International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Impact Factor (2020): 6.733

A Review of Engineering Materials Used in the Dairy Processing Equipment

Subhash Prasad

Assistant Professor, Dairy Engineering Department, College of Dairy Science, Kamdhenu University, Amreli. Gujarat, India
subhashprasad85[at]gmail.com

Abstract: ***Milk and milk product contact surfaces should be smooth, impermeable, the free from cracks and fissures, non-porous, non-absorbent, non-contaminating, non-reactive, corrosion resistant, durable, and cleanable from a sanitary design standpoint. Materials of construction for dairy processing equipment are also on the avoidance of food contamination with microbes, dirt, chemicals, and physical substances during the short duration of contact between the product and equipment surfaces. Some of the drawbacks of equipment made by metals and its alloys of aluminum, copper, tin, iron on milk and milk product contact surfaces include the development of off flavours, discoloration of material, corrosion of vessels, and the generation of hazardous chemicals. Stainless steels (SS) were invented to overcome the problem of corrosion which is a major concern of dairy industries. Stainless steel is considered noble metal for use in dairy industry. Dairy and food industries are concerned with reliability of equipment and product purity. Stainless steels' exceptional resistance to corrosion of has enabled the dairy industry to develop widely and rapidly. Stainless behaves quite neutrally and does not alter the taste of fresh milk. This study encompasses a review work on the review of engineering materials used in dairy processing equipment.***

Keywords: Stainless steel, Alloy steels, Dairy equipment's, Non-toxic, Strength

1. Introduction

Milk is an emulsion that contains around 87% water. The remaining 13% is made up of insoluble fatty acids, inorganic substances, vitamins, and enzymes. Fresh milk is an excellent culture medium for microbial flora that can contaminate the final product. As a result, the production of milk and milk products is subject to extremely severe regulations. These regulations govern how milking, as well as preparation procedures, additives, processing equipment, and the transport tanks that transport milk from the farm to the processing facility. Milk comes into contact with the walls of the equipment in which it is processed or transported.

Construction materials are usually chosen based on their strength, elasticity, hardness, toughness, sensitivity to wear, corrosion and fatigue resistance, ease of fabrication, availability, and cost pricing. The qualities and cost of materials are critical elements in the design, construction, operation, and maintenance of general processing equipment. The principles of metallurgy and materials science are used in the selection and use of these materials (Cardarelli, 2000).Certain features are required for equipment and machinery for milk handling processing plant. They should not react with milk and milk products, non-corrosive. Should have enough protection against any damage. Pipes, fittings, valves, and other milk handling equipment in a dairy plant play a significant role in maintaining product quality as well as the cost of plant construction. Materials used in the manufacture of dairy equipment also play an essential role in sanitary design and hygiene maintenance.

They are roughly classified as those parts of equipment that come into contact with milk and milk products and those that do not. Iron, steel, stainless steel, aluminium, plastics, glass, and other materials are mostly used. Material selection becomes critical, owing to the fact that certain metallic components should not enter milk and milk products. The fundamental quality requirement of material selection any dairy equipment are classified into chemical, physical, and mechanical categories. Chemical factors such as material composition and structure help in understanding the degree of strength imparted to material by various heat treatments. Physical qualities help in understanding potential applications such as weight selection, thermal conductivity of heat, and so on. Mechanical qualities help in the design and manufacture of equipment. The strength of a material reflects its ability to endure external force, and hence tensile and compressible stresses. Stiffness and rigidity are measures of resistance to deformation. Ductility is a measure of elongation, while hardness is a measure of scratch resistance. Construction materials should not react with milk or milk products and should be long-lasting.

Most of the Dairy Equipment's requirements viz. more wear and tear, wide temperature variations during operations, with stand of water, steam, brine, refrigerants cleaning and sanitizing solutions and are flexible. Sanitary conditions are of very importance in dairy industry, hence to achieve these requirements, the equipment's must be designed and materials chosen suitably. Contact material must be (i) Dust proof, corrosion resistant external surface (ii) Smooth polished internal surface (iii) Minimum clearance of 100 mm between equipment base and floor with ball foot (iv) Absence of sharp corners and edges (v) Elimination of vertical dead spaces (vi) proper slope towards drain points (vii) Properly ground and polished welds (ix) Raised edge opening to prevent surface drainage in to container and (x) Sanitary type inlet and outlet fittings.

