The integration of hygienic design principles in the optimization process of the technological system for the valorization of membranes of animal origin

SUMMARY
OF PhD THESIS

Politehnica University Timișoara
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PhD in the Field of INDUSTRIAL ENGINEERING

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THE IMPORTANCE AND NECESSITY OF THE THEME. OBJECTIVES AND STRUCTURE OF THE THESIS

Importance and necessity of the theme

In the present, with so much turmoil over the various forms of crisis that almost the entire population of the world is going through, one of the existential problem remains, the provision of food in conditions of food security and safety.

As early as 1963, FAO launched the manifesto 'Proclamation of the Right of Everyone to Eat to End Hunger', which introduced the concept of food security. Since then, the definitions of the concept have been refined several times, and it is now addressed at several levels, from the individual, household, national, regional and global.

Food security is only ensured when all people have uninterrupted access, both physically and economically, to sufficient, safe and nutritious food so that they can fully satisfy their food needs and food preferences, ensuring an active and healthy life.

The concept of food safety refers to the bioavailability of food at the time of consumption, with an expected energy content, a healthy composition and free of toxic, anti-nutritive, radioactive substances, pathogenic micro-organisms or excess additives, with a nutritional value well expressed quantitatively and qualitatively in main macronutrients and micronutrients.

Today, food security occupies a very important place and is an integral part of food security, which in turn is part of the security agenda of every country in the world and of global security. The two concepts are interrelated, even having common influencing factors, and both have a significant impact on people's well-being.

Scientific research and studies have highlighted a number of recommendations for ensuring an optimal level of food safety, including:

- increased investment in a national food safety system as a priority part of public health;
- proactive government action to establish and improve food safety at both producer and supplier levels;
- coordination, cooperation and optimised communication between the various institutions and competent bodies in order to improve the conditions under which food is manufactured, stored and transported to end users;
- preventive actions to avoid the transmission of various diseases through food;
- avoid contamination of any kind throughout the food chain;
- multi-sectoral and international cooperation on ensuring food safety at all stages of processing and consumption.

In this general context, the issue of integrating hygienic design principles into the process of optimising the technological system for the valorisation of animal membranes is topical and of great need for national food safety and security strategies.

The present work comprises a corollary of the results acquired in several years of own experience in the food industrial environment and research of some phenomena that have led to a great regression of the production capacities regarding the valorisation in the country of the generous resources offered by Romanian agriculture.

The starting point was the analysis of the quality of the food prepared from meat, where uncertainties were frequently observed due to differences from general or own standards, due to factors that are very difficult to determine.

Traceability is an important element of food safety, by ensuring the possibility of identifying the route of raw materials to the finished product, but it does not eliminate the risk of hidden technological deficiencies, some of which affect the quality of the food even after delivery to the consumer.

In the specific case of the processing of pork membranes for meat preparations, a systemic management approach using integrative elements on the whole technical and technological complex is considered necessary, taking into account the principles of hygienic design, a concept under development in the European Union.

The subject of the paper is part of the pioneering initiatives in Romania to implement the principles of hygienic design of equipment in production facilities and technological processing of animal membranes.

The research itself was carried out taking into account both the requirements of the meat and preparations market and the current problems faced by the entire food industry in Romania in terms of food safety and security.

The technological manufacturing process in the natural membrane processing sector was chosen for its food processing, and a certain degree of superfluity in supervision and control was observed. The research was more concerned with those situations that can be found in other branches of the food industry.

Objectives and structure of the thesis

The main objective of the PhD thesis was to identify and integrate the most effective principles of hygienic design in order to go through a real process of optimization of the technological system for the valorization of animal membranes, in particular by improving the manufacturing and maintenance technologies of machines, equipment and related installations.

The following sub-objectives follow from the main objective:

1. Analysis of the current state of hygienic design systems and principles to be applied to technological equipment for processing animal intestines for food processing;
2. Simulation and analysis of contamination processes in critical areas of technological equipment;
3. Identificarea unor metode și procedee tehnologice de determinare a parametrilor optimali pentru diminuarea efectelor de contaminare;
4. Identification of technological methods and procedures to determine optimal parameters to mitigate contamination effects;
5. Statistical analysis of the results of application-experimental research for the process of food valorization of animal intestines;
6. Determination of technological processes and optimum values for the working parameters of the resulting components according to the evolution of contamination.

