Selection of Stainless-Steel Grades for Food Processing based on Pitting Corrosion

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Stainless steel is the most widely used material in the food industry. It is hygienic, durable, and mechanically robust, making it the suitable choice for the pipes, tanks, and heat exchangers that process the food we consume every day. However, not all stainless steels are equal, and selecting the wrong grade can have serious consequences for both equipment integrity and food safety. One of the most dangerous threats in these environments is pitting corrosion: a form of localized attack in which microscopic holes form on the metal surface and grow inward, largely invisible to the naked eye. Because pitting develops without obvious external signs, it can go undetected until it causes contamination of the food product, hygiene failures, or even the complete breakdown of processing equipment, with potentially severe economic and environmental consequences.

The challenge is that stainless steel comes in many different grades, each with distinct properties and costs. Selecting a grade that is more resistant than necessary represents an unjustified expense, while selecting one that is too basic for the application introduces unacceptable risk. Striking the right balance has traditionally been done based on experience rather than systematic data, a gap that becomes especially critical when new food products with different chemical compositions are introduced into existing processing lines. This project, carried out in collaboration with Tetra Pak in Lund, Sweden, set out to address exactly that. Three grades widely used in the food industry, 316L, 2205 Duplex, and 254 SMO, were evaluated under conditions representative of real processing environments, including varying salt concentrations, temperatures between 30°C and 90°C, and the presence of acetic acid, a component commonly found in products such as ketchup or vinegar-based sauces.

The results were clear and, in some cases, genuinely unexpected. The most economical grade, 316L, proved unsuitable for demanding conditions. At 90°C, its protective surface layer degrades to such an extent that the addition of salt or acetic acid produces no meaningful further damage, because the material is already critically compromised. For the other two grades, the appropriate choice depends on the specific processing environment. At moderate conditions, 2205 Duplex offers corrosion resistance practically equivalent to 254 SMO at a significantly lower cost, making it a well-justified selection in many scenarios. However, as temperature increases and acetic acid is present, 254 SMO consistently emerges as the more suitable candidate. The most surprising finding of the study was that while acetic acid slightly reduces corrosion resistance in 316L and 2205 Duplex, in 254 SMO the effect is reversed: the acid appears to enhance the resistance of the material to pitting in a significant and consistent way. The mechanism responsible for this behavior remains to be fully understood and represents one of the most interesting open questions for future research.

As a practical outcome, the project developed a set of material selection diagrams that Tetra Pak can use as a decision-making tool. Given a specific combination of temperature, chloride concentration, and acidity, these diagrams indicate which stainless-steel grade is most appropriate, giving engineers a concrete and data-driven foundation for a decision that until now was mostly made based on experience alone.