Some of the drawbacks of equipment made by metals and its alloys of aluminum, copper, tin, iron on milk and milk product contact surfaces include the development of off flavours, discoloration of material, corrosion of vessels, and the generation of hazardous chemicals. Stainless steel has a strong corrosion resistance, allowing the dairy business to expand extensively and rapidly. Stainless behaves quite neutrally and does not alter the taste of fresh milk. This study encompasses a review work on the review of engineering materials used in dairy processing equipment.

2. Literature Review

2.1 Materials used in Dairy processing equipment manufacture

The engineering materials are mainly classified as (a) Metals and their alloys, such as iron, steel, Copper, aluminium, etc. and (b) Non-metals, such as glass, rubber, plastic, etc.

2.1.1. **Metals:** Metals are the commonly used materials in the manufacture of food processing equipment. Metals are further divided into ferrous and non-ferrous categories. Recently, metals with antibacterial chemicals in their structure have been developed. Ferrous metals, which include iron as a main ingredient along with other elements, differ in strength, machining characteristics, and so on.

2.1.1.1Iron and steels: Wrought iron is the cleanest form of iron, with the least amount of carbon and other impurities. It is readily machined and welded, and making it suitable for high-temperature applications such as steam supply lines, heating coils, exhaust lines, and so on. Cast iron, on the other hand, has a carbon concentration of 2.5 to 4% and can be casted into any form using a mould. It is difficult to machine and weld. Cast iron is used mainly for supporting purposes, casing and cast part of dairy and food equipments and do not come directly contact with milk and milk products (Perry and Green, 1997). Iron combines with milk salts or lactic acid, producing bitter salts and, in certain cases, poisonous compounds.

Carbon Steel is an iron alloy containing 0.06 to 1.5% carbon. There is no graphite in the steel. The carbon occurs in the form of iron carbide, because of its ability to increase the hardness and strength of the steel. The steel becomes harder and tougher as its carbon content increases but reduction of welding ability (Schimpke, 1959)**.** To modify their usage, minor amounts of phosphorus, sulphur, silicon, and manganese are added. Carbon steel is defined as steel which has its properties mainly due to its carbon content and does not contain more than 0.5% of silicon and 1.5% of manganese. Dead mild steel contains 0.06 to 0.15% carbons. Mild steel with a carbon content of 0.15 to 0.45% is the most often used steel. This iron is commonly used to make vessels, pipelines, and fittings. This steel is the most easily manufactured and machined. Medium carbon steel with 0.45 to 0.8% carbon content increases strength. As a result, shafts, springs, and bolts are produced of this material. High carbon steel, having a carbon concentration of 0.8% to 1.5%, is extremely hard. As a result, cutting instruments such as blades, saws, chisels, and so on are constructed of this type of iron.Carbon steel is resistant to water-free mineral acids and reasonably resistant to lye solutions; nonetheless, it is absorbed by organic acid and dilute mineral acids, and it is extremely sensitive to moisture (Lincoin, 1969).Low carbon steel is widely used for bodies of tanks, vats, bottle-washers, conveyors, etc.

Alloy steel is a kind of steel that has make by combining nickel, chromium, silicon, manganese, molybdenum, titanium, and other elements. The alloying is done for specific purposes to increase wearing resistance, corrosion resistance and to improve electrical and magnetic properties, which cannot be obtained in plain carbon steels and are utilised for heat exchangers, milk pipelines, and dairy equipment in general. Iron alloys used for food packaging purposes are classified as 'carbon steel,' having a carbon concentration of less than 1%. (Lee et al., 2008).

2.1.1.2 Stainless steel (SS): Stainless steels are steel alloys that contain iron, chromium, and nickel. Stainless steel is a noble metal for use in the dairy sector. Moreover, steel with a chromium level greater than 10.5% is referred to as stainless steel (SS). Some of the limitations of SS used in the food and dairy industries are lactic and malic acid attack at high temperatures and low thermal conductivity. However, these restrictions can be avoided via careful selection and manufacture, appropriate working conditions, and equipment care and maintenance (Raghavan et al., 1994). It was later shown that at least 20% chromium was required to ensure resistance to oxidation or scaling. This served as the impetus for the creation of heat-resistant steels for use in the chemical, food, dairy, beverage, bio-processing, and pharmaceutical sectors (Covert and Tuthill, 2000).