The proposed objectives have been pursued to be achieved in the 196 pages of the thesis, which is structured in 7 chapters. The contents include 46 tables and 171 figures. To justify what has been stated, a list of the scientific works developed, supported and published by the author or in collaboration is attached at the end. As well as a bibliographic list of 120 titles and online references.

Chapter 1 presents an analysis of the current state regarding the equipment and restrictions required in plants designed to make the most efficient use of animal membranes.

A comprehensive literature review was conducted, based on both existing literature and data presented on various web resources, especially by companies with industrial concerns in the processing of by-products, specifically the food processing of animal membranes.

The analysis was based on a bibliographical study and on own documentation in national and international establishments.

Technical systems for the selection and processing of natural membranes, specialised machinery for membrane grinding, as well as aspects of mandatory sanitation operations required by regulations throughout the food industry were followed. More attention is paid to

general procedures for removing non-compliant products from the flow and to existing food safety risks. Some general considerations on the importance of healthy nutrition and on specific internal occupational safety and health rules in natural membrane processing plants are presented. At the end of the chapter, management issues are briefly addressed, both in terms of strategy and quality cost optimisation in the food industry.

Chapter 2 covers an analysis of the concept of hygienic design applied in current systems of design, manufacture, operation and maintenance of equipment in the food industry, legal requirements and general recommendations, European legal requirements and recommended standards for the hygienic design of technological equipment used in the food industry.

Chapter 3 contains an extensive study of and directions for the integration of hygienic design into technological systems in the food industry, current welding joining technologies, weldability of materials and general considerations on the welding of stainless steels used in the food industry.

Starting with chapter 4, the concrete aspects of the experimental research are presented, first of all the correlation of welding processes with food safety needs, research on stainless steel pipes butt-welded by different processes, carrying out sanitation tests to determine the quantities of microorganisms and statistical processing of the data obtained.

Chapter 5 presents experimental studies on the complex relationship between material - welding technology, identification of the dangers of contamination of the food product due to improper use of maintenance technologies, in particular the welding of metal pipes in related installations, statistical processing of the results obtained in order to determine the best welding process.

The presentation of the experimental research is continued in Chapter 6, with the objective of establishing measures for the integrated optimisation of technical-economic performance and hygienic design principles in the recovery of animal membranes.

Chapter 7 is dedicated to general conclusions and to the presentation of personal contributions, both theoretical and in the definition of experimental programs and applied measures, to solve the problems identified and presented in the first part of the thesis. Some prospects for research and improvement of equipment and technologies for food recovery from animal membranes in industrial systems are presented.

The studies carried out and presented in this thesis, through their applicative nature, open up new possibilities for the development of more efficient systems for monitoring the behavioural relationship between food materials and the metal surfaces they come into contact with throughout the processing and storage chain.

There is an urgent need to establish and implement a national programme to develop the country's own capacity to exploit domestic agricultural production and meet the country's food needs.

Financial efforts from the budget and from European funds are considered necessary to support investments in the manufacture of food based on livestock products, especially those with animal protein content.

1. ANALYSIS OF THE CURRENT STATE OF TECHNOLOGICAL EQUIPMENT AND RESTRICTIONS ON THE RECOVERY OF ANIMAL MEMBRANES

In Chapter I, were discussed the perspectives for the use of natural membranes and natural membrane processing systems, factors influencing quality of life, animal slaughter technologies, classification of meat processing machinery, technological operations in membranes processing and automated small intestine processing lines.

General considerations on natural membrane cleaning spaces, general considerations

on natural membrane cleaning machines, analysis on general sanitation issues in the food industry, general recall procedures for non-compliant food products, general considerations on food safety risks, general considerations on the importance of healthy food and on the importance of labour protection in the food industry, importance of strategic management to optimise quality costs in the food industry.

