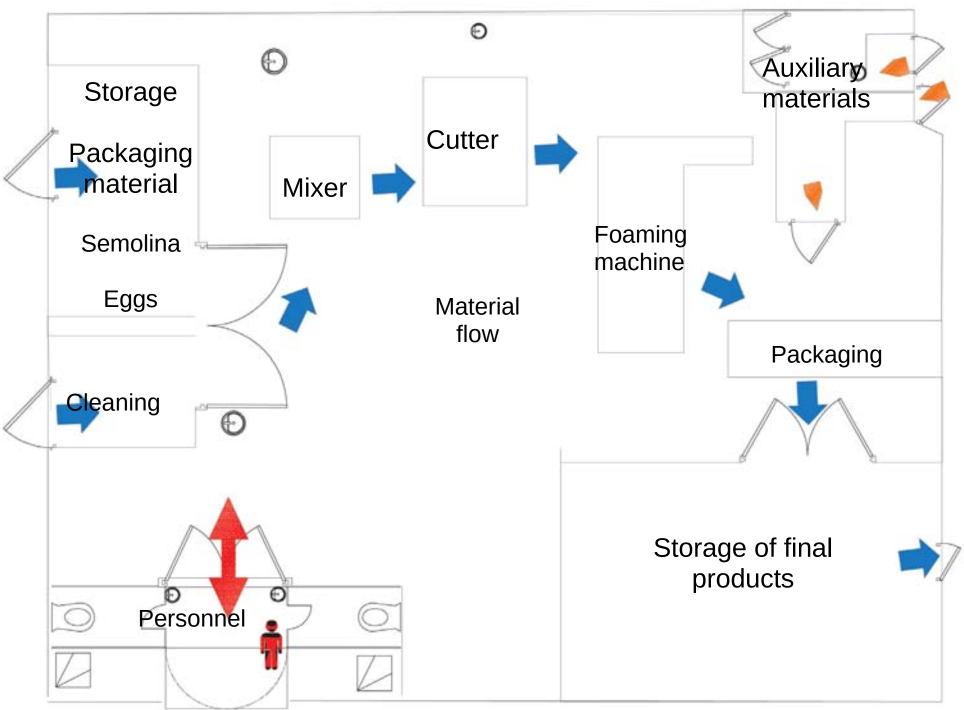

Figure 3. Master plan of the production site/No zoning required.

Table 3. Verification activities for egg-pasta production.

Verification activity	Frequency	Who is responsible	Report
Calibrated thermometer/ hygrometer	1 / a	Maintenance department	Certificate of calibration
MA & CA – liquid egg, durum & semolina	-1 / month (water – 1/a)	Microbiologist & 1/a in external accred. lab	HACCP team meeting
MA – water	4 / a	External accredited lab	HACCP team meeting
MA & CA – final products	2 / a & 1/a in external lab	Microbiologist & Ext. accredited lab	HACCP team meeting
Sensory testing (smell, taste, texture, colour)	1 per 14 days	Production technologist	Monthly to QM
Hygiene sampling for surfaces	1 / week 5 contact plates from surfaces	Microbiologist	HACCP team meeting
Physico-chemical anal. – a_w of end products	1 / a	External accredited lab	HACCP team meeting

MA = microbial analysis & CA = chemical analysis; QM = quality manager

RESEARCH NEEDS

In egg pasta, cholesterol can undergo oxidation depending on the raw material quality, the drying cycle or the storage of the finished product. However, the drying cycle used for egg-containing pasta should be milder with respect to those used for pasta without eggs, as shown by the determination of furosine in these products (Boselli et al. 2004). In a later study, Zunin et al. (1996) examined cholesterol oxidation in dried egg-pasta. Their data offered yet another critical point in the processing of cholesterol–containing foods materials. In this experiment, ten batches of commercially-prepared egg-pasta were selected as reference samples because the researchers knew the pastas were prepared with four eggs/kg semolina flour and that the drying conditions were well-controlled (75°C for 20 min and then at 65°C for 8 h). Other dried egg-pastas prepared with either fresh or powdered eggs were purchased from local markets. Commercially prepared egg-pastas containing powdered eggs tend to have a wide range of cholesterol oxidation product (COP) concentrations. In the study, the researchers quantified both native and oxidized cholesterol and this additional information helped to evaluate pasta samples containing low to medium levels of COP and low levels of native cholesterol. Among the 32 dried egg-pastas examined, no correlation between native cholesterol and 7-ketocholesterol (the major COP found) was seen. This finding confirms that, within a reasonable range, the initial cholesterol level has no effect on the COP level of the finished product. The manufacturing protocols on the other hand have a significant impact on the extent of cholesterol oxidation in the product. In order to produce less cholesterol oxidation product in the product drying and heating conditions need to be carefully evaluated (Yan, 1999).