More than 150 grades or types of stainless steel exist (Schmidt et al., 2012).Stainless steels are classed based on their chemical character, which gives information for dealing with various forms of corrosion. Austenitic, ferritic, martensitic, duplex, and super-austenitic stainless steel grades are the most common. Each of these major groupings has a number of alloys characterized by chemical composition and described in European and American International Standards (Tverberg, 2000).Aside from chromium, the alloy components molybdenum, nickel, and nitrogen have a significant role in corrosion resistance. Carbon is always present to some extent, and it is critical for welding qualities (Dillon et al., 1992).AISI (American Iron and Steel Institute) series designations for stainless steel include: 200 (high manganese austenitic), 300 (austenitic), 400 and 500. (ferritic and martensitic) (Dillon et al., 1992). Martensitic and ferritic steels are magnetic, and martensitic steels are often heat hardened and difficult to manufacture. Cold working hardens austenitic steels. Duplex grades (austenitic/ferritic) are harder than ferritic grades and more resistant to stress corrosion cracking than austenitic grades (Gonzalez, 2001).

Austenitic stainless steel with American Iron and Steel Institute (AISI) 300 series is most common S.S. used for fabrication of Dairy Equipment. Austenitic stainless steel has a high chromium and nickel concentration. 18/8 steel is the most often used steel that contains 18% Cr and 8% Ni. Austenitic stainless steel accounts for the majority (70-80%) of total stainless steel production and is especially common in dairy and food-processing applications (Weeks and Bennett, 2006).Austenitic stainless steel (AISI 200, e.g. 201, 202, and AISI 300, e.g. 304, 302, and 316) is nonmagnetic, ductile, heat-treatable, and readily manufactured (Dillon et al., 1992). Its main vulnerability is chloride stress corrosion cracking (SCC), which occurs at temperatures higher than 55°C (Avery, 1991). Apart from chromium, austenitic stainless steel generally contains 8 to 30% nickel and various amounts of molybdenum. Austenitic stainless steel has low carbon content and cannot be toughened by heat treatment. Nevertheless, cold deformation may cause some work hardening. The corrosion resistance, weldability, and shape capabilities of austenitic stainless steel contribute to its appeal. Similarly, their high and low temperature stability makes them beneficial for a wide range of applications (Tuthill et al., 1997).

Austenitic stainless steel should be used for dairy applications because it is more stable and resistant to corrosion than other stainless steels. SS applications in dairy include (a) processing equipment such as pasteurizer, homogenizer, separator, decanter, metal detector, heat-exchanger, mixing tank and process tank etc., (b) Storage tanks and form equipments are consists silo tank, road tanker, milking machine, cans and bulk milk cooler etc. and (c) Accessories include the fittings, valve, pumps, and lab instruments etc.(Francis, 2000).

Lower grade austenitic stainless steel alloys (e.g., AISI 100 and 200 Series) are generally not recommended for use in dairy and food equipment. AISI 302 stainless steel is used to improve the exterior design look of food equipment, but not milk or corrosive agent-contact equipment. AISI 304 is used to make pipes, fittings, silos, tanks, and vessels. The usage of AISI 303 stainless steel is restricted, and alloys containing lead, leachable copper, or other harmful compounds are specifically prohibited under the 3-A Sanitary Standards. Approximately 50% of all stainless steel produced is 304 stainless steel, formulated at 18% Cr and 8% Ni. To give greater strength, AISI 304 stainless steel is the most typically utilized for general uses. AISI 316 contains 2-3 % molybdenum, which enhances the alloy properties at higher temperatures, important in welding (Perry and Green, 1997). AISI 316 is utilised in the manufacture of plate heat exchanger plates, CIP tanks, and evaporator tubes that require increased corrosion resistance. 304L and 316L reduced carbon content (0.03%), which enables welding of thicker stainless steel sheets (Sinnott, 1996). Depending on the composition, there are variations in composition and qualities among stainless steel grades. To improve weldability, alloys with low carbon levels (e.g., 304L, 316L) can be developed. These alloys, however, would be weaker than the basic grade (e.g., 304, 316). Higher carbon levels, on the other hand, may be employed for stronger alloys (e.g., 304H, 316H). Consequently, modified stainless steel of a lower AISI grade may display attributes similar to those of a higher grade designation by compositional change (Schmidt et al., 2012).

