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Improving Cleanability by Changing Fish Processing Equipment Design

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***Abstract*—**The design of fish processing equipment greatly impacts how easy the cleaning process for the equipment is. This is a critical issue in fish processing, as cleaning of fish processing equipment is a task that is both costly and time consuming, in addition to being very important with regards to product quality. Even more, poorly cleaned equipment could in the worst case lead to contaminated product from which consumers could get ill. This paper will elucidate how equipment design changes could improve the work for the cleaners and saving money for the fish processing facilities by looking at a case for product design improvements. The design of fish processing equipment largely determines how easy it is to clean. “Design for cleaning” is the new hype in the industry and equipment where the ease of cleaning is prioritized gets a competitive advantage over equipment in which design for cleaning has not been prioritized. Design for cleaning is an important research area for equipment manufacturers. SeaSide AS is doing continuously improvements in the design of their products in order to gain a competitive advantage. The focus in this paper will be conveyors for internal logistic and a product called the “electro stunner” will be studied with regards to “Design for cleaning”. Often together with SeaSide’s customers, ideas for new products or product improvements are sketched out, 3D-modelled, discussed, revised, built and delivered. Feedback from the customers is taken into consideration, and the product design is revised once again. This loop was repeated multiple times, and led to new product designs. The new designs sometimes also cause the manufacturing processes to change (as in going from bolted to welded connections). Customers report back that the concrete changes applied to products by SeaSide has resulted in overall more easily cleaned equipment. These changes include, but are not limited to; welded connections (opposed to bolted connections), gaps between contact faces, opening up structures to allow cleaning “inside” equipment, and generally avoiding areas in which humidity and water may gather and build up. This is important, as there will always be bacteria in the water which will grow if the area never dries up. The work of creating more cleanable design is still ongoing, and will “never” be finished as new designs and new equipment will have their own challenges.

***Keywords*—**Cleaning, design, equipment, fish processing, innovation.

I. Introduction

THIS paper will present the effort that SeaSide AS has done with regards to product changes made to facilitate easier cleaning of fish processing equipment. This work has been done in an effort to reduce the risk of Listeria occurrence in fish processing plants. The Norwegian salmon industry is big, with domestic sales of salmon and trout around 46 bill NOK (5,24 bill USD) in 2015 in Norway, and with exports of almost 50 bill NOK (5,9 bill USD) in 2015 [1]. The industry is making a lot of money since the price per kilogram of fish is high. There are several factors that could be improved to further increase the earnings, one of which is to cut the costs of cleaning by some measure.

SeaSide AS is developing, producing, and selling machines and equipment for use in fish factories both nationally and internationally [8]. SeaSide is very innovation driven, with the employees doing much of the innovation on a daily basis by constantly looking for clever solutions and smarter ways to do and manufacture their services and products.

Most of the fish factories in Norway are customers, and there is an increase in the number of international customers. SeaSide is looking to increase the number of products and services they provide, so they have looked more and more into cleaning of fish factories, and thinks this is an area with great potential. SeaSide therefore started a quest to improve the design of their equipment and machines to make it easier to clean in, so the customers could save money related to cleaning.

II. Background of Cleaning Processes and Listeria in the Salmon Industry

A. Cleaning

When producing salmon and/or trout, the factory has to be cleaned each day in order to avoid growth of bacteria, especially listeria, which is the most unwanted bacteria [2] and the main concern. It causes 2500 serious illnesses and 500 deaths annually in USA, it can survive 0-45 degrees and it grows well in damp environment. Listeria also thrives in neutral to alkaline pH but not in highly acidic environments. The growth rate in pH from 5 to 9,6 depends on substrate and temperature. Human listeriosis may occur in humans if they eat meat with listeria, with meningitis or meningoencephalitis as most common manifestations in adults.

