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What the Cannabis Industry Should Know About Stainless Steel

Article

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Stainless steel is widely used in many areas of the cannabis industry, including in cutting and grinding equipment, extraction/processing vessels, mixing tanks, storage containers, screens, vaping delivery devices and much, much more. It is probably the most widely used material in the preparation, processing, and manufacturing of cannabis consumer products. However, **because cannabis and hemp are hyper-accumulating plants**, which naturally absorb metals from the soil and even surfaces and materials they are in contact with, there needs to be careful consideration to the purity and quality of the grades of stainless steel used.

This has been exemplified by recent reports of high chromium levels in cannabis flower and biomass samples, which have been attributed to cutting them with stainless steel shears and blades[1]. Normally this might escape the scrutiny of most state regulators, because the majority of states only require the big four heavy metals (lead, cadmium, arsenic, mercury) to meet compliance. However, states that include chromium and/or nickel in their panel of regulated heavy metals would immediately flag this as being a potential problem, especially if the cannabis material was intended for vaping applications, where the inhalation action limits are significantly lower than for orally delivered products.

It is therefore worth exploring what types of stainless-steel are used in the cannabis industry, because it is such a common material found in many areas of the production process. And as there are a multitude of types and grades of stainless steels available, with different physical and chemical properties, it is critically important that the optimum grades are used to ensure they do not contaminate any of the products they are in contact with.

Pharmaceutical manufacturing

The cannabis industry should look for guidance from pharmaceutical manufacturers on the real-world applicability of stainless steel and what types are most suitable, as they have a much better understanding and experience of the risks associated with sources of elemental impurities generated by manufacturing equipment, including the optimum grades of stainless-steel components to minimize the likelihood of product contamination[2].

So, before we focus on the different grades used in the pharmaceutical manufacturing process, let us first take a closer look at how stainless steel gets its corrosion resistance properties.

What is stainless steel?

The term stainless steel is used to describe more than two hundred different grades of steel, containing alloying elements such iron, chromium, nickel, molybdenum, and niobium with each one tailored to give corrosion resistance in specific applications[3]. We know that all metals react with oxygen in the air to form a film or oxide layer on the surface. The oxide formed on ordinary steel allows the oxidation to continue producing the typical brown rusty appearance. However, since stainless steels contains high levels of chromium (up to 20%), the characteristics of the oxidation process are different. In stainless-steel, the chromium reacts with oxygen to form a protective passive layer of chromium oxide, (Cr_2O_3) on the surface of the bulk matrix, as shown in Figure 1[4].

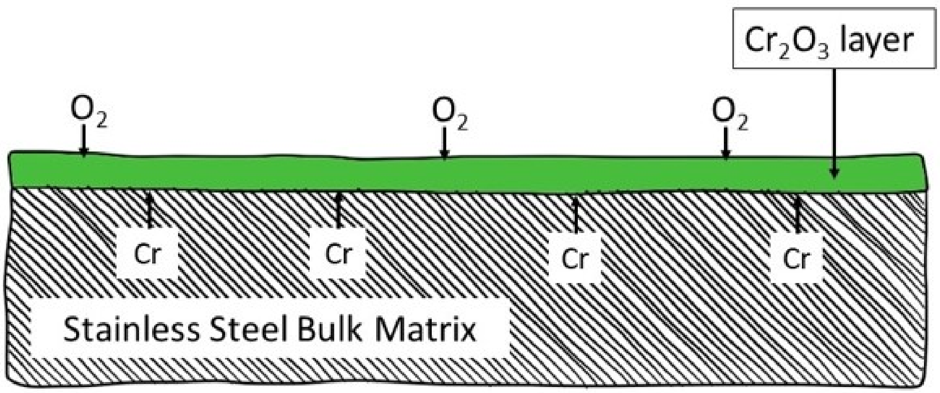

Figure 1: The chromium forms an oxide layer of Cr2O3 on the surface on the stainless steel. (Credit: Glenna Thomas).

In most cases, the passive film is self-healing if damaged, but because it is only a few microns thick, it can lead to permanent damage under certain environmental and stress-related conditions. And when this happens, stainless steel typically does not provide enough resistance below the chromium oxide layer, as the grain boundaries between the alloying elements (mainly chromium and nickel) and the bulk iron matrix are exposed, and as a result, once corrosion starts, it progresses very rapidly. The grain structure of austenitic stainless steel, underneath the Cr_2O_3 layer is exemplified in Figure 2[5].