Ferritic stainless steel contains a higher percentage of Cr (16-18%) and roughly 0.12 percent carbon. Ferrite SS (AISI 400 series, e.g., 410, 430) is magnetic and heat hardenable; it includes only trace amounts of nickel in addition to chromium. It is relatively resistant to corrosion. Impact resistance is significantly decreased at low temperatures (Dillon et al., 1992), with lower fracture toughness but higher strength and SCC resistance when compared to austenitic SS (Raman, 2003). They are more difficult to construct and weld due to their great strength. Ferritic stainless steel grades are employed in highly oxidising situations (e.g., nitric acid) (Dillon et al., 1992).They are largely resistant to chloride SCC(Tuthill et al., 1997), although they are vulnerable to IGA (inert granular attack), pitting, and crevice corrosion (Johnson, 1988).

The first group of stainless steel is the 'martensitic' SS. The high level of carbon in the martensitic stainless steels makes them difficult to form and weld, it also makes them very hard and strong, and heat treatment can make them even harder. Grade AISI 420 contains a minimum of 0.15% carbon and is ideal for knife blades (Dillon et al., 1992).

Duplex stainless steel has both austenite and ferrite properties in its microstructure (Covert and Tuthill, 2000). Because of their great strength and ductility, they may be useful for food processing. In very corrosive settings, such as cheese manufacturers, one of the second groups of iron-carbon chromium-nickel stainless steels, known as 'duplex' steels, may be required. They feature exceptionally high quantities of chromium (22% in grade AISI 2205 and 23% in grade AISI 2304), as well as roughly 3% molybdenum. They have overall corrosion resistance equivalent to austenitic stainless steels but substantially better mechanical strength (Johnson, 1988).

Super-austenitic stainless steels can withstand exceedingly harsh environments Covert (Tuthill, 2000) Austenitic stainless steels have exceptional corrosion resistance in a wide range of harsh conditions due to high quantities of chromium, nickel, molybdenum, and nitrogen, as well as a low carbon content. A typical example is grade (AISI 904L), which contains more than 4% molybdenum, and grades (AISI 254 SMO), which contain more than 6% molybdenum (Tverberg, 2000).Stainless steel should not be used with saline solutions (salt in water). A specific stainless steel coated with the antibacterial chemical AgION and particular titanium dioxides that may be utilised in cutting equipment are two examples of such metals (Curiel, 2001).

2.1.1.3Aluminum and alloys: It is a light metal having specific gravity 2.7, melting point 658°C and tensile strength 150MPa.This metal and its alloys are frequently used in the manufacture of milk cans, milk pails, tank and tanker linings , and so on. Aluminum is commonly used to make milk cans. It is light in weight, insoluble in milk, has no odour, excellent conductor of heat and may be spun into a variety of forms. As a result, it is one of the recognized metals. Yet, it is permeable, making welding problematic. Abrasion resistance is low, resulting in a grey stain. The surface is usually provided. Anodizing is a surface treatment in which portions to be treated are produced anodes and immersed in an electrolytic bath (of sulphuric, chromic, or oxalic acid) to generate a colourless and stable layer. Since its strength remains stable at temperature down about -250°C,and its thermal conductivity is high (208.8 w/mK), it is used for milk and food freezing equipment (Loncin, 1969). Aluminium alloys contents one or more other elements like copper, magnesium, manganese, silicon and nickel. The addition of small quantities of alloying elements converts the soft and weak metal into hard and strong metal, while still retaining its light weight. The main aluminium alloys are Duralumin, Y-alloy, Magnalium and Hindalium. The strength of duralumin is greater than that of pure aluminium, but corrosion resistance is lower (Sinnott, 1996).

Aluminium may enter milk and milk products during the manufacturing process or by contamination from metal processing equipment (Soni et al., 2001; Deeb and Gomaa, 2011). The use of aluminium utensils for milk processing and storage may significantly increase the level of this metal in milk and milk products (Semwal et al., 2006), and the leaching of this metal from utensils is influenced by container quality, pH level, preparation conditions, and the presence of complexing agents (Al Juhaiman, 2010).