Traditional cleaning of fish slaughterhouses is currently done by manual labor, and often during night since the slaughterhouse utilizes two shifts to slaughter the daily quota of fish. The labor is time consuming and takes place in a harsh environment with a lot of chemical use. There is a high passage in the workforce. The current way of cleaning a fish processing plant is largely conceived by trial and error, and little formal research has been done other than the formal demands from *Mattilsynet* (Norwegian Food Safety Authority)

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stating that only approved disinfection aids are to be used [5], together with different cleaning companies having done their internal research.

There are increasingly tougher quality demands both from customers and from governments, and there is a growing requirement for documentation of the processes of slaughtering fish, and therein the usage of cleaning chemicals. The cleaning of equipment used in fish slaughterhouses is closely related to the fish quality, and eventual outbreaks of *Listeria* is very unwanted and damaging both to the fish factory and the industry as a whole [6], [7].

As of today, the process of cleaning fish slaughterhouses is a costly process for the factories, with an average of 10 workers each night for 6-7 hours. Each worker is earning around 600 000 NOK (71 000 USD) each year.

B. Listeria

Fail-safe procedures for the production of Listeria-free products have not been developed. The most critical areas for the prevention of contamination are plant design and functional layout, equipment design, process control operational practices, sanitation practices, and verification of L. monocytogenes control.

Listeria monocytogenes can adhere to food contact surfaces by producing attachment fibrils, with subsequent formation of a biofilm, which impedes removal during cleaning. The attachment of Listeria to solid surfaces involves two phases; 1: primary attraction of the cells to the surface and 2: firm attachment following an incubation period.

Various studies have demonstrated that L. monocytogenes is resistant to the effects of sanitizers, like the effects of trisodium phosphate (TSP), especially after a colony has grown on the surface and biofilm has formed. It is more resistant to cooking processes than other pathogens. Listeria monocytogenes is susceptible to irradiation. Generally, the extrinsic factors that have the greatest effect on microbial growth kinetics are temperature, oxygen availability and relative humidity [3]. Listeria is found “everywhere”, in earth, water, vegetation and raw fish, but in small quantities [4].

III. Research Question

Listeria can grow pretty easily, and especially it grows in areas which rarely get dry. Also places where the organic material is not easy to wash away experiences increased growth of bacteria. The question that needs answering is that these areas can be avoided or the effects of these areas can be reduced by changing the design. *How should equipment be designed to make it easier to clean*?

IV. Method

SeaSide is mostly working in level 7-9 in Technology Readiness Level [9], meaning that SeaSide is using the existing technology to build machines for customers. Sometimes SeaSide also dives down in level 5-6 together with research partners. The mentality is very customer oriented, and much of their product development happens together with customers. It often starts with a need or a question by one or several customers, or SeaSide could see that there is a need for a new machine or service, a new product or changes to existing machines and products. Relevant research is done, and prototypes are built, tested, and often installed in fish processing plants and these prototypes often becomes zero-series of machines.

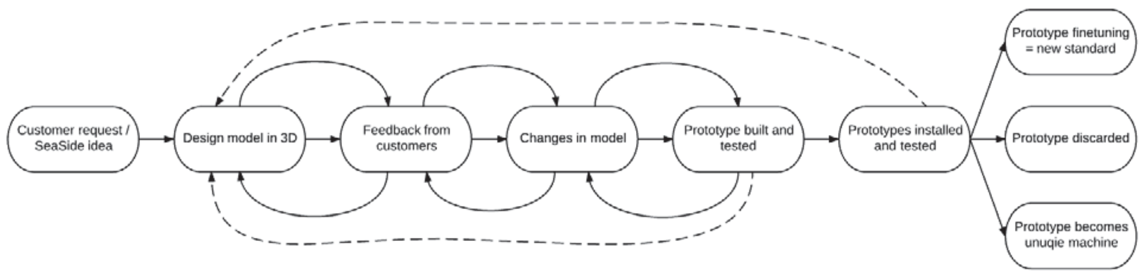


Fig. 1 SeaSide Innovation Workflow

The typical workflow of SeaSide is illustrated in Fig. 1 and can be summarized as follows:

1. Design change or problem definition proposed by SeaSide or the customer.
2. Design change modeled in 3D and reviewed by the customer and SeaSide.
3. If necessary, changes have been implemented and reviewed again, this loop could go 2-4 times.
4. Design change is brought to life and built, and prototypes of the change have been installed at the customer.
5. The customer has given feedback with regards to functionality, performance, and cleanability of the design change.
   - If the feedback has been good, it has become the new standard delivered to all customers. The case could also be that there is no feedback, often meaning that everything is fine. If something is not all right, the feedback is very present.
6. The experiences made are implemented in all new products sold, thus ensuring a continuous innovation both in design and on the shop floor.