Fig.1.1 a Automatic small intestine processing line, personal photo archive

Fig.1.1 b Automatic small intestine processing line, personal photo archive

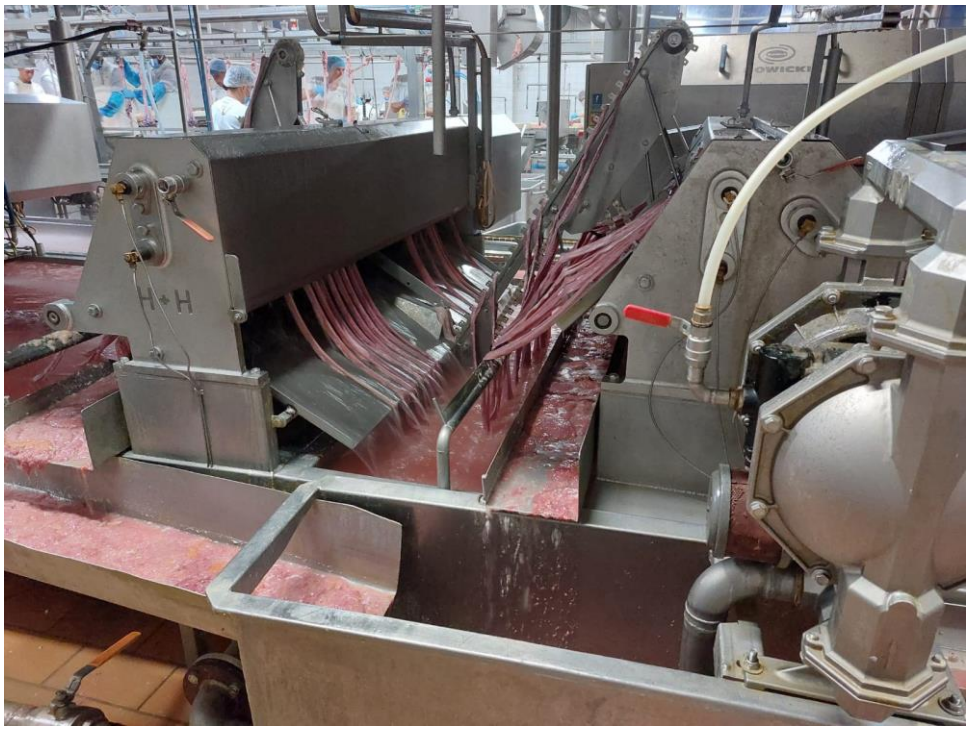

Fig.1.1 c Automatic small intestine processing line, personal photo archive

2. CURRENT HYGIENIC DESIGN SYSTEMS

In Chapter II, legal requirements and general recommendations, European legal requirements and recommended standards for the hygienic design of equipment used in the food industry were analysed such as:

1.) Regulation (EC) 178/2002 on the hygiene of foodstuffs;
2.) Regulation (EC) 852/2004 on the hygiene of foodstuffs;
3.) Regulation (EC) 853/2004 Specific hygiene rules for food of animal origin;
4.) Regulation (EC) 854/2004 Specific rules on the organisation of official controls on products of animal origin intended for human consumption;
5.) Regulation (EC) 2073/2005 on microbiological criteria for foodstuffs;
6.) Regulation (EC) 1935/2004 for materials and components intended to come into contact with food;
7.) Regulation (EC) 2023/2006 on good manufacturing practice for materials and components intended to come into contact with food;
8.) Regulation (EU) 10/2011 on plastic materials and components intended to come into contact with food;
9.) Directive (EC) 2006/42 on machinery for food production and machinery for cosmetics or pharmaceutical products;
10.) Directive 2006/42/EC on technical documentation for equipment;
11.) CE mark.

Hygienic design criteria according to EHEDG - European Hygienic Engineering and Design Group pentru:

Hygienic equipment class I

Class I equipment is that which can be cleaned on site and from which dirt can be removed without dismantling.

Hygienic equipment class II
Equipment that is cleanable after disassembly and can be freed of dirt after reassembly.

3. DIRECTIONS FOR INTEGRATING HYGIENE DESIGN INTO TECHNOLOGICAL SYSTEMS

In Chapter III the joining of materials by welding, the main fusion welding processes, the reaction of materials to welding, general considerations on the welding of stainless steels used in the food industry, quality assurance in welding were discussed.

Introduction of the concept of hygienic welding, according to EHEDG - European Hygienic Engineering and Design Group, the ideal hygienic weld, from a sanitary point of view, is as easy to clean as the adjacent piping.