2.1.1.4 Copper and alloys: It is one of the most widely used non-ferrous metals in industry. It has a reddish-brown colour and is soft, malleable, and ductile. It has a specific gravity of 8.9 and a melting temperature of 1083°C. Copper has a tensile strength of roughly 360 MPa (Perry and Green, 1997). It is an excellent electrical conductor. Copper tubes are commonly utilised in mechanical engineering. It is also utilised in the manufacture of ammunition. It is utilised in the production of useful alloys with tin, zinc, nickel, and aluminium. Brass is the most common copper-zinc alloy. Brass is also an undesirable component since it affects the flavour. Bronzes are metal alloys composed of copper and tin. After coating with nonoxidized metals such as nickel or chromium, bronze is utilised in various dairy and food equipment (Loncin, 1969, Perry and Green, 1997). The concentration of copper in hot milk or cream is affected, especially when rinsed with alkaline solution. Anything more acidic than milk, in general, causes corrosion in copper equipment, making it unsuitable for large-scale manufacture.

This metal is primarily used in the manufacture of milk pails , coolers, vats, strainers, pipe fittings, milk pumps, pasteuriz er coils, and other similar items (used for tinning only). Tain ts in milk or dairy products will result from the action of mil k. Tin is applied to the surface to counteract this effect. The action of milk on this metal produces a Green corrosion prod uct that is harmful for human ingestion.

When milk comes into touch with copper, it dissolves and exists in active form as copper ions. In the presence of direct sunshine and/or air, copper ions catalyse the hydrolysis of milk fat, an irreversible event that results in the formation of off taste. This taste flaw is especially prevalent in high-fat items. Copper salts are greenish in colour, harsh to taste, and poisonous when their ions combine with milk slats or lactic acid.

2.1.1.5 Tin: The tin coating is likewise not very abrasion resistant. Tin plate is less expensive and heavier than aluminium, recyclable, has a magnetic property that aids in segregation, is easy to decorate, is impermeable to moisture and gases, and can withstand high temperatures during product processing, making it suitable for sterile products such as beverages for longer storage. Nevertheless, because it may react with food, it requires surface coatings, and its containers often require an opening to access the substance (Catala et al. 2005).The Bureau of Indian Standards (IS: 9396 1987) specifies that the tin plate for food and drink cans be 0.15-0.49 mm thick and coated on both sides by dipping or electro-deposition. This metal is primarily utilised as a 'coating' for milk/dairy product contact surfaces on cans, vats, and other containers. While it is soluble in milk, it will not contaminate it. This metal is far too soft to be utilised in any machinery. Tin coating is not long-lasting because it is easily worn away by corrosion, abrasion, and other factors. But, re-tinning is a simple operation. To increase shelf life and promote exports, ethnic Indian milk-based confections such as khoa, rasogolla, gulabjamun, rasomalai, paneer, chhana, and ghee are packaged in tin containers. Lacquered tin containers with sizes ranging from 1 to 15 L are commonly used for ghee packing (Sabikhi et al. 2018).

2.1.1.6Nickel and alloys: Nickel is used to cover the surfaces of pasteurizing vats, coolers, and other milk/dairy product contact surfaces. Ni-alloy is utilized in the freezing chambers of ice cream freezers, as well as the cylinders and plungers of homogenizers. While it is the most soluble in milk among dairy metals, it has only a little influence on milk flavour. It is just mildly poisonous. An iron alloy makes it highly tough and difficult to work with during manufacturing. This metal, on the other hand, is considerably more durable than tin coating, but it is more costly. This metal is corroded by lactic acid, but it is not corroded by alkaline washing powders. The most significant drawback of using this metal is that it is more expensive than chromium and tin.

2.1.1.7. Chromium and its alloys: It is better suited for covering various sorts of equipment. It is most commonly utilized on milk/dairy product contact surfaces. This metal is non-tainting and resistant to acid and alkaline cleansers' corrosive activity. The most crucial feature of this metal is that it is extremely pricey.

2.1.2Non-metal Materials

Glass, rubber, plastic, and other nonmetal materials are extensively utilised in the dairy sector.

2.12.1 Glass: It is typically utilised when product visibility is critical. Because of its brittleness and fragility, it must be protected once again by exterior pipes made of appropriate metal. It is also utilised in milk storage tank level gauges, sight and light glasses. None the less, in some cases, it can be utilised as an inner liner for storage tanks or pipes. The glass should be splinter-free. Replacement of glass by transparent alternatives like Perspex (poly methyl methacrylate) or polycarbonate is recommended (Hauser, 2008).