Unfortunately, the determination of cholesterol oxidation products (COPs) is not yet a routine analysis, due to the time-consuming purification of the analytes, the possibility of artefact formation during sample preparation, the interferences due to plant sterols, and plant sterol oxidation products, as happens when egg-pasta is analyzed. For these reasons, high resolution techniques, such as high performance liquid chromatography and gas chromatography have been coupled with mass spectrometry in order to confirm the identification of oxycholesterols (Boselli et al. 2004). The strength of RA modelling is its iterative nature. Models can be built with incomplete data and assumptions, and updated as new scientific studies are completed. Good RA differentiates what is known from what is not known, so that future research initiatives can be directed toward filling the data gaps that would most enhance the scientific basis for food safety regulations. Filling the research needs would improve understanding of the farm-to-table system modelled in the assessment by identifying the variability of the variables that affect risk reducing the uncertainty in the model. Some studies already in progress that might fill research needs but there should be additional research needs for Exposure Assessment and Hazard and Risk Characterization as well as from sensitivity analysis of the draft simulation model. Some research needs are likely to require long-term commitments from multi-disciplinary teams and may require expert consultations before more explicit applications in RA modelling are possible. The potential usefulness of new research initiatives to RA and public health protection is addressed.

Fast and sensitive methodologies of food analysis, especially for industrial purposes, are useful tools to determine the quality of final commercial products. Moreover, the possibility to use always easier tools to analyse the authenticity of the certificated food is a daily challenge. Thermal analysis is recognized as an instrumental method of food analysis able to give unique information regarding the nature of the sample or the modifications induced by industrial processing. Moreover, thermal analysis combined with evolved gas analysis techniques (EGA) allows the optimisation of heating treatments as well as the recognition of alterations, caused by the heat during evaporation of water (to be avoided as much as possible in the field of pasta processing). This very important aspect is in fact strictly related to the more rapid industrial production but also to the possible decrease of the final product quality because of the loss of nutrients (i.e. proteins) which is more important at high temperatures. Thermogravimetry (TG) and derivative thermogravimetry (DTG) are fast and accurate useful tools to check the industrial drying process and to determine the spaghetti pasta quality (Materazzi et al. 2005). The bound water can be the discriminant to relate the egg-pasta quality, either before or after the cooking process. The low-temperature drying process is clearly a better way to obtain the best egg-pasta quality, even if the final cost for the consumer is higher because of both the longer time needed and the higher quality of the starting semolina and egg (Materazzi et al. 2008).

IMPROVEMENTS

Future improvements in the production include:

- vacuum cleaning which will aid in a more efficient and faster cleaning,
- use of rapid tests which will increase productivity and improve the controls upon the product,
- better training.

CONCLUSIONS

The RAs for dry egg-pasta is based on the best of the knowledge of the authors available from universities and pasta manufacturing companies. Pasteurization and after that rapid cooling of eggs used as ingredients and cooking during the pasta manufacturing are predicted to be effective for reducing/preventing illnesses from pathogens (Salmonella enteritidis and Salmonella spp. in eggs and egg-pasta products, respectively). Technology for processing and storing egg-pasta give to the products a good record, so good overall that their safety is taken for granted by the consumer. This compares favourably with the other foods particularly meat, poultry, eggs and dairy products: all perishable foods that readily support microbial growth and have a history of causing food poisoning when not stored or prepared correctly. Dry egg-pasta can be considered as a very low risk product because of its low a_w, and because is has to be cooked before consumption. It would be unwise, however, to assume that there are no microbial hazards associated with dried pasta products.

ACKNOWLEDGEMENTS

Completion of this article was facilitated by constructive comments and suggestions provided by. Prof. Dr. Alan Friis, National Food Institute, DTU, Denmark and Mrs. Jana Ramus, CCIS, Slovenia.

REFERENCES

Anonymous. 1992. Census of Manufactures: Miscellaneous Food and Kindred Products, Preliminary Report Industry Series, U. S. Department of Commerce, Bureau of Census, Issued August 1994.

Aureli, P., Fenicia, L., Gianfrancheschi, M., Pasoli, B. 1986. Microbial aspects of fresh and dried pasta, In Pasta and Extrusion Cooked Foods: Some Technological and Nutritional Aspects. Food Technology and Nutrition Series 1: 109–119.