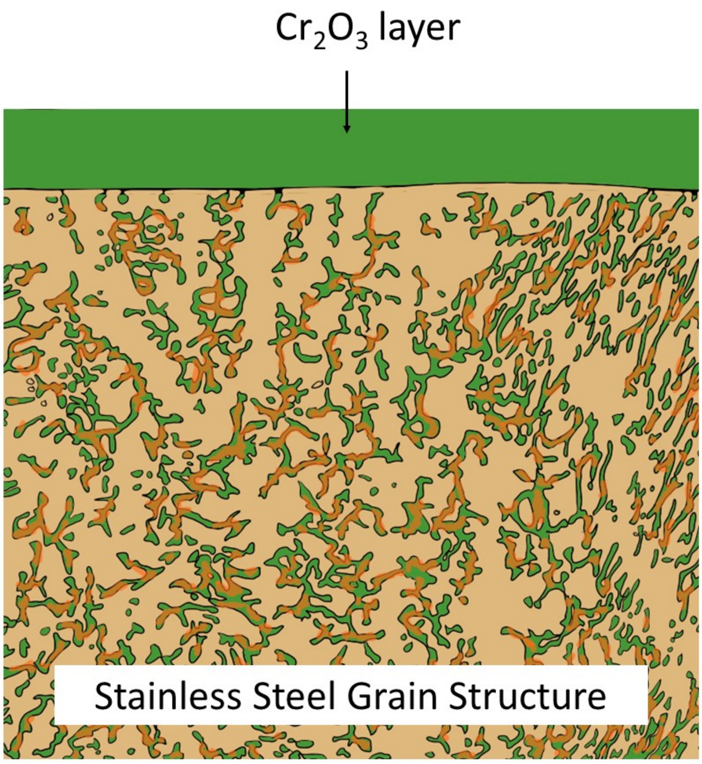

Figure 2: Austenitic stainless steel grain boundaries are exposed below the Cr2O3 surface layer. (Credit: Glenna Thomas).

Note: Austenitic stainless steel is the most widely used grade in the pharmaceutical industry. Austenite is a metallic, non-magnetic allotrope (solid solution) of carbon and iron that exists in steel above the critical temperature of 1333°F (723°C). Austenitic stainless steel is another allotrope containing carbon, iron, and the alloying elements of chromium and nickel and sometimes other elements such as molybdenum and niobium.

The four most common reasons for damage to this protective passive layer include:

- Mechanical abrasion: Anything that can scratch the steel's surface including the material it's in contact with, other metal surfaces and/or cleaning with steel wool, wire brushes, and scrapers.
- Water and deposits: Hard water as well as dirt and sample debris left sitting on the surface will leave spots and inclusions and can break down the layer of protection.
- Chlorides and other salts: Found in water, food, plant material, table salt, and industrial cleaners.
- Heat: If the equipment generates an excessive amount of heat, it can lead to accelerated oxidation.

Stainless steel will show rust stains if contamination on the surface prevents the formation of this protective layer. Furthermore, accumulation of metal particles, biomass material or dirt may lead to concentrations of corrosive substances that can break down the passive film and show discoloration over time. While this is a natural oxidation aging process, it can lead to contamination of the product it is in contact with. And if chromium and nickel are in the heavy metal panel required by the individual state, the product could fail if the levels are above the regulated action limits.

If discoloration and stains are noticed early enough, the equipment can sometimes be cleaned, which will temporarily slow down the corrosion process. These cleaning procedures can definitely extend the lifetime of the components, but if the passive layer has been penetrated, it is only a matter of time before the equipment has to be replaced. There are a multitude of recommended cleaning procedures based on the material it is in contact with. For example, if metallic particles are the cause of the corrosion, dilute solutions of nitric acid are suggested. On the other hand, if it is caused by an excessive build-up of plant material, perhaps an organic solvent like iso propyl alcohol could be the most suitable. Alternatively, if it is from oily residues of cannabinoids, ultrasonic cleaning using a surfactant might be the best approach. There are excellent publications in the public domain on different kinds of cleaning procedures, based on how the equipment is being used, which are recommended reading for anyone involved in the production of cannabis consumer products[6,7,8].

Let us now take a closer look at the different types of stainless steel used in pharmaceutical manufacturing.

Stainless steel used in the pharmaceutical industry

Stainless steel is a popular choice for product processing and handling in the pharmaceutical industry. In general, stainless steel is durable, able to withstand exposure to many of the chemicals used to sanitize pharmaceutical products and has a high temperature tolerance to withstand heat-based sanitation methods. However, there are many different uses for stainless steel in the pharmaceutical industry.

Some of the most common ones include:

- Parts-washing baskets.
- Product-processing containers.
- Biosample processing.
- Sanitary product handling.
- Sample incineration/disposal.
- Storage vessels.
- Mixing tanks.

But which type of stainless steel is optimum for these types of pharmaceutical applications? Over time and experience with different manufacturing scenarios, it has been found that four grades of stainless-steel best met these demands. These grades are briefly described here[8].