2.1.2.2Plastic: Plastics have a wide range of applications and are divided into two types, thermoplastics and thermosetting plastics (Sinnott, 1996). Thermoplastics are created using a process known as addition polymerization. Because of their smaller molecular structure, they are liquids at higher temperatures and crystallized easily at low temperatures. They are often susceptible to organic liquids. Poly Tetra Flouro Ethylene (PTFE), Poly Ethylene (HDPE & LDPE), Poly Venyle Chloride (PVC), Acrylonitrile butadiene styrene (ABS), Cellulose acetate butyrate (CAB), and others are typical goods used in the dairy business. Pump shaft seals are made of PTFE. Thermo setting plastics, on the other hand, have cross connections in their structure and undergo irreversible modifications when heated. As a result, they cannot be recycled. Fibre Reinforced Plastic (FRP) storage tanks, Epoxy glass, polyester reinforced glass, plastic gears, Phenol formaldehyde, and Elastomers such as Polybutadiene and Polychloroprene (Neoprene) are popular commodities used in the dairy sector. Epoxy resins are used as adhesive of plastic or even metal equipments parts but temperature should not exceed 100- 180°C (Ullmann, 1973). Plastic are widely employed in the construction of certain pipes and flexible tubing, in addition to being used as packaging material. Polypropylene pipes and tubes must be food quality and must not transmit any bad flavours. Its smoother surface provides fewer barriers to fluid movement and is lightweight. It should be more resistant to detergents. Yet, it has a lesser temperature resistance and the most constant heat exposures. While aqueous solutions are less effective in wetting it, fats are more effective. This can cause fat to penetrate into the surface. It can be extracted, and if it is not extracted, a rancid odour develops on the surface of the plastic substance owing to fat degradation. The repercussions might include discoloration, fissure development, permanent shape distortions, bacterial contamination in tiny crevices, and milk taints caused by released plasticizer. Fermented items such as dahi, yoghurt, kefir, and kumiss are typically packaged in high impact polystyrene (HIPS) and polypropylene containers for sale and short-shelf life (Raju and Singh 2016). Ice cream is mostly packed in reusable plastics, with steel cans being used infrequently. Reusable ice cream cans are cylindrical tin cans with lead soldered lids and rounded edges. Ice cream (particularly 'Gelato') is frequently packed in reusable stainless steel containers to improve display at scooping shops (Goff and Hartel 2013).

2.1.2.3 Rubber and gasket: Most commonly used synthetic rubbers are neoprene, nitrile, butyl, silicone, fluro-elastomer or viton for sealing or gaskets. These materials do not react with milk or milk product and offer leak proof joint packing. Gaskets are used to prevent leakage between two metal surfaces. In addition to flexibility, the dairy sector requires them to be fat-resistant, as well as resistant to detergents and sanitizers. Hard rubber has a tensile strength of 70-100 MPa and its thermal conductivity is about 0.4 W/mK (Loncin, 1969). In applications such as Pasteurizer gaskets, they must also withstand a particular amount of heat. Stainless steel pipe fittings, manhole gaskets, milk pumps, cream separators, homogenizers, diaphragm valves, and other products are used in the dairy sector. The following are commonly used in dairy and their heat tolerance limits: Nitrile rubber (130 °C), Butyl rubber (140°C), EPDM (165 °C) , Silicon rubber (175°C), and Viton (180°C).

Several ways are employed to maintain the gaskets in place. Most typically, glues, gasket cements, and mechanical procedures are utilized. A particular process is required to secure the gaskets in place when using glues and gasket cements. This occasionally restricts their use in high-temperature situations. The gaskets must be stored in a cold, dry area. It should not be subjected to ozone, as in electric arc welding.

2.1.2.4. Wood: Wood is normally not recommended due to its porosity and its vulnerability to microbial attack. It is mostly used as building material. To reduce pest infestations and mould growth, as well as the generation of mycotoxins, wood in contact with food is frequently treated with pesticides and fungicides. Food in touch with wood should be tested for the presence of residual amounts of these fungicides and pesticides (De la Cruz Garcia et al., 2014).

Wooden vats and shelves serve as a microbiological biodiversity reservoir, contributing to the ultimate quality, safety, and character of dairy products. Furthermore, the natural biofilms that grow on hardwood surfaces are harmless and capable of inhibiting and limiting pathogen implantation via mechanisms that are currently being investigated. Wood has also been shown to be difficult to replace by other synthetic materials as a tool for regulating cheese and cellar humidity (Licitra et al., 2017).