A good weld does not require internal end-treatment. Defects in the welding process are cracks, porosity or oxidation which will cause: increased adhesion of the product, potential for bacterial growth, negative effects on the cleaning process, potential for corrosion. A minimum level of bacteria during the process reduces the need for subsequent cleaning cycles and maximises plant efficiency.

Hygienic welding can be achieved if no removable connections are required and if the material allows welding and the results allow for better cleaning and maintenance free results compared to joints.

4. EXPERIMENTAL RESEARCH ON THE CORRELATION OF WELDING PROCESSES WITH FOOD SAFETY NEEDS FOR EQUIPMENT IN OPERATION

In Chapter IV, research on butt-jointed stainless steel pipes using oxyacetylene flame welding and research on butt-jointed stainless steel pipes using manual metal arc welding, establishment of the methodology to determine the amount of microorganisms, experimental determinations, statistical processing of the results obtained from sanitation tests using STATGRAPHICS software, frequency tabulation for coliform bacteria and for NTG were carried out.

Table 4.1 Coliform bacteria, oxyacetylene flame welding

	Lower	*Upper*			*Relative*	*Cumulative*	*Cum. Rel.*
Class	*Limit*	*Limit*	*Midpoint*	*Frequency*	*Frequency*	*Frequency*	*Frequency*
	at or below	-1000,0		0	0,0000	0	0,0000
1	-1000,0	5000,0	2000,0	6	0,6000	6	0,6000
2	5000,0	11000,0	8000,0	1	0,1000	7	0,7000
3	11000,0	17000,0	14000,0	0	0,0000	7	0,7000
4	17000,0	23000,0	20000,0	0	0,0000	7	0,7000
5	23000,0	29000,0	26000,0	0	0,0000	7	0,7000
6	29000,0	35000,0	32000,0	0	0,0000	7	0,7000
7	35000,0	41000,0	38000,0	1	0,1000	8	0,8000
8	41000,0	47000,0	44000,0	1	0,1000	9	0,9000
9	47000,0	53000,0	50000,0	1	0,1000	10	1,0000
10	53000,0	59000,0	56000,0	0	0,0000	10	1,0000
	above	59000,0		0	0,0000	10	1,0000

Mean = 15540,0 Standard deviation = 19830,0

Table 4.2 NTG, oxyacetylene flame welding

	Lower	*Upper*			*Relative*	*Cumulative*	*Cum. Rel.*
Class	*Limit*	*Limit*	*Midpoint*	*Frequency*	*Frequency*	*Frequency*	*Frequency*
	at or below	-3000,0		0	0,0000	0	0,0000
1	-3000,0	7000,0	2000,0	1	0,1000	1	0,1000
2	7000,0	17000,0	12000,0	2	0,2000	3	0,3000
3	17000,0	27000,0	22000,0	0	0,0000	3	0,3000
4	27000,0	37000,0	32000,0	0	0,0000	3	0,3000
5	37000,0	47000,0	42000,0	2	0,2000	5	0,5000
6	47000,0	57000,0	52000,0	0	0,0000	5	0,5000
7	57000,0	67000,0	62000,0	2	0,2000	7	0,7000
8	67000,0	77000,0	72000,0	1	0,1000	8	0,8000
9	77000,0	87000,0	82000,0	1	0,1000	9	0,9000
10	87000,0	97000,0	92000,0	1	0,1000	10	1,0000
	above	97000,0		0	0,0000	10	1,0000

Mean = 48750,0 Standard deviation = 31795,4

5. EXPERIMENTAL RESEARCH ON THE CORRELATION BETWEEN MANUFACTURING TECHNOLOGY AND HYGIENIC DESIGN BASED ON THE RELATIONSHIP BETWEEN WELDING TECHNOLOGY AND FOOD CONTAMINATION

Chapter V investigated the case of butt-jointed stainless steel pipes using arc welding in a shielding gas environment with a fusible electrode and arc welding in a shielding gas environment with a non-fusible electrode, established the methodology for determining the amount of microorganisms, statistically processed the results obtained from sanitation tests using STATGRAPHICS software, tabulated the frequency for coliform bacteria and NTG.