Grade 304 stainless steels

Grade 304 is one of the many 300 series of austenitic stainless steel, which are the most common grades of stainless steel on the market and often used in for washing components because of its high resistance to chemical corrosion. It is also used for the manufacture of surgical instruments so is often referred to as “surgical stainless steel” because of its ability to resist oxidation and its ease of cleaning and sterilization. A variation of the 304 grade is 304L, which contains slighter lower carbon content.

Compared to some other varieties of stainless steel, 304 grades have good all-around performance for a comparatively modest cost. However, they are not always the best option, as hard water and chemicals can degrade the metal, causing surface pitting that impairs performance.

Grade 316 stainless steels

Next in the 300 series of austenitic stainless steels is grade 316. This variety of steel contains more nickel and molybdenum than grade 304, which helps to enhance the metal's resistance to pitting from exposure to chemical attack.

In general, 316 stainless steel is used for production of cookware and in the food and pharmaceutical industries. It is often preferred for sample and materials handling applications where saline solutions and other chemicals may come into contact with the metal. It is also useful for high-temperature sanitation processes, as it has applicability over a maximum continuous use temperature of around 800˚C (1,472˚F) – more than enough to kill microbial agents and sanitize the surface of the steel.

A variant of this grade is 316L, which is a low-carbon version of the alloy that has enhanced resistance to corrosives and improved weldability at the cost of some tensile strength (toughness). In many pharmaceutical manufacturing applications, 316L is preferred to 316 stainless steels because it is more resistant to attack and the difference in tensile strength is negligible.

Improving the applicability of stainless steel

While stainless steel with a natural finish is certainly useful for pharmaceutical applications, it is often beneficial to electropolish the steel. Electropolishing removes tiny flaws in the surface leaving a microscopically smooth finish. By electropolishing different types of stainless steel, it is possible to further improve the steel's sterility and ease of sanitation. The smooth surface of electropolished steel makes it even more difficult for microbes to adhere to the steel, making it easier to clean.

Chemical composition

There are other grades of stainless steel which are optimum for certain applications, but the 304 and 316 grades are by far the most widely used in the pharmaceutical industry. The chemical composition of some of the most common grades of stainless steels are exemplified in Table 1.

Table 1: Chemical composition of common austenitic stainless-steel grades used in the pharmaceutical industry[9].

Grade	201	301	304	304L	316	316L	318
Carbon %	0.15	0.05-0.15	0.07	0.03	0.07	0.03	0.025
Silicon %	1.00	2.00	1.00	1.00	1.00	1.00	0.70
Manganese %	5.5-7.5	2.00	2.00	2.00	2.00	2.00	0.80
Phosphorus %	0.045	0.045	0.045	0.045	0.045	0.045	0.020
Sulfur %	0.015	0.015	0.015	0.015	0.015	0.015	0.010
Chromium %	16.0-18.0	16.0-19.0	17.5-19.5	17.5-19.5	16.5-18.5	16.5-18.5	17.0-20.0
Nickel %	3.5-5.5	6.0-9.5	8.0-10.5	8.0-10.5	10.0-13.0	10.0-13.0	11.0-13.0

Molybdenum %	-	0.80	-	-	2.0-2.5	2.0-2.5	2.5-3.0
Niobium %	-	-	-	-	-	-	0.6
Iron %	Balance	Balance	Balance	Balance	Balance	Balance	Balance

Final thoughts

It is well accepted that the cannabis industry does not have a good understanding of sources of heavy metals in its consumer products, especially contaminants derived from the cultivation and manufacturing process. There have been many cases where **products have been recalled** because of high lead (Pb) levels, resulting from environmental fallout from decades of using leaded gasoline, lead-based paint, and lead water pipes. There have **also been examples of contamination** from elements such as arsenic (As), which is used as a pesticide to spray on apple trees, and mercury (Hg), which has been used as a way to extract silver and gold from its mineral ores[10], and cadmium (Cd), which is commonly found in phosphate-based fertilizers[11].

However, chromium and nickel are not typically monitored in most states, so they will escape the scrutiny of most state regulators. And if recent reports are anything to go by, stainless steel cutting equipment can easily contaminate cannabis flower or plant biomass as they are being prepared for cannabinoid extraction[1]. Of course, cleaning the equipment might possibly alleviate the problem, but this is often a sign that the material is rapidly degrading, so it might only be a matter of time before the component fails and needs to be replaced. And if there is contamination from one stainless steel component in the manufacturing plant, the chances of it occurring in other areas are significantly higher.

It is only a matter of time before there is federal oversight of the cannabis industry, so it is highly likely that the **heavy metal panel will be expanded to look more like the 24 elemental impurities regulated by the pharmaceutical industry**. Furthermore, there are signs of this happening now as **more and more states are beginning to scrutinize cannabis vaping devices,** which very often contain stainless components. When that happens, the microscope will be on elements like chromium and nickel, which are highly toxic and, in most cases, have escaped the scrutiny of the regulatory process.

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