SeaSide manages to work like this, and reaps benefits from it, since they are extremely close to the customers, with daily contact and direct lines to the people making decisions. This is important, because with this work method it is important to know which customers are susceptible to innovations and which customers are more conservative. The most conservative customers also want "old" designs because they want machines that they know work.

For the specific case for the design changes proposed by this paper, the problem definition was defined by SeaSide which wanted to see if it was possible to build more easily cleanable equipment, and it was proposed new design to open minded customers. The method used is described above, and in this case there was often opened a line directly between designers and factory supervisors (and cleaning supervisors) at the customers willing to test the new designs, making fast changes possible and brainstorming easy. This was invaluable to succeed. The product being modified was a conveyor. It was picked because:

- It is sold in relatively high volume, meaning it is possible to test a lot of different types of measures
- It is in direct contact with fish, and thus making it important to keep clean
- It is not technologically complex, meaning that the changes proposed is easy to see and understand. This is important because it would not deteriorate customers from buying it since they could easily understand the changes, and realize by themselves that the changes would not propose a threat to the functionality of the machine.

With regards to material, only PEHD500, stainless steel and polyacetal (POM) have been used in the prototypes. Steel and Nylon are some of the best materials to use in food processing; however, the surface treatment and resistance to acid is also important, since acid is commonly used as a cleaning aid and could potentially deteriorate the surface and thus increasing the biofilm adherence [10]. Products and machines for the fish processing industry are usually made in stainless steel. This is the preferred construction material, due to the fact that it is corrosion and abrasion resistant, easily cleaned and resistant to sanitizers [9]. The most common of stainless steel used is 304 of the 300-series. 316-quality is also used to some extent, but it is more expensive than the 304 steel quality. In addition to this, a literature study was conducted to see if there has been done any research on Design for Cleaning.

V. Results and Knowledge Gained

Design for cleaning is a hot topic in the Norwegian Salmon Industry; however, the literature study revealed that it is a field with little documented results, and with little published research. Each equipment manufacturer does their own version and adaptation of the meaning of it, and only publishes internal documentation or guidelines. The specific results from SeaSide's tests with customer feedback together with the literature review have concluded that one should:

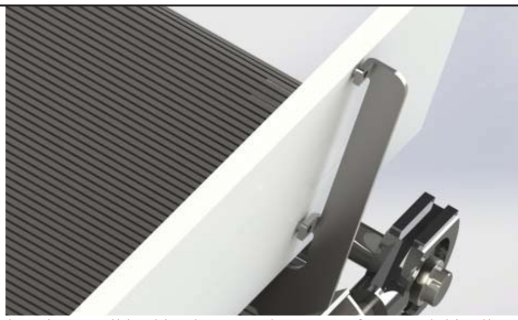
- Use materials that are corrosion, abrasion, and sanitizer resistant, preferably with good anti-stick features and a smooth surface.
- Think "less is more" – keep things simple, open for cleaning and be careful with a lot of edges, holes and gaps where water could end up being stored and not vaporize or drain away.
- Be aware that where there is water, there could be bio film that could contain bacteria. Try to design the equipment such that water will drain off (meaning as little horizontal surfaces as possible)
- Make the different parts in the equipment should be easily accessible, there should not be a need to move parts in order to clean other parts – when it comes to cleaning, parts will usually not be moved in order to clean parts (partially) hidden by them.
- Try avoiding the usage of pipes as much as possible, because water will always find its way inside even if it is welded shut at the ends due to microscopic pores, and there will be bacteria growth inside.
- Use welding as method for connecting parts instead of nuts and bolts. There will always be bacteria growth in the threads, these parts must be dismounted to be cleaned. Sometimes this is not possible, and nuts and bolts must be used.
- Be aware that a design that facilitates easy cleaning often collides with good functionality when it comes to moving parts and complexity.
- Consider that the arrangement of equipment and layout of the processing plant itself could be a problem, if the arrangement is such that it is hard to access areas for the cleaners.
- Be mindful of the points in [2]:
  - Pipes or other material with condensed water is also a source to contamination, as dripping water could bring bacteria with it
  - Old equipment or equipment in general with wear and tear, e.g. cracks, rifts, broken seals, materials with a coarse surface could often contribute to listeria growth
  - Hosing down equipment could potentially do more harm than good, as it can spray contaminated water to new places, meaning that the cleaning has to be done intelligently.