Table 5.1 Coliform bacteria, welding with fusible electrode

	Lower	Upper			Relative	Cumulative	Cum. Rel.
Class	Limit	Limit	Midpoint	Frequency	Frequency	Frequency	Frequency
	at or below	13,0		0	0,0000	0	0,0000
1	13,0	14,5	13,75	1	0,1000	1	0,1000
2	14,5	16,0	15,25	1	0,1000	2	0,2000
3	16,0	17,5	16,75	1	0,1000	3	0,3000
4	17,5	19,0	18,25	2	0,2000	5	0,5000
5	19,0	20,5	19,75	1	0,1000	6	0,6000
6	20,5	22,0	21,25	1	0,1000	7	0,7000
7	22,0	23,5	22,75	1	0,1000	8	0,8000
8	23,5	25,0	24,25	1	0,1000	9	0,9000
9	25,0	26,5	25,75	0	0,0000	9	0,9000
10	26,5	28,0	27,25	1	0,1000	10	1,0000
	above	28,0		0	0,0000	10	1,0000

Mean = 20,0 Standard deviation = 4,08248

Table 5.2 NTG, welding with fusible electrode

	Lower	Upper			Relative	Cumulative	Cum. Rel.
Class	Limit	Limit	Midpoint	Frequency	Frequency	Frequency	Frequency
	at or below	0		0	0,0000	0	0,0000
1	0	40,0	20,0	0	0,0000	0	0,0000
2	40,0	80,0	60,0	0	0,0000	0	0,0000
3	80,0	120,0	100,0	2	0,2000	2	0,2000
4	120,0	160,0	140,0	2	0,2000	4	0,4000
5	160,0	200,0	180,0	1	0,1000	5	0,5000
6	200,0	240,0	220,0	1	0,1000	6	0,6000
7	240,0	280,0	260,0	1	0,1000	7	0,7000

8	280,0	320,0	300,0	1	0,1000	8	0,8000
9	320,0	360,0	340,0	1	0,1000	9	0,9000
10	360,0	400,0	380,0	1	0,1000	10	1,0000
	above	400,0		0	0,0000	10	1,0000

Mean = 220,0 Standard deviation = 96,9536

6. EXPERIMENTAL RESEARCH ON THE INTEGRATED OPTIMISATION OF TECHNO-ECONOMIC PERFORMANCE AND HYGIENIC DESIGN PRINCIPLES IN THE RECOVERY OF ANIMAL MEMBRANES

Chapter VI compared oxyacetylene flame welding process and manual metal arc welding, oxyacetylene flame welding process and arc welding in shielded gas environment with fusible electrode, oxyacetylene flame welding process and arc welding in shielded gas environment with non-fusible electrode, the process of manual metal arc welding with shielded gas shielded arc welding with a fusible electrode, the process of manual metal arc welding and shielded gas arc welding with a non-fusible electrode, the process of shielded gas arc welding with a fusible electrode and shielded gas arc welding with a non-fusible electrode.

Simultaneous comparison of microbiological results for coliform bacteria and statistical processing of the results for the four welding procedures was performed using STATGRAPHICS software.

Table 6.1 Summary statistics for coliform bacteria

	Count	*Average*	*Standard deviation*	*Coeff. of variation*	*Minimum*	*Maximum*	*Range*
EF-BC	10	20,0	4,08248	20,4124%	14,0	27,0	13,0
EN-BC	10	6,6	2,06559	31,2968%	3,0	9,0	6,0
FO-BC	10	15540,0	19830,0	127,606%	1700,0	52000,0	50300,0
EI-BC	10	3460,0	1459,98	42,1961%	1600,0	6200,0	4600,0
Total	40	4756,65	11533,5	242,471%	3,0	52000,0	51997,0

	Stnd. skewness	*Stnd. kurtosis*
EF-BC	0,474342	-0,387852
EN-BC	-0,717773	-0,522418
FO-BC	1,48988	-0,364223
EI-BC	1,55569	0,456461
Total	8,61308	13,4501