Boselli, E., Caboni, M.F., Frega, N.G., Lercker, G. 2004. Cholesterol oxidation in pasta produced with eggs of different origin. European Food Research and Technology, 218(5): 410–414.

Grady, G.F., Parkin, W.E., Morse, D.L. 1986. Salmonellosis outbreaks associated with commercial frozen pasta. Massachusetts. New Jersey. New York, MMWR 35, 387.

Hsieh, F., Acott, K., Labuza, T.P. 1976. Death kinetics of pathogens in a pasta product, Journal of Food Science, 41: 516–519.

ISO 22000:2005. Food safety management systems – Requirements for any organization in the food chain.

ISO 9001:2000. Quality management systems – Requirements.

Jöhr, H., Ware, B. 2007. Supply chain risk management: an effective lever to enhance sustainability on agricultural materials supply. I.A.M.A Proceeding Book. Pp. 1–3.

Jouve, F. 1999. Establishment of food safety objectives. Food Control, 10: 303–305.

Keoseyan, S.A. 1971. Incidence of Clostridium perfringens in dehydrated soup, gravy, and spaghetti mixes. J Assoc OFF Anal Chem, 54(1):106–108.

Lee, W.H., Staples, C.L., Olson, J.C. Jr. 1975. Staphylococcus aureus growth and survival in macaroni dough and the persistence of enterotoxins in the dried products, Journal of Food Science, 40(1): 119–120.

Legan, J.D. 2000. Bakery Products. In: The Microbiological Safety and Quality of Food, Lund, B.M., Baird-Parker, T.C., Warwick, G. (eds.). Cereals and Cereal Products Baked Gould. Springer. P. 2080.

Materazzi, S., De Angelis Curtis, S., Sagone, F., Quaglia, G.B., Bucarelli, F.M., Aquili, S., Paolesse, R., Vecchio, S., Curini, R., D'Ascenzo, G. 2005. Thermal analysis and food quality: The possibility to qualify the pasta processing. Journal of Thermal Analysis and Calorimetry, 80: 465–467.

Materazzi, S., Maccari, G., De Angelis Curtis, S., Aquili, S., Ruggieri, P. 2008. Bound water is a quality discriminant of dried egg-pasta, Journal of Thermal Analysis and Calorimetry, 91 (1): 47–50.

Rayman, M.K., Weiss, K.F., Riedel, G.W., Charbonneau, S., Jarvis, G.A. 1981. Microbiological quality of pasta products sold in Canada. Journal of Food Protection, 44: 746–749.

Rotaru, G., Borda, D. 2007. Safety Models: HACCP and Risk Assessment Ch 11. In: Food Safety: A Practical and Case Study Approach. McElhatton, A., Marshall, R.J. (eds.). Springer Science Business Media, LLC.

Wallace, C., Williams, C. 2001. Prerequisites: a help or a hindrance to HACCP. Food Control, 12: 235–241.

Walsh, D.E., Gilles, K.A. 1977. Pasta Technology. In: Elements of Food Technology. Desrosier, N.W. (ed.). AVI Publishing Company, Inc.

Walsh, D.E., Funke, B.R., Graalum, K.R. 1974. Influence of spaghetti extruding conditions, drying and storage on the survival of Salmonella typhimurium, Journal of Food Science, 39: 1105–1106.

Walsh, D.E., Funke, B.R. 1975. The influence of spaghetti extruding, drying and storage on survival of Staphylococcus aureus. Journal of Food Science, 40: 714–716.

Woolaway, M.C., Bartiett, C.L.R., Weieneke, A.A., Gilbert, R.J., Murrell, H.C., Aureli, P. 1986. International outbreak of staphylococcal food poisoning caused by contaminated lasagne. J. Hyg. (Camb.), 96: 67–73.

Yan, P.S. 1999. Cholesterol oxidation products: their occurrence and detection in our foodstuffs. Pp. 79–99. In: Impact of Processing on Food Safety [proceedings of the American Chemical Society Symposium on Impact of Processing on Food Safety], held April 14–18, 1997, in San Francisco, California] Jackson, L.S., Knize, M.G., J Morgan. N. (Eds.), PP. 270 Kluwer Academic, NY, USA.

Zunin, P., Evangelisti, F., Calcagnao, C., Tiscornia, E. 1996. Cholesterol oxidation in dried egg pasta: Detecting 7-ketocholesterol content, Cereal Chemistry, 73: 691–694.