2.2 Finishing of surfaces of dairy equipments

The most commonly used stainless steel for food contact surfaces is the No. 4 ground finish (80 - 150 grit). All surfaces, including fabricated, welded, and soldered connections, must be at least as smooth as a No. 4 (150 grit) finish and devoid of pits, folds, fissures, fractures, and misalignments in the final manufactured form, according to the 3-A Sanitary Standards and USDA recommendations (3-A Sanitary Standards, 2023).The roughness parameter was expressed as Average Roughness (Ra), and given in micrometer (Milledge, and Jowitt, 1980). R_a of less than 0.8 µm is stipulated under 3-A Sanitary Standards requirements and is regarded comparable to a No.4 finish. Surface roughness has been linked to the cleanability of stainless steel surfaces in general, with smoother surfaces being thought to be more cleanable (Steiner et al., 2000).

3. Conclusions

Fresh milk is an excellent culture medium for microbial flora that can contaminate the final product. As a result, the production of milk and milk products is subject to extremely severe regulations. Materials used in the manufacture of dairy equipment play an important role in sanitary design and hygiene maintenance. The engineering materials are mainly used in milk and milk processing plants are iron, steel, stainless steel., copper, aluminum, tin and its alloys and glass, rubber, plastic, wood etc. but these materials have some drawbacks on milk contact surfaces include the development of off flavours, discoloration of goods, corrosion of vessels, and the generation of hazardous chemicals. To fulfill these goals, stainless steels are frequently the most cost-effective and practical materials for process equipment. The most appropriate grade of stainless steel must be chosen based on the needs of the individual application. Stainless steel is used in dairy equipment nowadays because it is easy to clean and disinfect, and it does not react with the lactic acids created by fermenting milk. High sanitary requirements are possible at all stages of usage. This study encompasses a review work on the review of engineering materials used in dairy processing equipment.

References

[1] 3-A Sanitary Standards, Inc. Available at: www.3-a.org. Accessed 14 March 2013.

[2] Al Juhaiman, L.A.., (2010). Estimating Aluminum leaching from Aluminum cook wares in different meat extracts and milk.J. Saudi Chem. Soc., 14: 131-137.

[3] Avery, R.E. (1991) Resist chlorides retain strength and ductility with duplex stainless steel alloys. Chem Eng Prog 87: 78-82.

[4] Cardarelli, F. (2000). Materials handbook: a concise desktop reference. Berlin: springer-verlag.

[5] Catala, R., Alonso, M., Gavara, R., Almeida, E., Bastidas, J.M., Puente, J.M., De Cristaforo, N. (2005). Titanium-passivated tinplate for canning foods. Food Sci Technol Int.; 11(3):223–227.

[6] Covert, R.A., Tuthill, A.H. (2000) Stainless steels: an introduction to their metallurgy and corrosion resistance. Dairy Food Environmental Sanitary 20: 506-517.

[7] Curiel, G.C. (2001). Future requrements in the hygienic design of food factories. Paper presented at the symposium food factories of the future. SIK-Swedish institute of food preservation. Gothenburg, Sweden.June.

[8] De la Cruz Garcia, C., Sánchez Moragas, G., and Nordqvist, D. (2014). Food contact materials. Food Safety Management: A Practical Guide for the Industry, San Diego, United States, Academic Press, pp. 397-419.

[9] Deeb, A.M.M. and Gomaa,G.M. (2011). Detection of aluminium in some dairy products at Kafr El-Sheikh, Egypt. Glob. Vet., 6: 1-5.

[10] Dillon, C.P., Rahoi, D.W., Tuthill, A.H. (1992) Stainless steels for bio-processing, Part III: Classes of alloys. Bio-pharmaceutical 5: 30-38.

[11] Francis FJ (2000) Wiley Encyclopedia of Food Science and Technology. (2ndedn) John Wiley and Sons, Inc, New York.

[12] Goff, H.D., Hartel, RW. (2013). Ice cream. Berlin: Springer.

[13] Gonzalez, M.M. (2001). Stainless steel in bio-technology tubing industry. Biotechnology /Pharmaceutical Facilities Design 7: 23-30.

[14] Hauser, G. (2008). Hygienic production technology (in German). Wiley-VCH GmbH & Co. KGaA, Weinheim, Germany, pp. 540.

[15] IS: 9396 (1987) Specifications for round open top sanitary (OTS) cans for food and drinks. Bureau of Indian Standards, Manak Bhavan, India

[16] Johnson MJ (1988). The beneficial effects of increasing Cr, Ni, Mo and N on the corrosion resistance of stainless steels. Bioprocess Engineering Symposium 4: 53-58.