Table 6.2 Summary statistics for NTG

	Count	*Average*	*Standard deviation*	*Coeff. of variation*	*Minimum*	*Maximum*	*Range*
FO-NTG	10	48750,0	31795,4	65,2213%	2200,0	91000,0	88800,0
EI-NTG	10	4050,0	1546,5	38,1852%	2300,0	7000,0	4700,0
EF-NTG	10	220,0	96,9536	44,0698%	110,0	370,0	260,0
EN-NTG	10	13,9	4,12176	29,6529%	9,0	22,0	13,0
Total	40	13258,5	25829,2	194,813%	9,0	91000,0	90991,0

	Stnd. skewness	*Stnd. kurtosis*
FO-NTG	-0,395595	-0,861667
EI-NTG	0,886412	-0,234645
EF-NTG	0,656336	-0,832503
EN-NTG	1,08283	0,145772
Total	5,22157	3,55818

7. CONCLUSIONS AND PERSONAL CONTRIBUTIONS. RESEARCH PERSPECTIVES

Given the unanimous concern for food security, research, development and implementation of the most viable solutions remain the way forward for the European Union and individual member countries.

Food safety and security cannot be ensured without the responsible and competitive involvement of the relevant institutions, but also with greater responsibility for management teams in food manufacturing and marketing establishments.

Compliance with hygienic design and manufacturing conditions in the food industry is not only a response to certain regulations imposed by law, but must be taken on as an ethical responsibility of all persons involved in food manufacturing and trade.

The detailed study of welding technology applied irresponsibly on food processing lines is a model approach for any mechanical technology that is found in the manufacturing flow, operation and maintenance programme of the technical equipment that ensures food production and supply.

Finally, it can be noted that the present research confirms the initial assessments regarding possible solutions for the integration of hygienic design principles into the wider process of optimisation of the technological system applied for the food processing of animal membranes.

Personal contributions

The present PhD thesis brings both personal contributions, from a theoretical, experimental and applicative point of view, based on a related documentary study, on the definition of an appropriate experimental program and on a correct theoretical and experimental approach to situations taken from the industrial reality in the food field.

Theoretical contributions

From a theoretical point of view, the following contributions are highlighted in the thesis:

- critical analysis of the main food safety risk factors on the animal membrane processing line;
- a documentary study on the current level of concern of scientific research undertaken in this field;
- critical analysis of the main welding technologies used in assembly and maintenance operations in fluid transport installations, in technical systems for processing natural membranes of animal origin;
- comparative analysis of non-detachable joints, by welding, in direct relation to the hygienic conditions they cause as a result of sanitation testing;
- development of an original model for a systemic approach to risk factor analysis of uncontrolled bacterial growth and food contamination;
- determination of a model of the minimum profile of the internal deflection of metal pipes joined by welding processes.

Experimental contributions

In terms of experimental contributions the thesis makes a number of contributions on appropriate experimental programmes, of which those with significant impact are presented:

- experimental comparative study of the technologies for welding stainless steel pipes,

currently applied in the maintenance of fluid transport installations in the food industry;
- determining the level of contamination caused by the various welded joints found in installations;
- experimental identification of welding processes and technologies that ensure minimum hygienic conditions for the inner surfaces of stainless steel pipes;
- adoption in the experimental programme of specific procedures for analysing the quality of welded joints, especially for investigating interior surfaces.

Industrial application contributions

- identification and validation of the main technical conditions that must be met in order to comply with European hygiene and health standards, as revealed by specialist European institutions;
- to establish the main parameters of advanced welding technologies for special stainless steel pipes for the food industry (304), possibly for the rotating electric arc process, those that can ensure the conditions established according to the principles of hygienic design and manufacture of food equipment;
  optimise the industrial process of maintenance of technological equipment on the processing flow of animal membranes by adopting and partially recommending general and particular principles of hygienic design and manufacturing.

Perspectives for further research development

The content and conclusions of this thesis can form the basis for new directions of study and research, such as:

- extension of experimental research to other industrial mechanical technologies applied in the manufacture and maintenance of industrial food equipment;
- further experimental research on other risk factors that may affect the quality of the final food due to errors in the design and manufacture of food machinery;
- multidisciplinary approach to research on the compatibility of materials and technologies applied to ensure the desired technological processes throughout the necessary transformation of raw materials to the finished food product phase;
- linking quality management activities practised in food technologies with those in manufacturing and maintenance of related technical systems.

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