Studies have shown that just a small bacteria colony between a nut and a bolt could cause contamination all over a fish processing plant. Also, the bacteria could come from the fish, as the fish could get contaminated during transport from fish cage to the processing plant, although listeria found on finished food is often traced back to the processing equipment [4].

Product changes done and feedback from the customers are presented in Table I. The product tested with changes is a conveyor, which is widely used for internal logistics and processing in fish processing plants.

There are no qualitative measurements confirming that the design proposals made will result in less bacteria growth, however "common sense", the visual behavior of water observed by SeaSide employees together with the informal feedback from customers conclude that there is less water retention on the conveyors, and thus less likelihood of bacterial build up.

TABLE I
CUSTOMER FEEDBACK

Bad	Better
	
Reason: The design in the figure on the right is better than the one to the left because there is a small bushing between the contact faces, and this allows for cleaning between the contact faces. Contact faces without bushing(s) are prone to bacteria growth since water will penetrate in between the faces due to capillary forces and this will never dry.	
	
Reason: The design in the figure on the right is better than on the left because water will travel inside the closed profile (40x40 mm pipe in the figure to the left and will stay there "forever". With an open profile, this will not happen. The open profile leaves a bigger footprint than the closed profile due to structural strength.	
	
Reason: The design in the figure on the right is even better, in this case, than the figure on the left (which is the same as on the row above) since the open profile is moved further down, which allows more access to clean the conveyor belt itself. This is important, since the conveyor belt is in contact with the fish.	

VI. Conclusion

Design for cleaning is a complicated task, with many factors to consider, the most important being making sure the improved design does not reduce functionality. This is especially difficult with machines with a lot of moving parts. The general rule of keeping things simple and try to think "open" – easy access to areas needed to be cleaned is important. It is also generally a good idea to avoid areas and design that will gather water (cracks, adjacent faces, openings, flat surfaces etc.). If there need to be an opening, it should be so big that it is possible to clean inside it. Stainless steel and other materials with at low surface roughness is generally the better choice for materials for the equipment. The process of achieving better cleanability is still ongoing, and further work must be done both with regards to actual product/machine design and supporting activities.

VII. Further Work

The material used are usually stainless steel and PEHD500 (and other plastics). There has been some research on hydrophobic materials, and studies show that hydrophobic materials could reduce the attachment of Listeria bacteria [11]. In order to get the full comprehension on the effects of materials with high hydrophobic properties, they should be used in actual machines/equipment in actual fish processing plants.

There are other ways to go about achieving hydrophobic properties. Hydrophobic nano-coating is now commercially available, and a solution could be to apply these coatings to machines in the fish processing industry. This would also require further testing with regards to tolerance to the cleaning aids used in the industry and it has to be approved for food contact. It also almost goes without saying that it should not be dangerous to people. Further on, the cleaning process itself could be developed further with regards to cleaning methods, chemicals and equipment. The human factor is always present, meaning that the quality of cleaning is never better than the effort put in by the cleaner, which could vary from day to day and person to person.

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