[17] Lee, D.S., Yam, K.L., Piergiovanni, L.(2008). Metal packaging. In: Lee DS, Yam KL, Piergiovanni L, editors. *Food packaging science and technology*. Boca Raton: CRC Press.

[18] Licitra, G., Caccamo, M., Valence, F. and Lortal, S. (2017).Traditional Wooden Equipment Used for Cheesemaking and Their Effect on Quality. Global Cheesemaking Technology: Cheese Quality and Characteristics: 7, 157-172.

[19] Loncin, M. (1969). Principles of process technology in the food industry.Aarau, German: Sauerlander.

[20] Milledge, J. J., and R. Jowitt. (1980). The cleanability of stainless steel as a food contact surface. Inst. Food Sci. Technol. 13:57–62.

[21] Perry, R.H., and Green, D.W. (1997). Perry's chemical engineers' handbook, 7thed. New York: McGraw-Hill.

[22] Raghavan, C.V., Shrichandan, B.R., Shrinivas, R.P.N. (1994) Selection and uses of stainless steel in food industry. Indian Food Industry 13: 26-32.

[23] Raju, P.N., Singh, A.K. (2016). Packaging of fermented milks and dairy products. In: Punyia AK, editor. *Fermented milks and dairy products*. Boca Raton: CRC Press, Taylor and Francis Group; pp. 637–671.

[24] Raman, R.K.S. (2003) Interplay of microbiological corrosion and alloy microstructure in stress corrosion cracking of weldments of advanced stainless steel. Sadhana 28: 467-473.

[25] Ronald, H. Schmidt, Daniel J. Erickson, Steven Sims and Philip WoWolff. (2012). Characteristics of Food Contact Surface Materials: Stainless Steel Food Protection Trends, Vol. 32, No. 10, Pages 574–584.

[26] Sabikhi, L., Khetra, Y., Raju, P.N. (2018) Processing and packaging of dairy-based products. In: Mohan CO, Carvajal-Millan E, Ravishankar CN, Haghi AK, editors. *Food process engineering and quality assurance*. Boca Raton: CRC Press, Taylor and Francis Group, pp. 311–375.

[27] Schimpke,P.(1959).Technologie der maschinenaustoffe, 15th ed, Stuttgart: verlag S. Hirzel.

[28] Semwal, A.D., A. Padmashree, M.A. Khan, G.K. Sharma and A.S. Bawa, (2006). Leaching of aluminium from utensils during cooking of food. J. Sci. Food Agric., 86: 2425-2430.

[29] Sinnott, R.K.(1996). Chemical process design. In chemical engineering, vol 6.J.M.Coulson and J.F. Richardson,eds. London.

[30] Soni, M.G., S.M. White, W.G. Flamm and G.A. Burdock, (2001). Safety evaluation of dietary aluminum. Regul. Toxicol. Pharmacol., 33: 66-79.

[31] Steiner, A. E., M. M. Maragos, and R. L. Bradley. (2000). Cleanability of stainless steel surfaces with various finishes. Dairy Food Environ. San. 20(4):250–266.

[32] Tuthill, A.H., Avery, R.E., Covert, R.A. (1997) Cleaning stainless steel surfaces prior to sanitary service. Dairy Food Environmental Sanitary 17: 718-725.

[33] Tverberg, J.C. (2000). A stainless steel primer. Part I. The types of stainless steel. Flow Control 6: 30-42.

[34] Tverberg, J.C. (2000). A stainless steel primer. Part III. Proper selection of stainless steels. Flow Control 6: 28-36.

[35] Ullmann, (1973). Enzyklopaedie der technische chemie, Vol 3. Chemical process equipment. London.

[36] Weeks, D.T., Bennett, T.M. (2006). How to specify equipment for high-purity processes. Pharmaceutical Processing 23: 16-20.

Author Profile

Subhash Prasad is an Assistant Professor and Head in Dairy Engineering Department, College of Dairy Science (Kamdhenu University), Amreli, Gujarat. He obtained his B.Tech. (Dairy Technology) degree from faculty of Dairy Technology, WBUAFSC, Kolkata and M.Tech degree in Dairy Engineering from ICAR-NDRI, Karnal. He has nearly 14 years' experience inclusive of industrial, research, and teaching, and has published numbers of research papers, review article and book chapter in national and international journals.